Final

environmental statement

related to operation of

INDIAN POINT
NUCLEAR GENERATING PLANT
UNIT NO. 2

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

DOCKET NO. 50-247

September 1972
Volume I

UNITED STATES ATOMIC ENERGY COMMISSION

DIRECTORATE OF LICENSING

SUMMARY AND CONCLUSIONS

This Final Environmental Statement was prepared by the U. S. Atomic Energy Commission, Directorate of Licensing.

1. This action is administrative.

2. The proposed action is the issuance of a license to Consolidated Edison Company of New York, Inc., for the operation of the Indian Point Nuclear Generating Plant, Unit No. 2 (Docket No. 50-247), located in the State of New York, Westchester County, Village of Buchanan, 24 miles north of the New York City boundary line.

   The Indian Point Station will have three Units each with a pressurized water reactor. Although the present action is concerned with the proposed issuance of a license for Unit No. 2, this Statement considers the environmental impact of the simultaneous operation of Units Nos. 1 and 2 (265 and 873 megawatts electrical, respectively). In view of the proximity of Units Nos. 1, 2, and 3 and the similarity in design of the Units, it is reasonable to expect that any and all requirements placed on Unit 2 as a consequence of this Statement will apply as well to Units Nos. 1 and 3. Nevertheless, separate studies of the environmental impact of Units Nos. 1 and 3 will be made, in which the combined effects of the Units will be taken into account, and conclusions will be drawn and recommendations made based on those studies.

3. Summary of environmental impacts, including beneficial and adverse effects, follows:

   a. About 35 acres of 239 acres of land formerly used as an amusement park, and later zoned for heavy industry, have been converted to industrial use.

   b. The applicant's plans to develop an 80-acre forested park with a freshwater lake and to build a new visitors' center, nature trails, gardens and public facilities will enhance the value of the site to the general public. A 14-acre area, transferred by the applicant to the Village of Buchanan, will be developed into a marina.

c. A minimal land area was used for the right-of-way of the transmission lines from Unit No. 2 to the nearby Buchanan Substation from which the power is distributed to the applicant's system; no additional right-of-way was needed to distribute the electrical output of Unit No. 2. Transmission towers from Unit No. 2 to the Buchanan Substation were designed in accordance with Federal guidelines.

d. In constructing Unit No. 2, the change in pattern of land use was kept to a minimum; areas disturbed during construction will be improved by landscaping and planting.

e. About 2,650 cubic feet per second* of water for once-through cooling and service water systems will be withdrawn from the Hudson River and increased in temperature by about 15F° during passage through the steam condensers and heat exchangers of Units Nos. 1 and 2. This heated water from both Units will be combined in a common discharge canal and released into the Hudson River at a velocity of about 10 feet per second via a 270-foot long, submerged multiport discharge structure.

f. The applicant's conclusion that the thermal discharges from Units Nos. 1 and 2 will meet the New York State thermal standards throughout the entire year has not been confirmed by the staff's review and evaluation. Although the staff's assessment shows that the thermal discharges will result in a temperature of less than 90°F at the river surface, even during the summer months, and thus meet part of the New York thermal standards, the staff finds that the New York State standards for surface area and cross-sectional area enclosed within the 4F° isotherm may not be met. Under the severest anticipated operating conditions, the staff's evaluation indicates that the area included within the 4F° isotherm will be on a tidal average basis less than 50% of the vertical cross-sectional area of the river, but the increase in temperature at the surface of the river may be on a tidal average basis more than 4F° for more than two-thirds of the surface area of the river and may even extend across the whole width of the river. Under transient peak conditions of the tide, which are not analysed by the applicant, the results are expected to be more severe than the average conditions mentioned.

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* 1 cubic foot per second (cfs) is equivalent to about 450 gallons per minute (gpm).

g. 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.

h. During the operation of Units Nos. 1 and 2 small quantities of phosphate, hydrazine, amines, boric acid, and chromate discharged into the Hudson River are not expected to produce important biological effects.

i. Chlorination of the once-through cooling system 3 times per week for a total of 6 hours per week may result in releasing cooling water containing up to 0.5 ppm of residual chlorine. This residual chlorine (and any chloramines formed from reaction with nitrogenous materials in the river water) may be toxic to aquatic life in the thermal plume and in the immediate vicinity of the cooling water outfall.

j. A detailed staff assessment of the biological impact of the once-through cooling system of Indian Point Units Nos. 1 and 2, using available information on the hydraulics and biota of the Hudson River estuary, shows that:

   1) Unless the applicant finds better means of preventing fish from entering the intake structure, fish, numbering between two to five million annually based on present population levels and composed mostly of young-of-the-year white perch and also large numbers of young-of-the-year striped bass and other fishes of about one to two inches in length, will be killed by impingement on the intake structure;

   2) Aquatic organisms including phytoplankton, planktonic crustaceans, larval stages of benthic invertebrates and eggs and larvae of many of the estuarine fishes such as striped bass, alewife, blueback herring, tomcod, American shad, bay anchovy, smelt, and white perch will be subject to entrainment in the cooling water and thereby exposed to mechanical, thermal, and chemical (chlorine) effects. The staff has estimated that during the summer months, an average of about 25% of those organisms passively drifting downstream will be entrained. The staff analysis further indicates that during June and July of most years from 30 to 50% of the striped bass larvae which migrate past Indian Point from upstream spawning areas are likely to be killed by entrainment. There is a high probability that the combined effects of entrainment and impingement will also result

in a similar decrease in recruitment to the adult population of striped bass in the New York, New Jersey, and New England regions. The operation of Units Nos. 1 and 2 with once-through cooling beyond 5 years could result in cumulative effects that would cause the population to decline further.

k. Operation of Units Nos. 1 and 2 will not cause contamination of groundwater by either chemical or sanitary wastes.

l. Discharges of radioactive gaseous and liquid wastes to the environment during routine Plant operation will result in an insignificant radiological impact on man and natural populations of terrestrial and aquatic life.

m. Nearby residents will be exposed to a very low probability risk of accidental radiation exposure during abnormal operating conditions and during transport of radioactive material.

n. Electrical energy needed to maintain the health and welfare of the people of the New York metropolitan area and to support the economic growth of the area served by the applicant's power network will be generated by the Plant.

o. Operation of Unit No. 2 will allow the applicant to shut down or reduce the use of older oil-burning plants and thereby decrease the air pollution near the plants.

p. The local economy will be stimulated through taxes, direct employment, and visitors.

4. From review and evaluation of the applicant's Environmental Report and Supplements thereto, and from independent observations and analysis discussed in this Statement, the regulatory staff has reached the following conclusions concerning the environmental impact of the Plant's operation:

    a. The benefits of meeting an urgent need for power in the New York area in the short-term (e.g., the next 5 years which is the staff's estimate of the time required to design and install the alternate cooling system) outweigh the estimated corresponding environmental costs incurred over this short-term period. The need for power for the metropolitan New York area has been adequately demonstrated in terms of decreasing reserve margins and increasing frequency of brownouts during peak load periods of the past several summers. Indian Point Unit No. 2 will add needed new base-load capacity to the applicant's system and improve the reliability of service in the metropolitan New York area. Operation of Indian Point Unit No. 2 will also permit obsolete base-load fossil plants inside New York City to be retired, thereby improving the air quality of the City.

b. The existing information is insufficient to predict accurately the long-term impact on all aquatic organisms. For some species this impact could be quantified by long-term field studies, but by that time irreversible damage may have been incurred.

c. The operation of Units Nos. 1 and 2 with the present once-through cooling system has the potential for a long-term environmental impact on the aquatic biota inhabiting the Hudson River which would result in permanent damage to and severe reduction in the fish population, particularly striped bass, in the Hudson River, Long Island Sound, the adjacent New Jersey coast, and the New York Bight. The potential impact is due to impingement of aquatic biota on the intake structure and entrainment of fish eggs, larvae, and plankton in the cooling water system resulting in exposure to severe mechanical, chemical (chlorine) and thermal stresses.

d. Alternatives to the applicant's proposed method of operation are available for nearly complete reduction of long-term aquatic environmental impacts without jeopardizing the needed new base-load capacity and the reliability of the applicant's service in the New York area.

5. Principal alternatives considered:

   a. Purchase of power from outside sources.

   b. Use of fossil fuel at the same site and other sites.

   c. Use of hydroelectric pumped-storage facilities and gas turbines for peaking purposes.

   d. Location of the Station at other sites.

e. Heat dissipation with wet evaporative, natural-draft and mechanical-draft cooling towers and spray ponds operated in the open- and closed-cycle mode.

f. Heat dissipation with dry cooling towers.

g. Reduction of biological damage to biota from entrainment and impingement by (1) recirculation to reduce intake flows during the winter months and (2) installation of a new off-shore screening structure sized to maintain intake velocities through the screens below 0.3 feet per second during the winter season.

h. Other chlorinating schedules and procedures that would reduce the adverse effects of residual chlorine and chloramines on aquatic biota.

i. Replacement of aquatic species damaged by operation of the once-through cooling system.

6. The Federal, State, and local agencies and interested parties listed below and the applicant responded to the Draft Environmental Statement issued on April 13, 1972.

Advisory Council on Historic Preservation
Department of Agriculture
Department of the Army, Corps of Engineers
Department of Commerce
Environmental Protection Agency
Federal Power Commission
Department of Health, Education, and Welfare
Department of the Interior
Department of Transportation
New York State Department of Environmental Conservation
New York State Office of the Attorney General
New York State Historic Trust
Westchester County Department of Planning
Citizen's Committee for the Protection of the Environment
Environmental Defense Fund
Hudson River Fishermen's Association
Natural Resources Defense Council, Inc.
Scenic Hudson Preservation Conference
Congressman J. B. Bingham
Congressman J. G. Dow
Congressman W. F. Ryan

Mr. J. M. Burns III
Mr. R. L. Ottinger
Consolidated Edison Company of New York, Inc.

7. On the basis of the evaluation and analysis set forth in this Statement and after weighing the environmental, economic, technical, and other benefits against environmental costs and considering available alternatives, the staff concludes that the action called for is the issuance of an operating license authorizing operation of Indian Point Unit No. 2 subject to the following conditions for the protection of the environment:

   a. Operation of Indian Point Unit No. 2 with the once-through cooling system will be permitted until January 1, 1978 and thereafter a closed-cycle cooling system shall be required.

   b. Evaluation of the economic and environmental impacts of an alternative closed-cycle cooling system shall be made by the applicant in order to determine a preferred system for installation. This evaluation shall be submitted to the Atomic Energy Commission for review by July 1, 1973.

   c. After approval by the Atomic Energy Commission, the required closed-cycle cooling system shall be designed, built and placed in operation no later than January 1, 1978.

   d. Non-radiological as well as radiological, monitoring programs and limits on effluent releases will be incorporated as a requirement in the Technical Specifications to the Operating License No. DPR-26. The monitoring program as well as a study will be conducted by the applicant and will include determination of the following:

      1) The nature and extent of the entrainment mortality and damage of aquatic organisms, after passage through the condenser;

      2) The nature and extent of the impingement mortality by counting the number, types, and sizes of fish collected on the screens and trash racks of the intake structure;

      3) Concentrations of residual chlorine, free and combined, during each chlorination period, and effects of chlorine residuals on biota;

4) Concentrations of dissolved oxygen in the discharge water and the thermal plume;

5) The size, shape, and location of isotherms of the thermal plume with different fresh water flows during different seasons;

6) Any changes in aquatic life in the Hudson River from operation of the Plant with the once-through cooling system.

f. A plan of action for Plant operation to minimize detrimental effects on aquatic biota will be developed by the applicant by July 1, 1973. This plan should include means of reducing to a practical minimum fish kills from cold shock, impingement on the intake structure, entrainment of fish eggs, larvae and plankton, and provide for corrective measures such as aeration of the cooling water during periods when concentrations of dissolved oxygen in the thermal plume are reduced below 4.5 ppm. After approval by the Atomic Energy Commission, such a plan shall be implemented so as to eliminate or substantially reduce such effects as are revealed by the monitoring program prior to installation of a closed-cycle cooling system.

8. The applicant will assess and evaluate the environmental monitoring and study programs outlined in this Statement and in the Technical Specifications accompanying the operating license. In addition, the applicant may, if it so desires, consider the impact of an effective restocking program as well as expand the data which now exists in support of once-through cooling. Whenever the applicant believes it has accumulated information which can clearly demonstrate that the operation of Unit No. 2 in conjunction with Unit No. 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. The Commission will take appropriate action in accordance with the provisions of 10 CFR Part 2.

9. This Final Statement was made available to the Council on Environmental Quality, the public, the applicant and the above-mentioned agencies in September 1972.

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FOREWORD

This Final Environmental Statement (the Statement) related to the proposed issuance of an operating license to the Consolidated Edison of New York, Inc. (the applicant), for the Indian Point Unit No. 2 (Docket No. 50-247), has been prepared by the U.S. Atomic Energy Commission's (the Commission) Regulatory Staff (the staff) in accordance with the Commission's regulation, Title 10, Code of Federal Regulations, Part 50 (10 CFR 50) Appendix D as revised on September 9, 1971 (36 FR 18071), and further revised on September 30, November 11, 1971, and January 20, 1972, and corrected on September 21 and December 16, 1971, implementing the National Environmental Policy Act of 1969 (NEPA). (P.L. 91-90, 83 Stat. 852).

Section 102(2) of NEPA calls for all agencies of the Federal Government to utilize a systematic interdisciplinary approach which will insure the integrated use of the natural and social agencies and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment; to identify and develop methods and procedures which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations; and to include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement on:

(i) the environmental impact of the proposed action,

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) alternatives to the proposed action,

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

In addition, Section 102(2) of NEPA requires the Commission to study, develop, and describe appropriate alternatives to recommend courses of action in any proposal which involve unresolved conflicts concerning alternative uses of available resources; and to recognize the world-wide and long-range character of environmental problems.

This Statement reflects guidance of the Council on Environmental Quality as contained in the Guidelines published in the Federal Register on May 10, 1970 (35 FR 7390), on January 28, 1971 (36 FR 1398), and April 23, 1971 (36 FR 7724).

By application dated December 6, 1965, and amendments thereto (the application), the applicant applied for the necessary licenses to construct and operate a nuclear power reactor at the applicant's site at Indian Point, Village of Buchanan, Westchester County, New York. The application was evaluated by the Commission's regulatory staff and independent Advisory Committee on Reactor Safeguards (ACRS), both of which concluded that there is reasonable assurance that the facility could be operated at the proposed site without undue risk to the health and safety of the public. On October 14, 1966, the Commission, after a public hearing and after an initial decision by the Atomic Safety and Licensing Board (the Board), established by the Commission, issued Construction Permit CPPR-21 for this facility.

The application for a license to operate the Indian Point Unit No. 2 is presently pending before the presiding Board pursuant to a Notice of Hearing in this matter dated November 15, 1970. On October 19, 1971, the Facility Operating License No. DPR-26 was granted to the applicant in which the Board, through the Director of Regulation, authorized the applicant to load fuel and perform subcritical tests. Technical Specifications contained in Appendix A attached to the license were incorporated in this license. On September 24, 1971 with supporting testimony of October 19, 1971, the applicant filed with the Commission and submitted to the Board a motion to issue an interim limited license for Indian Point Unit No. 2 for testing purposes up to 50% of rated power. An Initial Decision authorizing the Director of Regulation to issue a testing license to the extent of 20% of rated power and referral to the Commission of the balance of the motion for authority for testing operations up to 50% of rated power has been issued by the Board on July 14, 1972.

In accordance with Appendix D of 10 CFR 50, of June 3, 1970 (35 FR 8594), the staff transmitted on August 17, 1970 copies of the applicant's Environmental Report-Operating Licensing Stage of August 6, 1970, and an operating license application for Indian Point Unit No. 2 to appropriate Federal and State agencies for review and comment. The applicant responded to the comments of the agencies. The staff incorporated these comments in the Final Statement of November 20, 1970.

The applicant submitted "Environmental Report Supplement No. 1 on Indian Point Unit No. 2 and Appendices Volumes Nos. I and II" on September 9, 1971. On September 9, 1971, the Commission issued a revised Appendix D to 10 CFR 50 (36 FR 18071). In compliance with this regulation, the applicant submitted "Supplement No. 2 to the Environmental Report on Transportation, Transmission Lines, and Accidents" on October 15, 1971, and "Responses to Environmental Questions Raised on October 12, 1971 by the Division of Reactor Licensing," on October 28, 1971, and "Supplement No. 3-Benefit-Cost Analysis" on February 15, 1972.

The applicant has also provided extensive testimony on environmental matters at the Hearing Sessions of November 17, and December 14, 1971, January 11-12, April 5, May 17-19, and June 19-20, 1972 and responses to questions from the staff on May 11, 1972, comments on the Draft Statement on May 30, and responses to comments on the staff's Draft Statement of April 13, 1972, from Federal, State and local agencies and interested persons on June 9, June 27, July 5, July 6, July 27, and August 1, 1972.

This Final Statement is based primarily on the applicant's Environmental Report and Supplements, the Final Facility Description and Safety Analysis Report (FFDSAR) and amendments thereto, the Commission's Safety Evaluation and Supplements, as well as on the referenced documents listed at the end of each chapter. Comments received from Federal, State, and local agencies and interested persons and organizations on the Draft Statement have also been taken into account in the preparation of this Final Statement which supersedes the November 20, 1970 Statement.

Independent calculations and public sources of information cited in the references in this Final Statement were utilized as a basis for the staff's assessment of the environmental impact. In addition, valuable insight into this assessment of impacts was gained from a visit to the Indian Point site and surroundings on September 2 and

3, 1971 by the staff and its consultants. This Statement considers the environmental impact of construction and operation of both Indian Point Unit No. 1 (Docket No. 50-3) and Unit No. 2. Indian Point Unit No. 3 (Docket No. 50-286) is currently under construction and the staff will prepare, in conjunction with the impact of Units Nos. 1, 2 and 3, a separate environmental statement for the proposed operation of Unit No. 3. A separate statement will also be provided for Unit No. 1.

All material submitted by the applicant in support of the application, and other pertinent documents are available for public inspection at the Commission's Public Document Room at 1717 H Street, N.W., Washington, D.C., 20545; and at the Hendrick Hudson High School, Albany Post Road, Montrose, New York. Copies of these documents also have been forwarded to appropriate Federal agencies, New York State and local officials for review and comment.

The applicant is required to comply with section 21(b) of the Federal Water Pollution Control Act, as amended by the Water Quality Improvement Act of 1970. The applicant is also required to comply with the Technical Specifications which will be issued with the proposed license.

Dr. Mary Jane Oestmann [Telephone: (301) 973-7370] is the AEC Environmental Project Manager for this Final Environmental Statement.

I. INTRODUCTION

The Indian Point Nuclear Generating Plant Unit No. 2 (Indian Point Unit No. 2) (Docket No. 50-247), owned and operated by the Consolidated Edison Company of New York, Inc., (the applicant) is located on a 239-acre site on the eastern bank of the Hudson River in an industrial area, about 24 miles north of the New York City boundary line, at Indian Point, Village of Buchanan, in the upper Westchester County, New York State.

The applicant received a construction permit CPPR-21 for Indian Point Unit No. 2 on October 14, 1966. The applicant applied for an operating license on October 15, 1968 and obtained a Facility Operating License No. DPR-26 to load fuel in the core and conduct subcritical testing on October 19, 1971. An operating license to test up to 50% of rated power is pending before the Commission.

The Indian Point site has three nuclear generating Plants on the Station with the following thermal and electrical output expressed in megawatts thermal or megawatts electrical.

(1)	Unit No. 1 (In operation since 1962)	-	890 MW(t) (total) 615 MW(t) (nuclear) 275 MW(t) (fossil)	285 MW(e) (gross) 265 MW(e) (net)
(2)	Unit No. 2	-	2,758 MW(t)[a] 3,216 MW(t)[b]	873 MW(e)[a] (net) 1,069 MW(e)[b]
(3)	Unit No. 3 (Under construction until 1974)	-	3,025 MW(t)[a] 3,216 MW(t)[b]	965 MW(e)[a] 1,069 MW(e)[b]

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[a] Initial output

[b] Design output

Each Unit utilizes the Hudson River as the water supply for a once-through cooling system.

The following chapters describe (1) the environment in the area, including the history, geography and geology, hydrology, climatology, ecology, land and water use including chemical characteristics, (2) the facility and its effluents, (3) the impacts from construction and operation of Unit No. 2 (Plant), (4) alternatives to the proposed action, (5) irreversible and irretrievable long-term commitments of resources from effects of the Plant operation, (6) need for power, and (7) the benefits-cost accrued from the proposed issuance of an operating license. Wherever possible, the Statement takes into account the combined impacts from operation of Unit No. 1 and Unit No. 2. The applicant shall be required to release all discharges to the environment in accordance with Federal and State regulations. Comments from Federal, State and local agencies, the applicant, interested persons and groups, some of which are parties in the proceeding of the Licensing Hearing before the Board, have been taken into account in the body of the text under the appropriate subject and further detailed in Chapter XII of this Statement.

A. SITE SELECTION

The selection of a site for construction of an electrical-generating facility depends on many factors. The generating capacity of the power plant is a primary factor. Large generating units (which are more economical than smaller units) place restrictive requirements on prospective plant sites. Power plants using fossil fuel (coal or fuel oil) must have available the means, such as railroads or navigable waters, of transporting bulk materials in large quantities. In addition, each fossil- or nuclear-fueled power plant requires a large volume of water for dissipating the waste heat inherent in the steam-electric cycle.

Another consideration in the selection of plant sites is the distance to the load centers, since transmission losses increase with distance. Nearness to existing transmission facilities decreases the capital investment required to place new power generation on line.

Public acceptance of a plant site is also desirable. Public pressure to preserve scenic natural features, or to prevent the placement of a power plant near residential areas of high population density, influences the ultimate selection of a power plant site. Suitable sites for large power plants are becoming increasingly scarce in the New York area. Limitations of the availability of the above-mentioned requirements has restricted the applicant in selecting suitable sites to build power plants to serve the applicant's service area.

A primary consideration for choosing the Indian Point site for Unit No. 2 was that the site was pledged to nuclear power generation as early as 1956, when the construction permit for Unit No. 1 was issued by the Commission. Unit No. 1 had been in commercial operation for over three years when the applicant filed its application for a construction license for Unit No. 2 on December 6, 1965. The applicant has had difficulty in finding sites within or near its service area upon which the Commission might approve construction of a nuclear plant and which could also win public acceptance.

Contributing to the siting decision were the following facts: the population density in the nearby area was low, cooling water was available, the geology of the site was adequate, and danger of flooding was extremely remote. Experience had been gained from operation of Unit No. 1 regarding the discharges of thermal, chemical, and radioactive effluents and their effects on the environment,[1] and studies had been made of the impact of incremental amounts of these discharges.

B. APPLICATIONS AND APPROVALS

Table I-1 lists the applications filed by the applicant and the approvals received from various governing bodies or agencies.[1] For those applications which have been granted, the date of issuance is included. The letters granting the permits are presented in Appendix I of the applicant's Supplement No. 1 to the Environmental Report.

Future Environmental Approvals

Future environmental approvals required by the applicant for the operation of Indian Point Unit No. 2 will include obtaining operating permits from the New York State Department of Environmental Conservation (Article 12, Public Health Law), the Department of the Army, Corps of Engineers (The Navigation and Navigable Waters Act, S407 - Refuse Act of 1899), and an operating license from the Atomic Energy Commission.

Application has been filed with the Department of Environmental Conservation for a permit for discharge of chemical solutions and an operating permit for the service boilers, and with the Department of the Army, Corps of Engineers for a permit to discharge effluents through the channel and diffuser into the Hudson River.

Table I-1

FEDERAL, STATE AND LOCAL AUTHORIZATIONS REQUIRED FOR CONSTRUCTION AND OPERATION OF INDIAN POINT UNIT NO. 2 AND UNIT NO. 1

AGENCY	DATE OF ISSUANCE	PERMIT, LICENSE, ETC.
Federal		
Atomic Energy Commission		
Indian Point Unit No. 1 (Docket No. 50-3)	5-4-56	Construction Permit CPPR-1
	3-26-62	Unit No. 1 Provisional Operating License DPR-5
Indian Point Unit No. 2 (Docket No. 50-247)	10-14-66	Construction Permit CPPR-21
	10-19-71	Facility Operating License No. DPR-26 to Load Fuel and Conduct Subcritical Testing
	Initial Decision by ASLB 7-14-72	Facility Operating License to Conduct Tests Up to 50% of Rated Power
Indian Point Unit No. 3 (Docket No. 50-286)	8-13-69	Construction Permit CPPR-62

AGENCY	DATE OF ISSUANCE	PERMIT, LICENSE, ETC.
Federal (continued)		Section 10 Permits
Department of the Army New York District Corps of Engineers	4-3-57	Permit No. 5236 to construct wharf, screenwells and discharge tunnel, to install pipes, to dredge and place fill.
	1-8-60	Permit No. 5891 to construct a dike in Lents Cove, Hudson River.
	2-23-66	Permit No. 7184 to place fill.
	3-15-66	Permit No. 7184-A to approve revised plans and to construct a discharge channel extension wall and screenwell structure, to place fill and to dredge.
	1-19-67	Permit No. 7184-B to approve revised plans to supersede plans approved by Permit No. 7184 and 7184-A.
	9-29-67	Permit No. 7562 to construct a screenwell, bulkheads and a discharge channel, to dredge, to place dredged material behind bulkheads and to install temporary dolphins.
	11-24-70	Permit No. 7562-A to approve revised plans to supersede plans approved by Permit No. 7562. Additionally to install a steel outfall section consisting of 12 submerged openings.

AGENCY	DATE OF ISSUANCE	PERMIT, LICENSE, ETC.
Federal (continued)		
Department of the Army New York District Corps of Engineers	12-11-67	Permit No. 7589 to dredge flotation channel and to construct ramp in Lents Cove, Hudson River.
	Applied 6-24-71 Estimated Date of Issuance 12-31-72	Section 13 permit to authorize discharge and control thermal, chemical and other waste discharges.
STATE OF NEW YORK		Discharge Canal and Outfall Structure
Department of Health	8-22-66 expired 8-22-71	(No permit number) - Unit No. 1 Approval of final plans for construction of 214-foot cooling water discharge channel facilities.
Water Resources Commission Conservation Department	3-2-66	Permit No. 8-4-66 Construction of extension of discharge canal to separate discharge from intake to a point 300-feet south of present location.
	6-30-70	Permit No. 8-22-70 Extend discharge canal 98 feet downriver and protect with sheet piling at Indian Point Generating Station.
Department of Health	5-19-70	(No permit number) - Unit No. 1 Outfall construction - construction of an effluent channel with a submerged diffuser.

AGENCY	DATE OF ISSUANCE	PERMIT, LICENSE, ETC.
STATE OF NEW YORK (continued)		Discharge Canal and Outfall Structure (contd)
*Department of Environmental Conservation Division of Pure Waters	12-10-70	Outfall Construction - construction of effluent channel with 12 submerged openings, 4 by 15 feet each, with 18-foot centerline depth submergence, including adjustable ports. Supersedes permits of 8-22-66 and 5-19-60.
Department of Environmental Conservation	11-4-71	Construction Permit of modified outfall structure to change from 18- to 12-foot depth of U.S. Coast and Geodetic Survey and Sea Level Datum. Operating Permit of modified outfall structure pending completion of construction of adjustable discharge ports.
		Chemical Discharges
Department of Health	6-10-59	Domestic sewage and waste disposal.
Department of Environmental Conservation	11-13-70	Permit to discharge chemical cleaning solutions. (Temporary use - no longer used.)

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*This Department was created in 1970 to take over and replace various functions of other State departments. Among other duties, it took over those of the Conservation Department which was abolished and those of water and air pollution control which had previously been under the Department of Health.

AGENCY	DATE OF ISSUANCE	PERMIT, LICENSE, ETC.
STATE OF NEW YORK (continued)		Chemical Discharges
Department of Environmental Conservation	2-10-71	Permit to discharge chemical cleaning solutions. (Temporary use - no longer used.)
		Dredging
Water Resources Commission Conservation Department	2-4-66	Permit No. 8-1-66 Deposit 50,000 cubic yards of rock spoil in Hudson River at Indian Point.
	4-13-66	Permit No. 8-11-66 Dredge an area of 135 feet by 63 feet by 22 feet deep. Dredged area to be used for concrete screenwell construction.
	6-22-67	Permit No. 8-31-67 Fill and dredge to carry out construction of new screenwell and relocate discharge canal.
	11-30-67	Permit No. 8-78-67 Dredge a channel approximately 150 feet wide by 1800 feet long in Lents Cove of the Hudson River.
		Air Quality
Department of Health	4-12-68	Permit No. HA 680101 Permission to construct two Babcock and Wilcox integral furnace boilers.

AGENCY	DATE OF ISSUANCE	PERMIT, LICENSE, ETC.
STATE OF NEW YORK (continued)		Environmental
Hudson River Valley Commission	9-14-67	Screenwell and discharge line.
	12-7-67	Dredging in Lents Cove.
	3-26-71	Changes in discharge canal.
		Water Quality Certificate
Department of Environmental Conservation	12-7-70	Water quality certification Indian Point Generating Station - Units Nos. 1 and 2. Under Section 21(b) of Water Quality Improvement Act of 1970.
LOCAL		
Westchester County Department of Planning	11-9-70	Approval of land-use for industrial purposes
Village of Buchanan	12-1-65	Permit No. 373 Building Permit for excavation for nuclear steam electric generating station.
Village of Buchanan	5-16-66	Permit No. 381 Building Permit for intake screenwell structure.
	5-24-66	Permit No. 387 Building Permit for turbine room, water bay and discharge water tunnel.

AGENCY	DATE OF ISSUANCE	PERMIT, LICENSE, ETC.
LOCAL (continued)		
Village of Buchanan	9-28-66	Permit No. 404 Building Permit for primary auxiliary building and waste hold-up tank pit.
	9-28-66	Permit No. 405 Building Permit for fuel storage building.
	9-28-66	Permit No. 406 Building Permit for containment building.
	2-18-67	Permit No. 411 Building Permit for control room.

C. THE APPLICANT'S ENVIRONMENTAL STUDIES

Environmental studies[1] of the Hudson River and the land near Indian Point have been sponsored by the applicant. These studies are classified below.

(1) River flow:

Quirk, Lawler, and Matusky Engineers
Alden Research Laboratories, Worchester Polytechnic Institute
Metcalf and Eddy Engineers

(2) Meteorology:

Geophysical Science Laboratory, New York University

(3) Biology:

Ichthyological Associates
Institute of Environmental Medicine, New York University Medical Center
Marine Research Laboratory, Raytheon Company
Northeastern Biologists, Inc.

Other supporting organizations include:

Regional Economic Development Institute, Inc.
Bechtel Corporation
Norman Porter Associates
Texas Instruments, Inc.
Lamont Geological Observatory, Columbia University

The applicant also has a number of consultants in special technical fields to assist it in developing the site for nuclear power. The ecological studies sponsored by the applicant, including the financial support,[2] are usually coordinated with the Hudson River Technical and Policy Committees that have representatives from State and Federal agencies: New York State Department of Environmental Conservation, New Jersey Division of Fish and Game, Connecticut State Board of Fisheries and Game (advisory only), U. S. Bureau of Sport Fisheries and Wildlife, and National Marine Fisheries Service. The committees outline the ecological studies and present their conclusions and recommendations to the applicant. In addition, the applicant has also organized the Fish Advisory Board consisting of expert biologists and engineers from the United States and Great Britain. These include 2 members from New York University, 3 from private consulting firms, a nonvoting member from the New York State Department of Environmental Conservation, and a nonvoting member from the New York Department of Public Service.

The applicant has also conferred with the Westchester County Department of Planning[1] in establishing the Indian Point site for construction of nuclear power plants. The Department of Planning comments on the fact that the site is zoned for industrial use, including the use of nuclear power generation, which is consistent with the overall land use development planned for Westchester County. It also strongly endorses the applicant's policy of making part of the site available for public use and for recreational purposes. Similarly, the State of New York Atomic Energy Council has expressed the opinion, consistent with that of the Department of Planning, that nuclear power development may have resulted in an improved land usage.

REFERENCES FOR CHAPTER I

1. Consolidated Edison of New York, Inc., Supplement No. 1 to the Environmental Report for Indian Point Unit No. 2, September 9, 1971.

2. Consolidated Edison of New York, Inc., "Cost Expenditures on Environmental Studies," Appendix T of the Supplement No. 1 to the Environmental Report, September 9, 1971.

II. THE SITE

A. GENERAL

The site of the Indian Point Station with Units Nos. 1, 2, and 3 occupies 239 acres on the east bank of the Hudson River near Peekskill, New York. The site is about 24 miles north of New York City boundary line in the Village of Buchanan in upper Westchester County of New York. The Indian Point site was formerly an amusement park.

The predominant environmental feature of this site is the Hudson River. The Hudson River at Indian Point cuts through the Hudson Highlands at the water level with a channel nearly a mile wide and an average depth of more than 30 feet. West of the river at Indian Point is the Palisades Interstate Park with its wooded mountains and recreational facilities. East of the river are mountains of smaller height and several communities, of which Peekskill, located about 2.5 miles northeast from the Station, is the largest. The nearest site boundary on land is 0.32 miles from Indian Point Unit No. 2. The Penn Central Railroad serves both banks of the river; U.S. Highway 9W serves the west bank, and U.S. 9 (Albany Post Road) serves the east bank (Fig. II-1).

Of importance is the estuarine nature of the Hudson River. This river, which supplies the cooling water for the 3 Units, is a tidal estuary at this site. Tidal mixing brings salt water upstream beyond Indian Point during much of the year; the salt-water boundary reaches occasionally as far as Poughkeepsie, 30 miles upstream from Indian Point. The upward extent of salt water varies strongly with the input of fresh water into the river and can actually be near the river mouth after protracted high flows during spring runoff. Along the river banks are rock quarries and industries that use the water. Years ago whaling vessels had their home ports along the river; more recently, in 1968, the Port of Albany, at the head of seaborne navigation on the Hudson, handled 1,050,000 tons of import-export trade and 2,150,000 tons of coastwise trade.[1]

The aquatic biota in the river is rich and diverse. The river near Indian Point serves as a spawning and nursery area for several important salt-water fish, including striped bass.

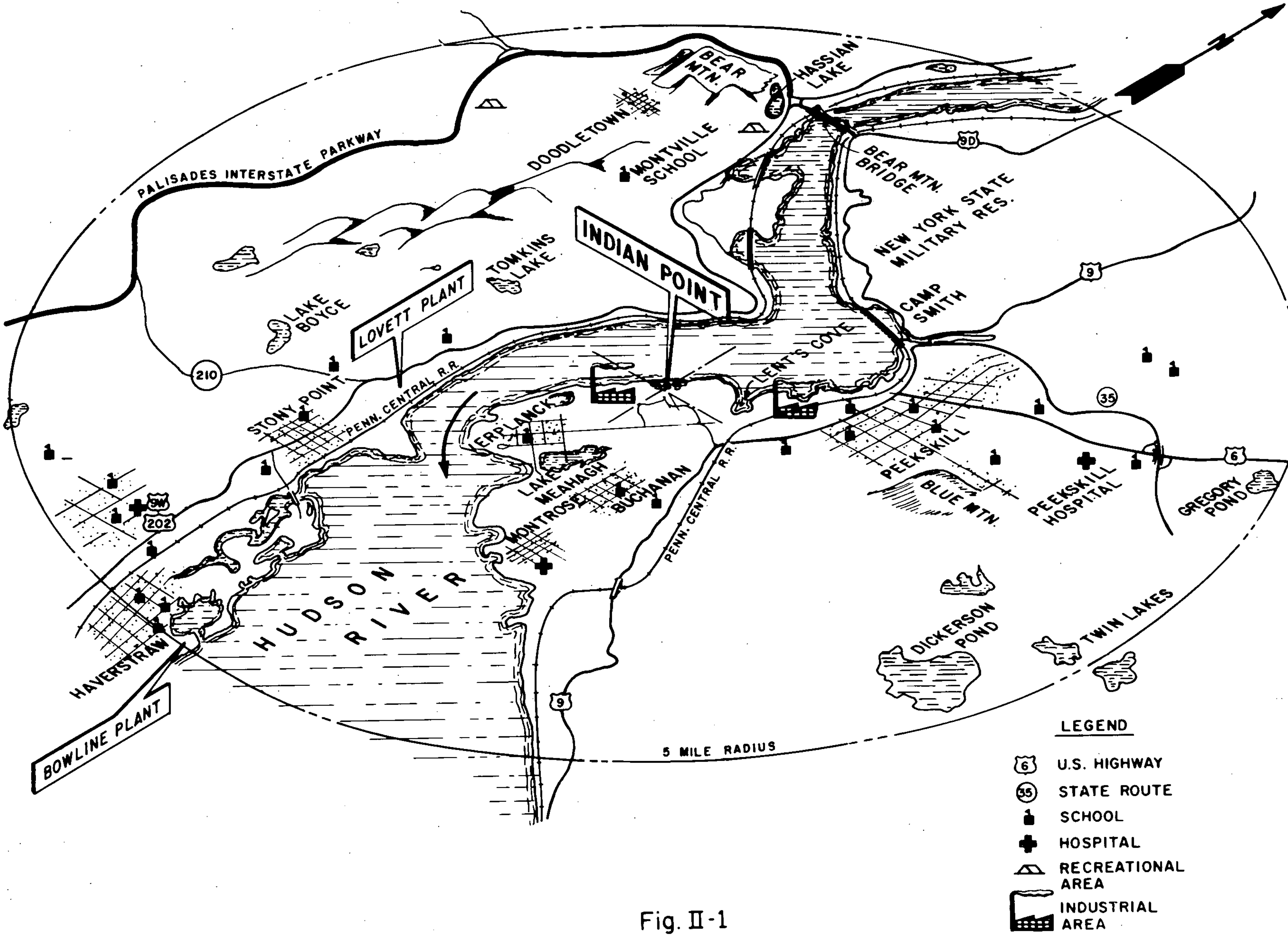

Fig. II-1
Indian Point 5 Mile Area.

B. LOCATION OF STATION

The 239-acre Station site is on a point of land inside a big river bend. Three nuclear reactors, Indian Point Units Nos. 1, 2, and 3, and generator buildings are rather compactly placed on 35 acres near the river cooling-water intake and discharge structures in the River (Fig. II-2). The minimum elevation of the site, 15 feet, is well above the highest recorded flood of 7.5 feet. Farther from the river are the service areas, and the fuel storage tanks for Unit No. 1. The transmission lines travel from the reactors about 2,100 feet southeast to an existing switchyard located across the road (Broadway) from the other facilties.

At the northern edge of the site there is an easement for the Buchanan sewer system and about 14 acres were transferred by the applicant to Buchanan for a marina in Lents Cove. A temporary visitors' center, which has been in use since 1959, is located on a hill overlooking the Station. The applicant also provides tours of its facilities. The applicant plans to build a new visitors' center near the Station (see Fig. II-2) and to enhance the education, recreational and scenic value of the site.[2] Between Lents Cove and the reactor buildings the applicant has an 80-acre forest and a lake set aside for recreation. South of the reactor buildings is an easement 65 feet wide and 2,800 feet long for two large gas lines of the Algonquin Gas Transmission Company. The nearest public road (Broadway) is a minor road which at its closest is 1,700 feet to the southeast of the site. The Hudson River forms a border more than 4,000 feet wide to the west and northwest. Along the riverfront to the southwest the fence line of the Georgia-Pacific Corporation wallboard factory is about 1,100 feet from the reactors. North along the river, beyond Lents Cove, are red brick industrial buildings that contrast with the modern design of the Indian Point buildings.

C. REGIONAL DEMOGRAPHY AND LAND USE

Westchester County, in which Indian Point lies, has long had industry along the river banks but otherwise serves as suburbia and exurbia for Metropolitan New York City. The hilly land with its lakes also provides water reservoirs and recreational facilities. The growth of industrial parks and the distribution and service industries have made the county as a whole a net importer of commuting workers. The permanent population within a 1-mile radius of the reactors is

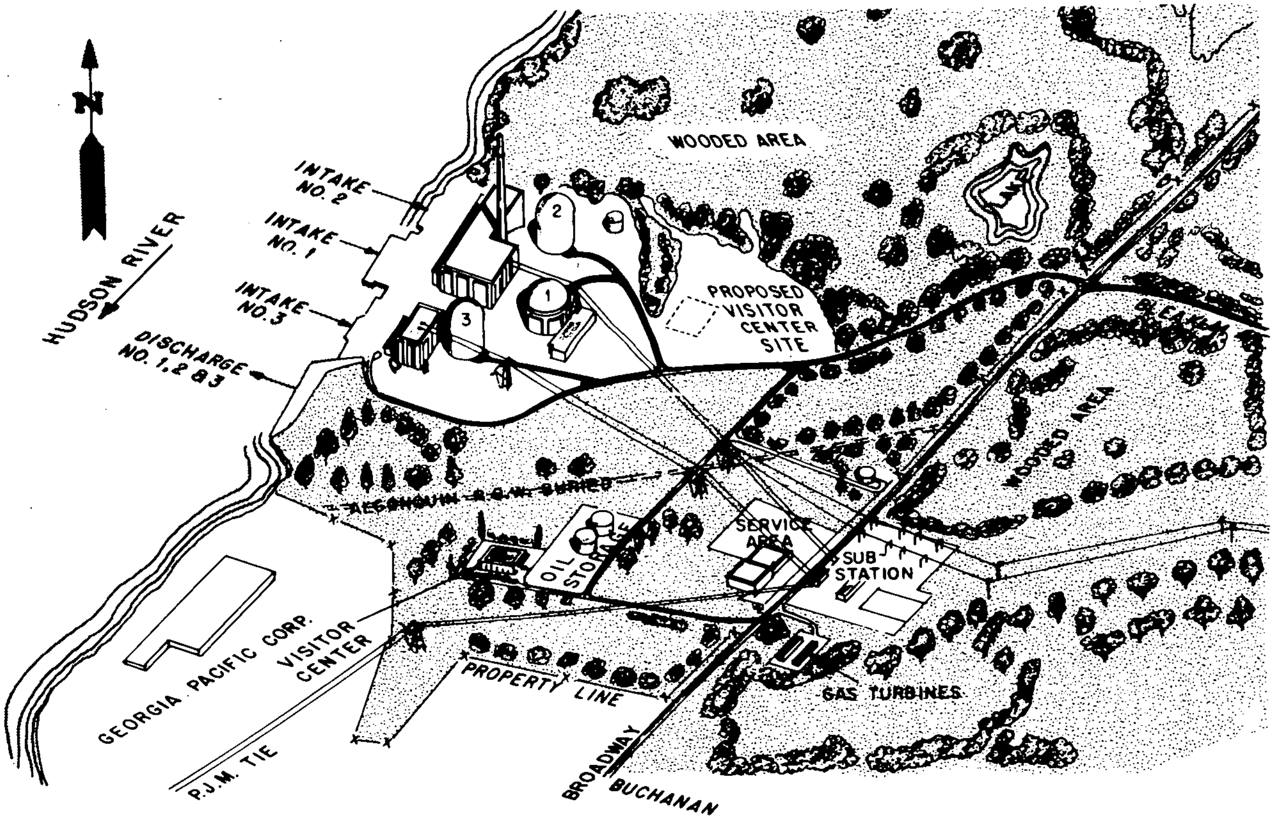

Fig. II-2
Indian Point Site

1,080 (census of 1960); within a 5-mile radius, 53,040 (Fig. II-1). The nearest city is Peekskill, to the northeast; the nearest city of more than 50,000 is White Plains, 17 miles to the south. The communities of Verplanck and Buchanan are also within 2 miles of the site. From there southward are the contiguous residential and industrial areas of New York City, its outer ring of suburbs and its inner core. The population within 55 miles of Indian Point was 16.1 million in 1960 and 17.5 million in 1970 (the staff's estimate). Demographically the Station is well placed with respect to nearby populations.

Most of the people live in the southern quadrant, from southeast to southwest, which includes New York City; they numbered 13.8 million in 1960 and half a million more in 1970 (Fig. II-3). The remaining three quadrants had 2.3 million in 1960 and nearly a million more in 1970. A more detailed summary of the population distribution was prepared from the 1960 census; the growth rates projected by the Regional Economic Development Institute in 1965 are slightly high for 1970.[3] The staff has made a simple projection of the population distribution to the year 2000 (Table II-1) for use in an assessment of radiation dose.

About 66 people (1960 census) reside within a 1,100-meter (3,600 feet) radius of Unit No. 2, all of them to the east southeast. This distance has been used as the outer boundary of the low population zone in the analysis of a postulated fission product release. The outer boundary of the more densely populated area of Peekskill has been used as the population center distance which exceeds one and one-third times the distance from the reactor to the outer boundary of the low population zone as defined in 10 CFR 100.11. The exclusion area for Indian Point Unit No. 2 includes Plant property within a 520 meter (1,700 feet) radius of the reactor containment. An exclusion radius of 520 meters satisfies both 10 CFR 100.3 and 10 CFR 100.11.

The closest schools are about a mile to the east and a mile to the south; altogether there are a dozen schools within 2 miles, many of them small schools. Nearby hospitals[4] are Peekskill Hospital (113 beds), 3 miles distant; a Veterans Administration Hospital (1,756 beds) at Montrose, 2.5 miles distant; New York State Rehabilitation Hospital (114 beds) at West Haverstraw, 4 miles distant; and the Letchworth Village Hospital (3,965 beds in a long-term unit, plus 64 additional beds) near Thiells, more than 5 miles distant. The nearest commercial airport is at White Plains, 17 miles south of the Station. Airports are also located at Poughkeepsie near Newburgh as well as in metropolitan New York City.

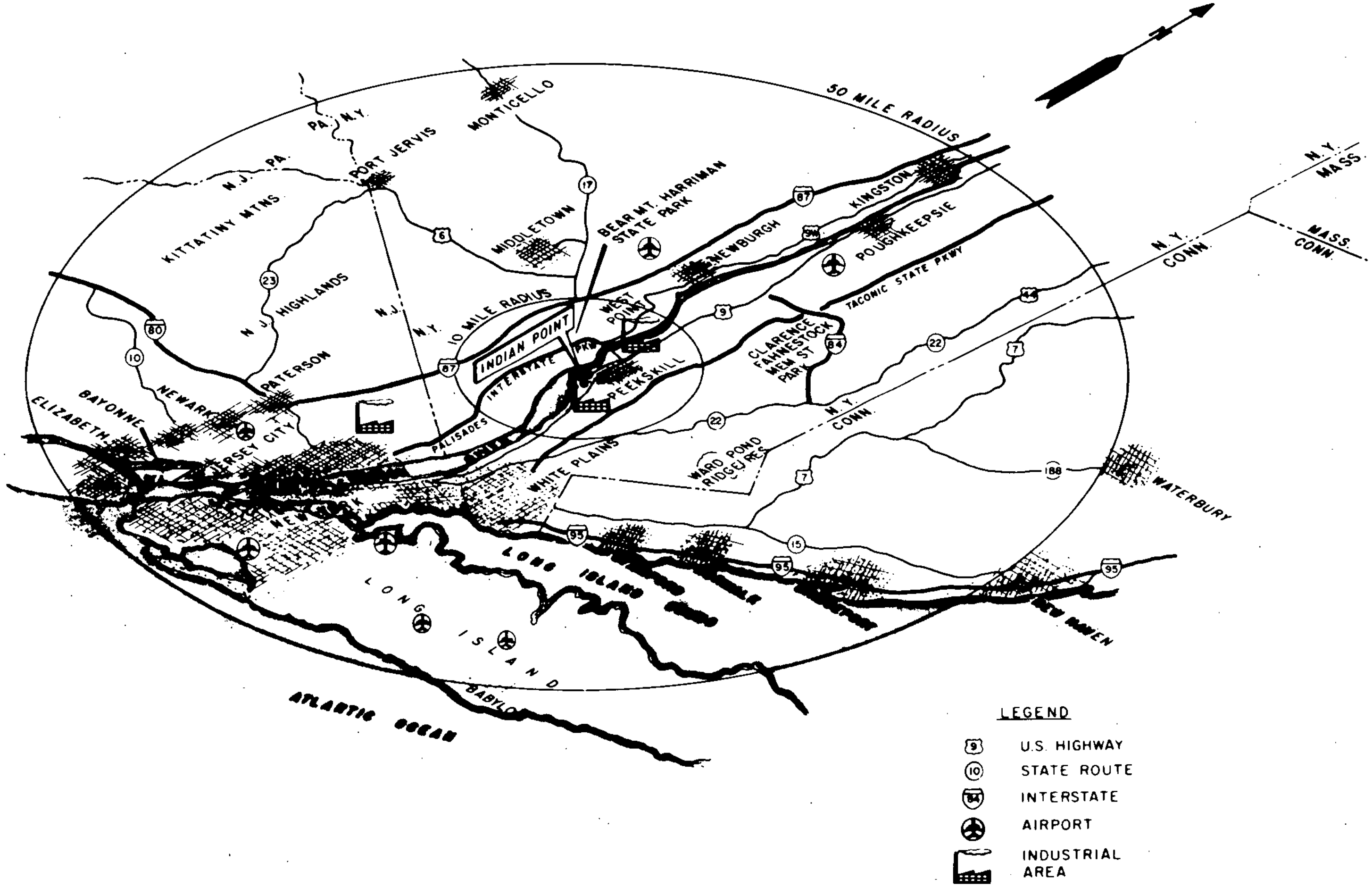

Fig. II-3
Indian Point 50 Mile Area.

TABLE II-1
PROJECTED POPULATION DISTRIBUTION FOR THE YEAR 2000
BY 22.5-DEGREE SECTORS

Sector	Population at a distance from center of site of -											
	0-1/2 mi.	1/2-1 mi.	1-2 mi.	2-3 mi.	3-4 mi.	4-5 mi.	5-10 mi.	10-15 mi.	15-25 mi.	25-35 mi.	35-45 mi.	45-55 mi.
East	0	687	886	510	1041	753	16065	26339	116062	165423	248696	463259
East-Northeast	0	37	8420	10400	4912	5311	16700	14359	54166	76490	98690	521146
Northeast	0	0	7113	29050	3612	4410	15157	9757	55087	90090	71386	276500
North-Northeast	0	0	355	4602	1137	2755	5702	5156	56009	103689	44081	31855
North	0	0	111	133	133	89	20142	13650	79916	66240	41326	43930
North-Northwest	0	59	52	148	266	9381	8199	22144	103824	28790	38570	56005
Northwest	0	0	177	111	355	576	554	20002	64346	39359	32921	33797
West-Northwest	0	0	177	59	89	0	3220	17860	24867	49927	27272	11588
West	0	0	89	399	266	0	199	14123	36078	67574	101762	39690
West-Southwest	0	0	473	724	325	332	739	10385	47289	85222	176251	67792
Southwest	0	0	155	1950	7445	2327	21051	39908	237907	794415	1309664	598964
South-Southwest	0	118	3176	451	3287	12187	39073	69431	428525	1503608	2443078	1130137
South	0	421	1330	111	111	665	60937	72503	583428	1625407	2527944	1091040
South-Southeast	0	406	2969	5879	362	222	29013	75576	738331	1747207	2612810	1051943
Southeast	0	886	2127	798	1507	1374	57635	37788	369166	873603	1306405	525971
East-Southeast	136	440	1137	281	2039	1898	8361	38320	177959	254355	398702	405373

Land use along the Hudson is varied. The good limestone has led to many quarries along the banks; one disused quarry is adjacent to the Station. Land is also used by a number of institutions: the prison at Ossining, the Veterans Administration Hospital at Montrose, the New York State Military Reservation (Camp Smith), and the West Point Military Reservation. For recreation there are several sections of the Palisades Interstate Park on the west bank, parks and beaches on the east bank, as well as fishermen's landings. The river provides for commercial and pleasure boating.

The area immediately around and including Indian Point is zoned for heavy industry. The industries nearest the Station are a wallboard factory and a yeast plant. Use of the Indian Point site by the applicant was approved by the Westchester County Department of Planning.

A number of power stations planned, under construction, or in operation, that will add their thermal loads to the river are on the Hudson River (See Section III.D, Table III-1). A study of assimilation of thermal discharges into the Hudson from power stations, from industry and municipalities, prepared for the State of New York, lists the stations.[5] Within 10 miles of Indian Point, there are two operating stations, Indian Point Unit No. 1 (265 MW(e)) and Lovett (503 MW(e)) located 1.5 miles southwest of Indian Point on the west bank of the river; four stations are under construction, Indian Point Unit No. 2 (873 MW(e)), Indian Point Unit No. 3 (965 MW(e)), and fossil-fueled Bowline Point Units Nos. 1 and 2 (each 600 MW(e)); and two projected nuclear generating stations, Verplanck Unit 1 and Unit 2 (2,230 MW(e)) to be located about 1 mile south of the Indian Point site on the east bank of the river. Within 50 miles of Indian Point are two fossil-fueled plants on the Hudson River - an operating facility, Danskammer (500 MW(e)), 23 river-miles north of Indian Point, and a power station that is under construction, Roseton Unit 1 and Unit 2 (1,200 MW(e)), 22 miles north of Indian Point. A pumped storage hydroelectric station is planned at Cornwall (2,000 MW(e)), 13 miles to the north. To the south, about 38 miles from Indian Point, there is a fossil-fueled unit that is in operation within metropolitan New York at 59th Street (221 MW(e)). See Chapter XII for further discussion of power plants on the Hudson River.

D. HISTORIC SIGNIFICANCE

Except for troop movements in the Revolutionary War, Indian Point has no historic significance. In 1777 the British landed at Lents Cove to raid Peekskill. The nearest landmarks of consequence are St. Patrick's Church and a cemetery in Verplanck and St. Mary's cemetery along Broadway Road. Stony Point Battle Reservation is on the west bank of the river 2 miles downstream. The Palisades Interstate Park is west of the Stony Point area on the west side of the river. The National Register of Historic Places[6] (including designated National Historic Landmarks) and the Hudson River Valley Commission's preliminary inventory of historic resources list many buildings and sites within several miles of the Station but none that are affected by it. Both Stony Point Battlefield and the Palisades Interstate Park are Registered National Historic Landmarks. The Hudson River Valley played an important role during the American Revolution. Table 2.1-1 in the applicant's Supplement No. 1 to the Environmental Report contains a list of historic places in the vicinity of the Station. The Advisory Council on Historic Preservation recommended that the New York State Historic Trust be contacted by the staff in regards to the listing of these landmarks and the effects the Plant has on the historic significance of the area. See Section V.A.4 for further details.

Only two archaeologic sites in Westchester County are mentioned by Ritchie.[7] "Most of the sites spared by construction or other modern activities have been heavily molested by relic collectors over a very long period and relatively few have received attention from competent...archaeologists." Indian Point was for many years before its acquisition by the applicant a commercial amusement area operated by the Hudson River Day Line and, presumably, was overrun by relic collectors.

E. HYDROLOGY AND OTHER ENVIRONMENTAL FEATURES

1. The Hydraulics of the Hudson River Estuary

The dominant environmental feature in the Indian Point area is the surface water of the Hudson River. It begins in the Adirondacks at an elevation of about 4,300 feet on the southwest slope of Mount Marcy and receives the Mohawk River about 150 miles downstream, just above Troy Dam.[8] Hilly, forested land along the river banks and the lakes near to the river also are predominant and serve as water reservoirs and recreational facilities.

The river at Indian Point is from 4,500 to 5,000 feet across and has a maximum depth of about 85 feet. The cross-sectional area in the region is about 160,000 square feet[16] but the 22-mile stretch from Indian Point to Chelsea is 140,000 square feet.[12] The section of the Hudson River extends from Troy to Clinton Point, about 30 miles upstream from Indian Point, and has a volume of approximately 29 billion cubic feet.[17]

Several municipalities use the Hudson for their principal water supply, as shown in Table II-2. The city of New York has also constructed a pumping station on the Hudson River at Chelsea, some 22 miles upstream from Indian Point. This station is to be used to supply Hudson River water to the city during drought periods when the water supply is low and the demand high. In addition, several of the small streams and lakes within a 5-mile radius of Indian Point are used for water supplies for local municipalities. Only two reservoirs, Camp Field which serves Peekskill and Stony Point on the west bank, are within a 5-mile radius of the Station.

Temperature in the estuary at Indian Point varies with the seasons. Temperature measurements taken by the applicant for the water intake of Indian Point Unit No. 1 during the summer months of 1967 showed a range of between 74 to 80°F; in 1968 the range was between 74-79°F.[9] In October 1966, the applicant recorded that the highest temperature of the cooling water to the condenser for Indian Point Unit No. 1 was about 81°F.[9] The applicant also collected temperature data from June-December 1969.[10] During the summer months, river temperatures ranged from 72 to 82°F with peak temperatures during August. A 10-degree F per month decrease in river temperature was observed from September to December 1969 at which time the river temperature stabilized at about 32°F.[11] During 1969-1970 the river temperature ranged from 34°F, which was maintained from January through early March, to 81°F in August.[12] There was little temperature variation across the stream, with a maximum variation of 2F° (1.1C°). The vertical temperature profile also showed little variation, with a maximum of 2.5F° (1.4C°) from top to bottom, the cooler water being on the bottom.[12]

Turbidity as measured with a Secchi disk ranged between 1 and 4 feet visibility, with higher turbidities nearer both shores. Dissolved oxygen (D.O.) at the Indian Point area is generally around 70% saturated at observed temperatures and for most of the year is around 6 to 7 ppm but varies seasonally from about 4 to 10

Table II-2. MUNICIPAL WATER SUPPLIES DRAWN FROM THE LOWER HUDSON RIVER[8]

Community	Population Served	Average Use in mgd[a]
Green Island[b]	4,016	0.37
Rensselaer[b]	10,745	2.4
Highland	4,469	1.0
Port Ewen	2,622	0.5
Poughkeepsie	63,590	7.36
	85,422	11.63

[a] mgd = million gallons per day.

[b] No longer draws water from Hudson River and probably will not in the future except for emergency purposes. (see p. 9 of Appendix XII-11)

ppm.[12,13] The value for D.O. is dependent on the water Biochemical Oxygen Demand (BOD) which is high in the vicinity of municipal waste outfalls. Consideration of average values as presented in Table 2.1-3 of Supplement No. 1 to the Environmental Report for Indian Point Unit No. 2[14] must be considered in this light. This table shows the variability of chemical constituents in part due to the tidal and fresh water flow. Nitrate, phosphate, and organic materials present are from both natural and man-made sources. (See Table III-15 for concentration levels of these chemicals in the river.)

The water in the Hudson River at Indian Point is principally derived from two sources, fresh water from runoff in the river watershed and ocean water from the Atlantic Ocean. Although the salt concentration of the fresh water is very low, the ocean water contains about 31 or 32 parts per thousand (ppt) of salt.[15] As a result, it is possible to determine the relative proportions of ocean and runoff water in the estuary. The runoff of fresh water supplies all the water in the estuary downstream as far as the salt water front. Below this point, the upstream flow of saline ocean water becomes a progressively more important source of water within the estuarine system. Superimposed on the above two flows there exists the estuarine tidal flow which dominates the flow phenomena at Indian Point.

a. Fresh Water Flow

The average flow of fresh water for the entire Hudson River is about 20,000 cubic feet per second* (cfs), which is discharged from a watershed of 13,370 square miles.[8] At Indian Point, as well as elsewhere on the river, the flow of fresh water is subject to large annual variations, with maximum flows in excess of 30,000 cfs in the spring and minimum flows of 3,000 to 4,000 cfs in late summer.[8] The net mean downstream flow due to runoff is in excess of 26,000 cfs 20% of the time; of 15,250 cfs 40% of the time; of 10,500 cfs 60% of the time; of 7,000 cfs 80% of the time; and of 4,000 cfs 98% of the time.[14] In addition, the flow from the reservoir north of the dam at Green Island is regulated to maintain fresh water flow downstream from Hadley at the highest possible level, generally about 3,000 cfs[8] or at least 2,000 cfs during periods of drought.[16] In contrast, floods of 215,000 cfs (1936), 181,000 cfs (1948), and 135,000 cfs (1960) have been measured at

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*Note - 1 cubic foot per second (cfs) is equivalent to about 450 gallons per minute (gpm) flow.

Green Island.[17] Monthly average flows and drought flow frequencies are given in Figs. II-4, and II-5, respectively.

b. Tidal Flows

Below the dam at Troy, 150 miles above the mouth, the Hudson is under tidal influence. In general, the range between high and low tide is 4.5 feet at the Battery in New York City, 2.7 feet at West Point, and 4.7 feet at Troy.[17] According to the U.S. Army Corps of Engineers,[17] the highest water level in the Indian Point region was between 7.3 and 7.5 feet above mean sea level (November 25, 1950). In general, the greatest flood threat in the middle and lower Hudson is associated with storm conditions where the effects of tide and wind are superimposed.[17]

Investigations of tidal flows in the Hudson in 1966 indicated that at the Battery, maximum tidal discharges of 300,000 to 400,000 cfs were not uncommon, with a few maximum tidal discharges of 500,000 cfs.[16] The tidal flow as measured at Poughkeepsie on May 24-25, 1966, is presented in Fig. II-6.[16] Figure II-7 illustrates the variation of flow velocity throughout one tidal cycle as measured along the axis of the channel.[18] If this velocity is assumed to exist over the entire flow cross section, the maximum ebb flow computes to be about 350,000 cfs and the maximum flood flow 275,000 cfs. It is interesting to note that a 13% variation in flow area occurs between high and low water slack, which partially accounts for the higher observed ebb velocities.

In comparison with the runoff of fresh water, the tidal flux has a large effect on the volume and chemistry of the water flowing past the Indian Point site. At Indian Point, the peak tidal flow is approximately 300,000 cfs; it is often more than 30 times the input of fresh water[8] and about 100 times the minimum fresh water flow for which the river is regulated. Details of flow characteristics of the Hudson estuary are also discussed in the applicant's Appendices of the Supplement No. 1 to the Environmental Report.[14]

Both the water velocity and direction change through time. In addition, changes in barometric pressure[8] and winds associated with storms[17] may cause changes in the flow characteristics of the water in the Hudson River. However, in all cases the tidal flows are much larger than either the flow of fresh water resulting from runoff (Fig. II-4)[19] or net nontidal flow caused by the ocean water from intrusion.

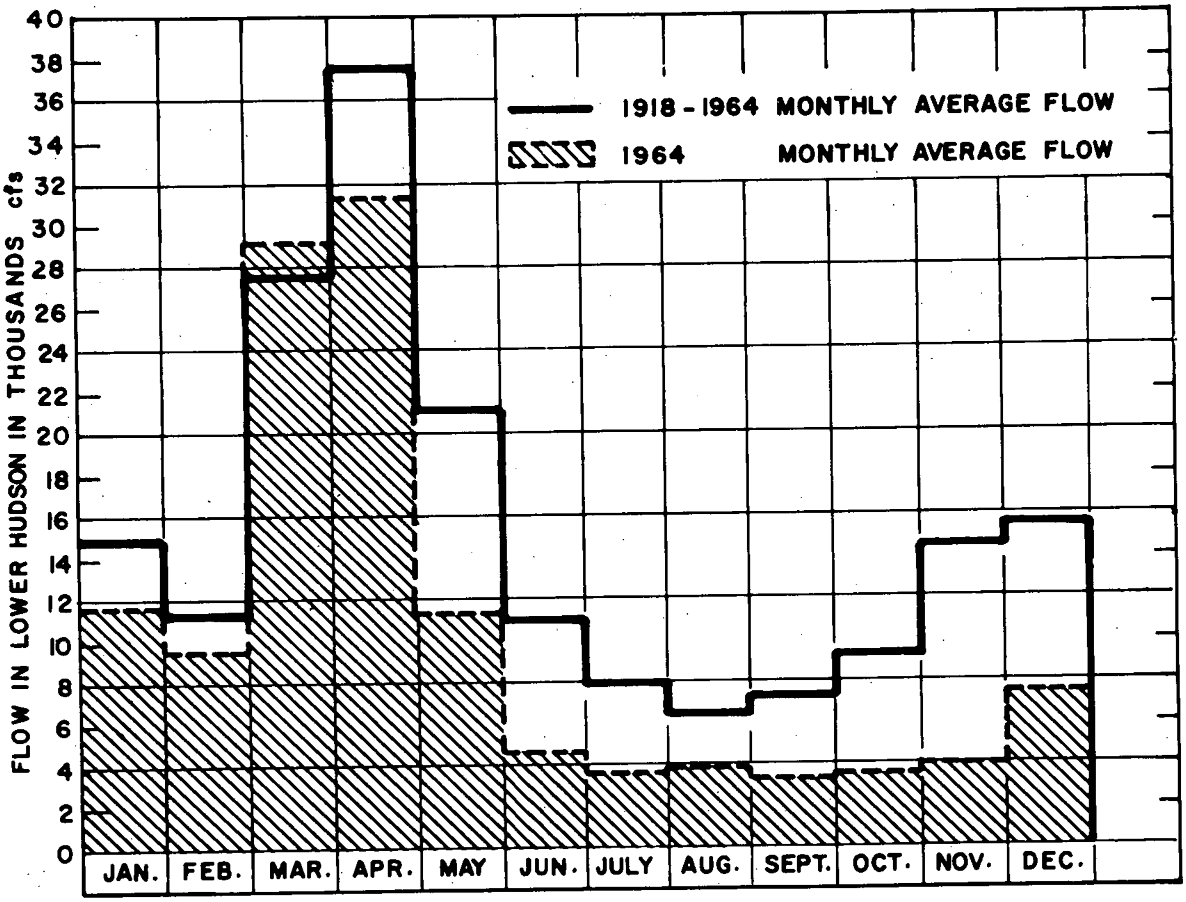
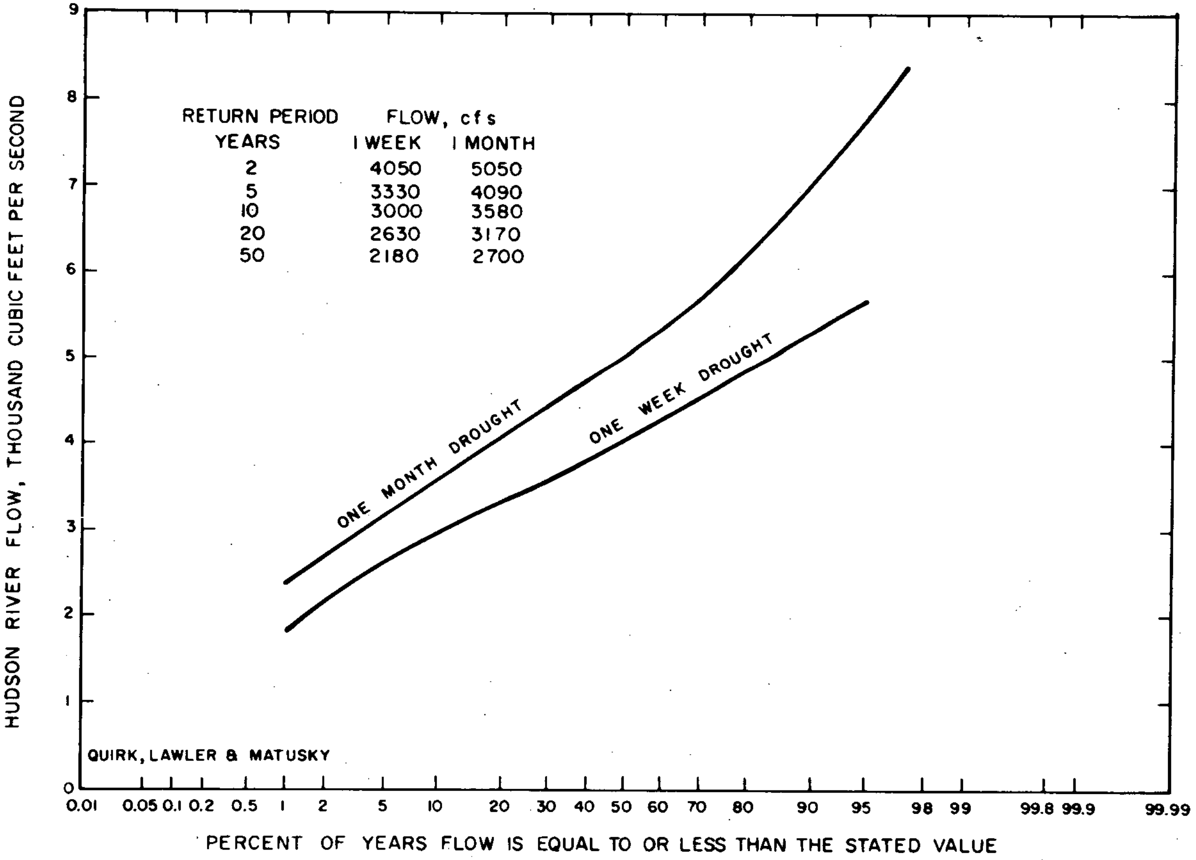


Fig. II - 4
Fresh Water Flow in Lower Hudson at Indian Point.



RETURN PERIOD YEARS	FLOW, cfs 1 WEEK	FLOW, cfs 1 MONTH
2	4050	5050
5	3330	4090
10	3000	3580
20	2630	3170
50	2180	2700

Fig. II-5
Monthly and Weekly Drought Flow Frequencies at Indian Point

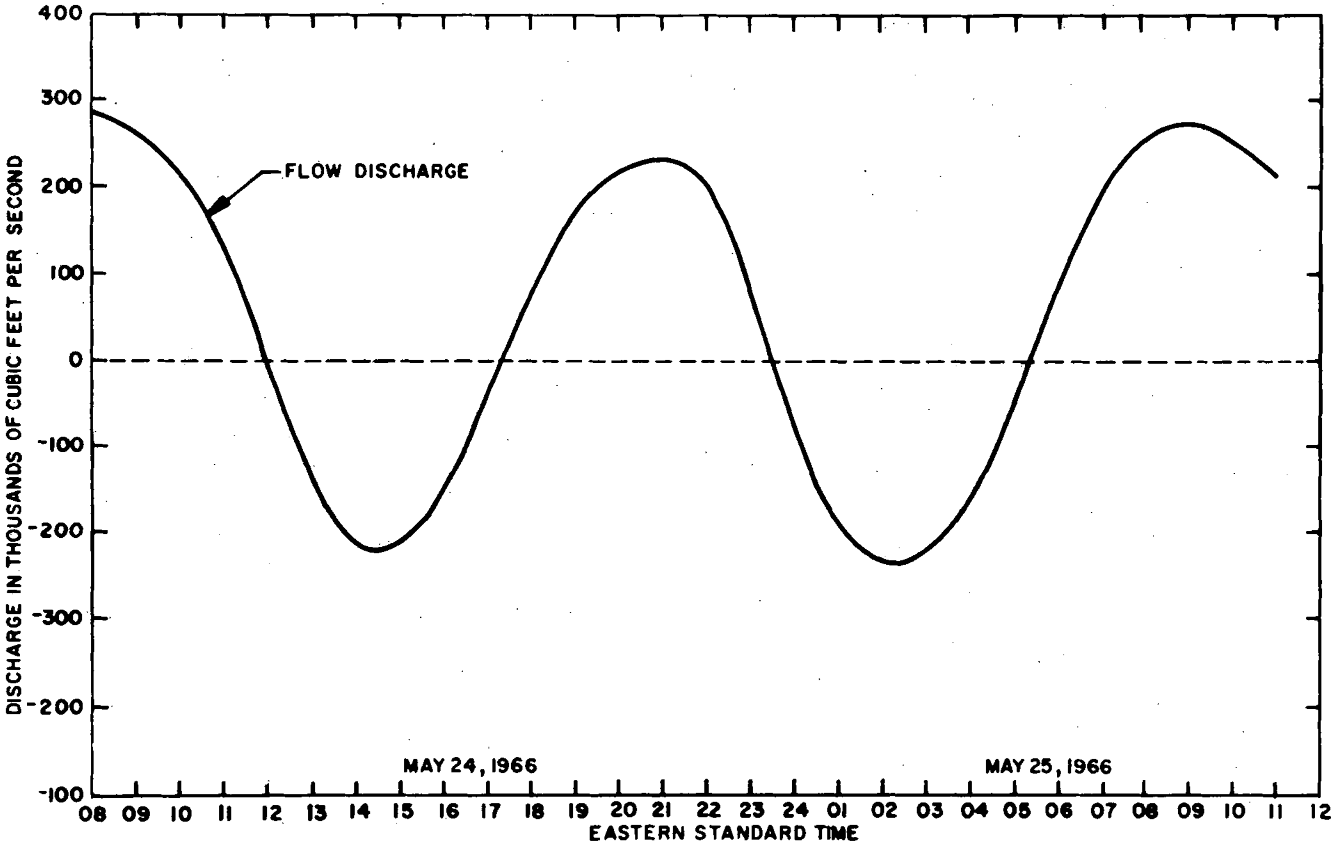


Fig. II-6
Flow Discharge During Tidal Measurement on May 24-25, 1966-Hudson River Near Poughkeepsie, N.Y.

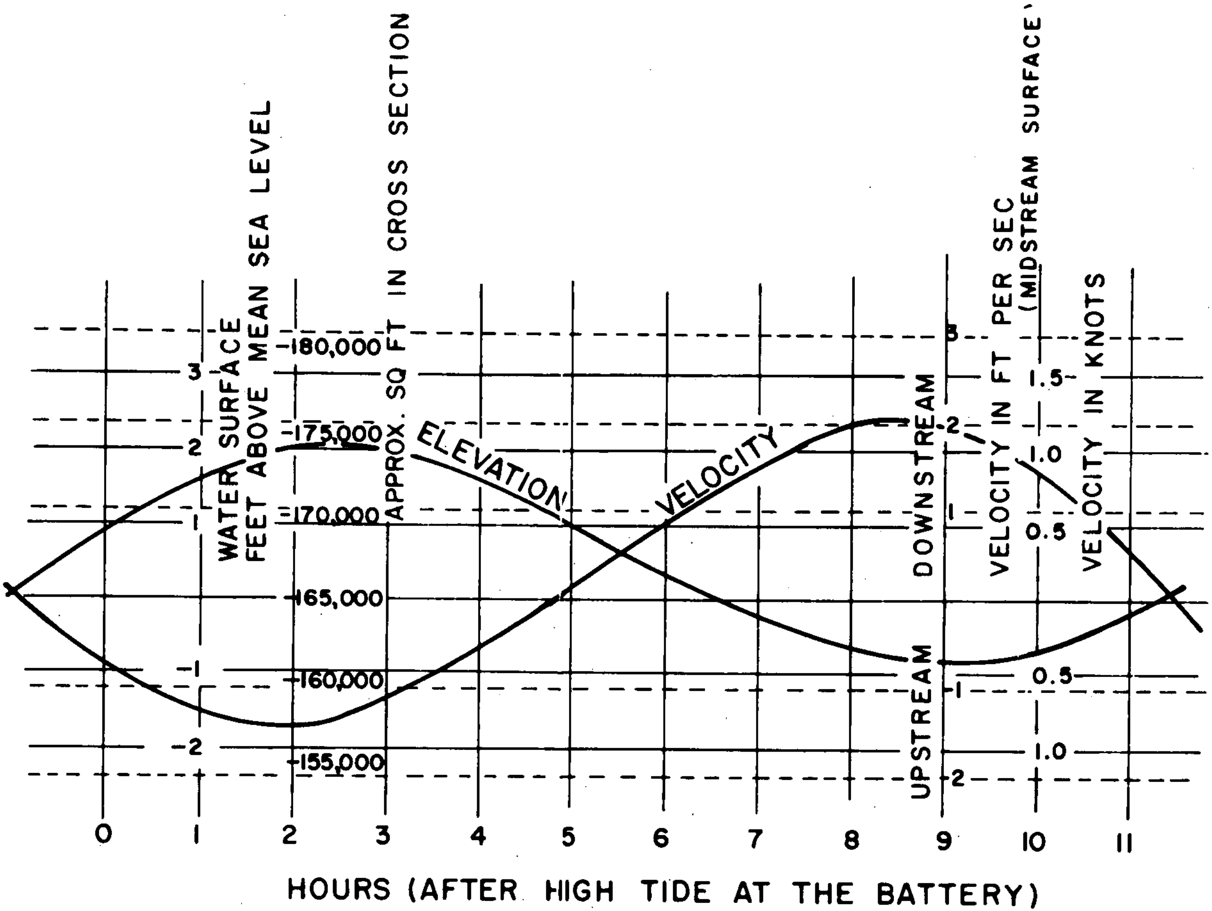


Fig. II-7 Tidal Velocities and Level Changes at Indian Point

c. Ocean Water Intrusion

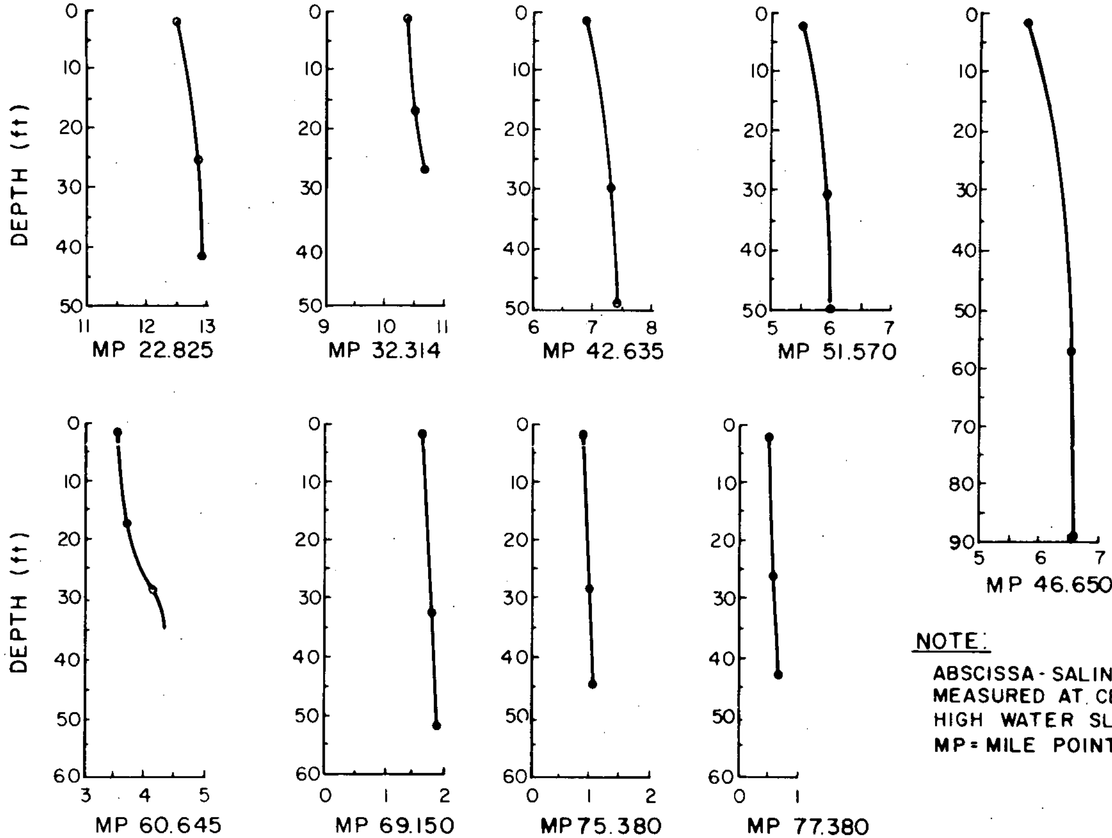
As a result of the variability of the magnitude of fresh water discharge, the salinity of the water at Indian Point is not constant. During the spring runoff period (March through early May), the water is essentially fresh; however, during periods of low flow in late summer and early autumn, saline water often reaches Poughkeepsie.[8] Vertical salinity gradients at 9 locations are given in Reference 20 for a condition when the river flow was relatively steady at 4,000 cfs for several months. Under these conditions salinity concentration in excess of 0.1 parts per thousand (ppt) extend to approximately Mile Point 85. These salinity profiles, taken in midchannel during high water slack, are shown in Fig. II-8. The salinity concentration decreases with distance from the Battery.

Annual salinity at Indian Point ranges from 0 to 5.5 ppt,[10,11,13] although values up to 7.3 ppt were observed in 1964 during a severe drought.[12,19] The relationship between fresh water discharge and salinity at various locations in the Hudson is shown in Figs. II-9 and II-10.

At a freshwater flow in excess of 20,800 cfs, the salt intrusion front is driven downstream from Indian Point for the entire tidal cycle.

The saline-intruded region of the Hudson River falls into the category of partially stratified estuaries (also called partially mixed). Inclusion of the Hudson within this category is justified because of the nature of the vertical and longitudinal salinity gradients.

The upstream intrusion of ocean water is an important characteristic of estuarine flow. This phenomenon causes both dilution and dispersion to increase toward the mouth of the estuary. However, the net effect of this increase in dilution capability depends on a variety of factors, many of which are difficult to evaluate. This characteristic is especially important in relationship to the dissipation of Plant effluents and to the migration of passive planktonic organisms. As a result, predictions of many physical and biological effects of Plant operation rely on an accurate evaluation of the circulatory nature of the Hudson during periods of ocean water intrusion. In addition, the highly variable nature of the flow area along the Hudson tends to limit the significance of analytic flow models, which usually assume constant flow area. Figure II-11 (from Reference 19) illustrates the cross section of the Hudson at



NOTE:
ABSCISSA - SALINITY ppt
MEASURED AT CENTER CHANNEL,
HIGH WATER SLACK.
MP = MILE POINT

Fig. II-8 Variations of Salinity with Depth in the Hudson at Nine Locations. Fresh Water Flow, 4,000 cfs.

INDIAN POINT

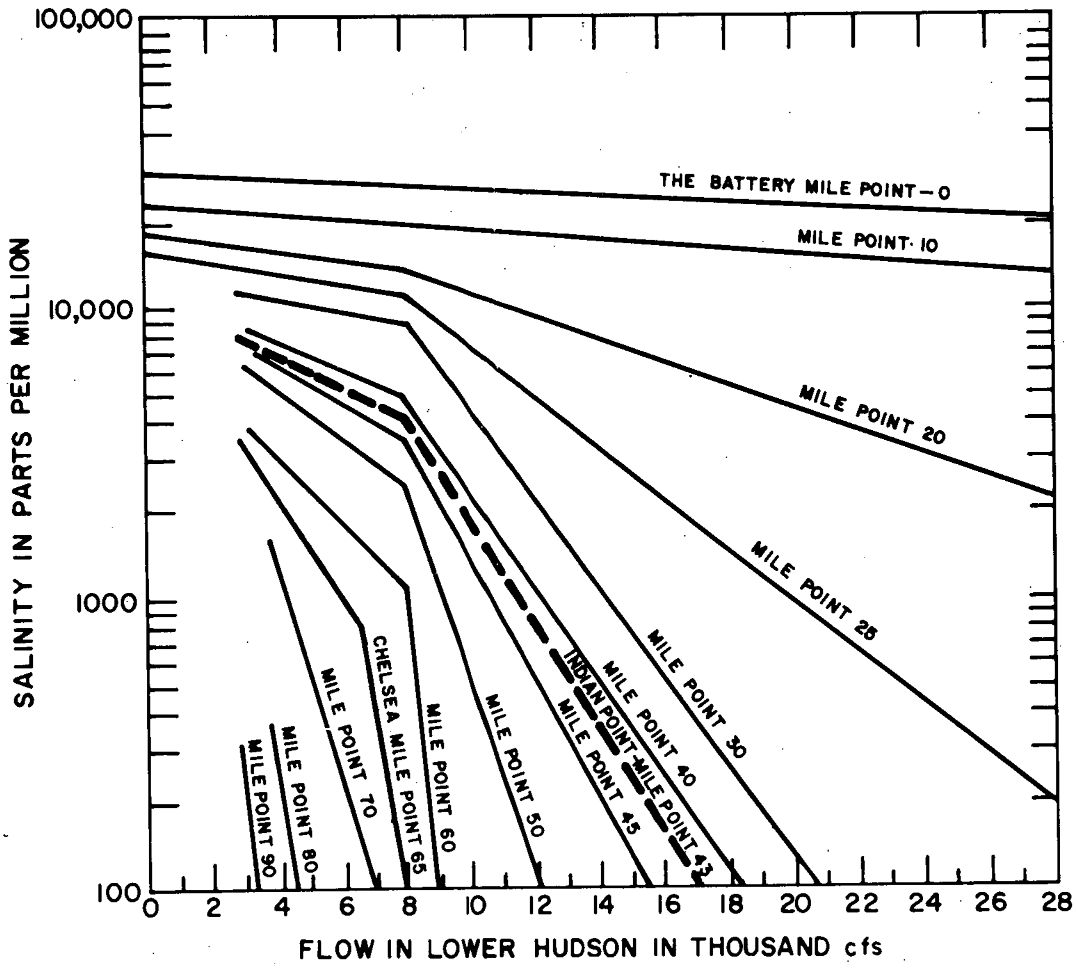


Fig. II-9
Hudson River Salt Intrusion Curves-Salinity Averaged Over Tidal Cycle and Channel Cross-Section.

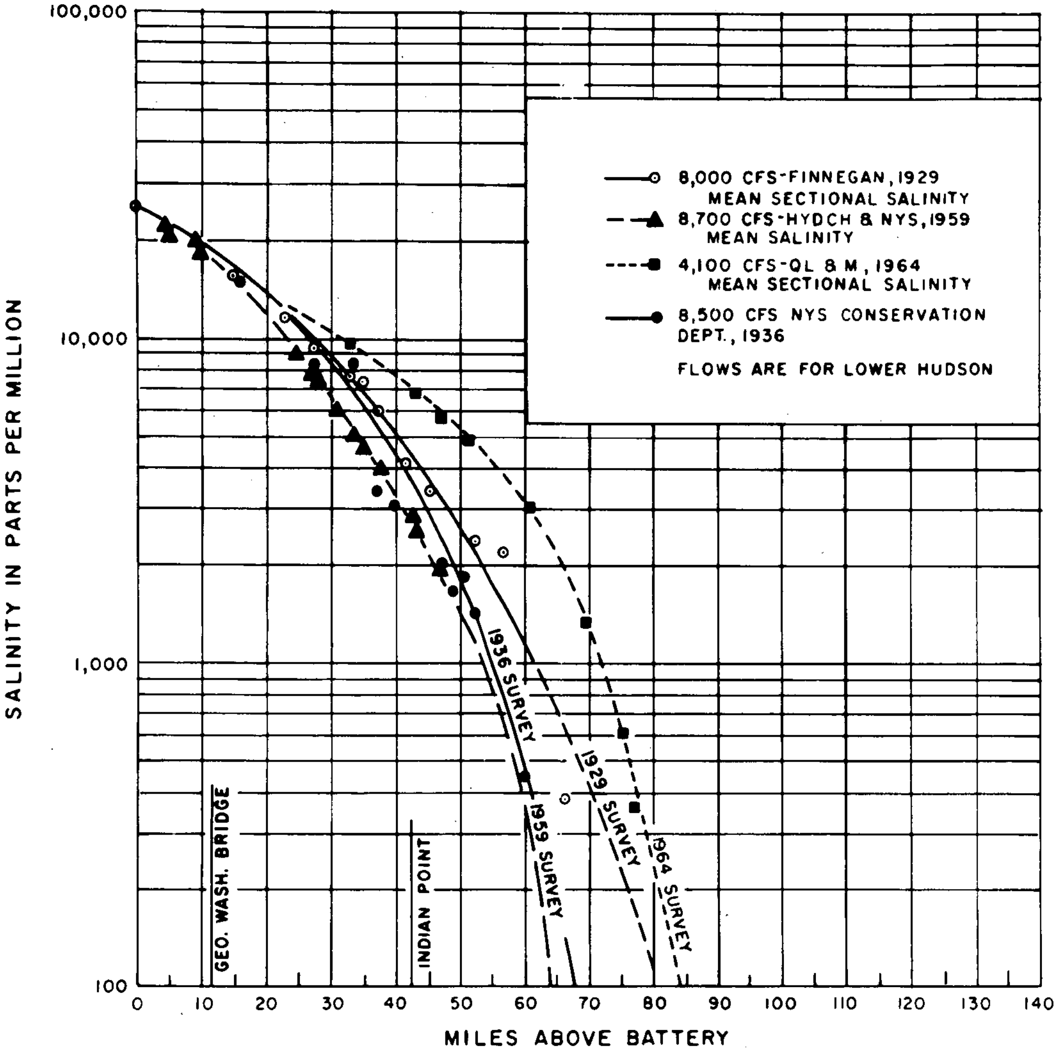
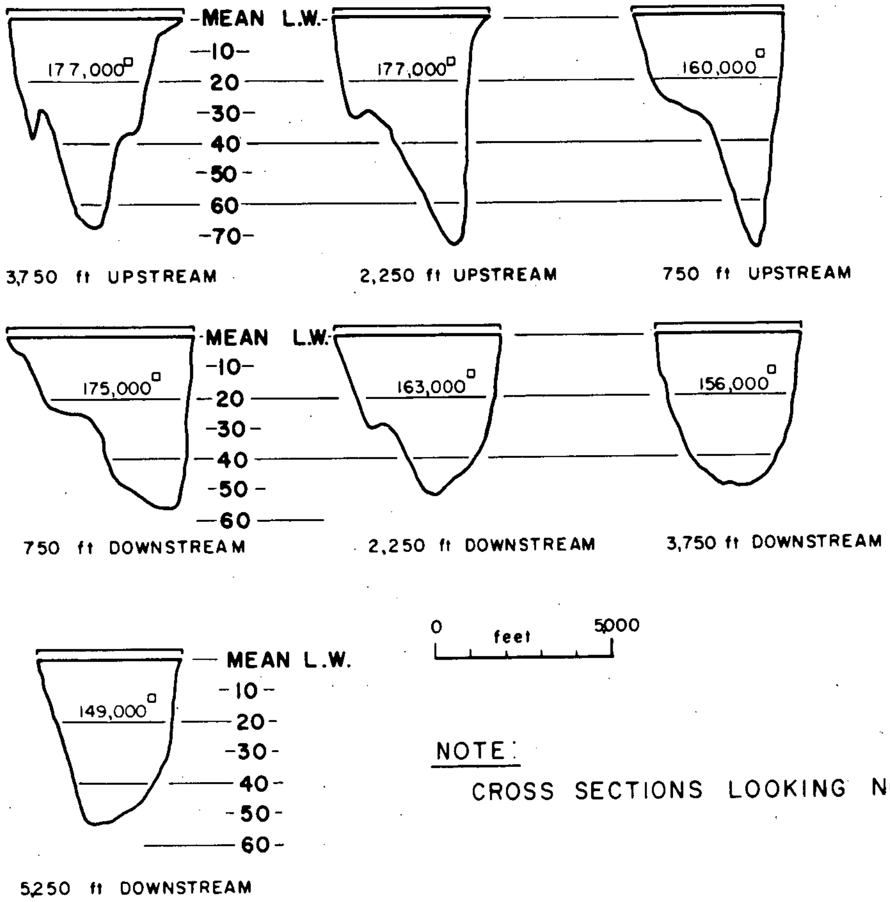


Fig. II-10 Longitudinal Salinity Distribution in the Hudson



NOTE:
CROSS SECTIONS LOOKING NORTH

Fig. II-11 Cross Sections of the Hudson Near Indian Point, Looking Upstream seven locations from 1 mile downstream to 3,750 feet upstream from Indian Point. The variation of flow area at mean low water with distance from the Battery is illustrated in Fig. II-12, also taken from Reference 19. The mean low water flow area at Indian Point is 160,000 square feet.

d. Flow Patterns and Velocity Structure

The above three flows do not, of course, exist independently; they combine to create a very complex flow pattern and velocity structure. In a partially mixed estuary like the Hudson the major flow patterns involved are (1) a two-layered horizontal flow with a net-tidal-average landward flow of more saline water in the lower layer, (2) a net-tidal-average vertical flow from the lower layer to the upper layer, and (3) vertical mixing in both directions between the two layers. Figure II-13 shows schematically these flow patterns. This concept of the two-layered flow is misleading if looked upon as if it were the description of conditions at any one instant. One must be aware that (1) no distinct interface exists between the two "layers", but vertical mixing extends throughout the depth (see Fig. II-8), mixing the fresher water downward and the more saline water upwards, although there are still two layers as far as the flow is concerned; (2) at no time except maybe at the time when the tidal flow reverses itself do such opposing lower and upper velocities exist at the same time because, as mentioned before, the tidal flow dominates (see Fig. A-V-7, Appendix V-2); however, when averaged over a full tidal period, the resultant flows will indeed show such a distinction; and (3) because of the vigorous vertical mixing, the upper layer flows might not be identical with the flow available for removal and transporting conservative effluents introduced into it (see discussion in Appendix V-2).

For evaluation of the upper layer flow magnitude, see Section III.E.1.d, and for its relation to net downstream movement, see Appendix V-2.

2. Groundwater

Groundwater occurs at the Station site largely in the joints of the limestone rock, although it would probably be wrong to call this rock an aquifer.[22] The jointing and fracturing are irregular, and so are the permeability and porosity of the limestone. In the surrounding area, wells drilled in the limestone, and to a lesser extent in the schist and phyllite, yield a few gallons of water a minute, enough for modest domestic supplies. Locally, where the

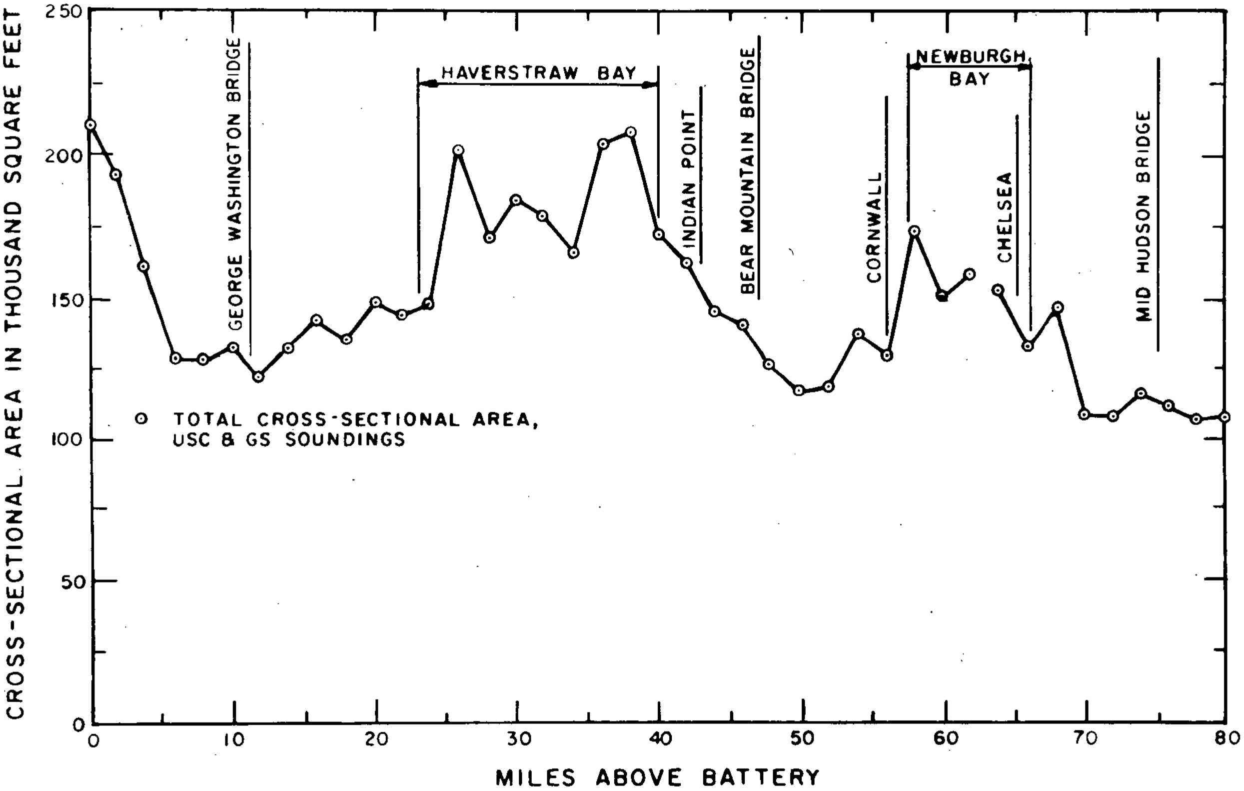


Fig II-12 Variations of the Hudson Flow Area at Mean Low Water

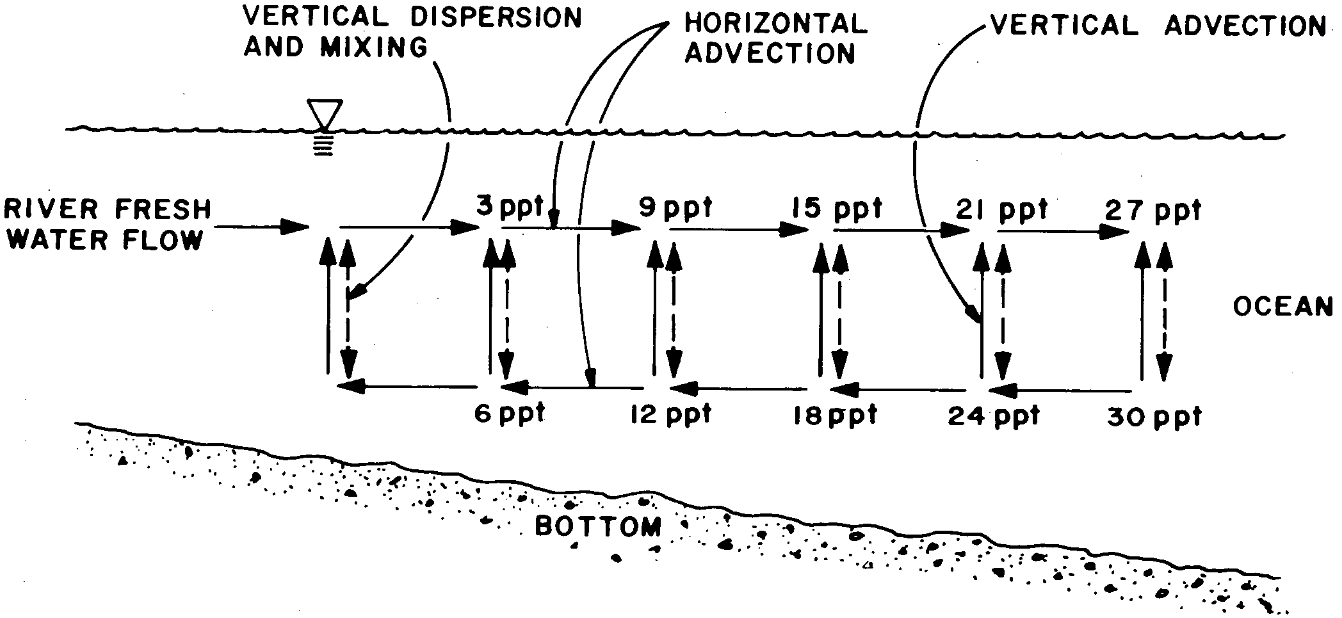


Fig. II-13
Schematic of Flow Pattern and Salinity Distribution (ppt) in a Partially Mixed Estuary. Indian Point

glacial till is thicker and more permeable than it was at the Station site, wells can be constructed which yield several hundred gallons of water a minute. A number of such wells serve industrial plants in the area. The only public water supply from wells within a 5-mile radius of the Station is the Stony Point system on the west bank of the Hudson. Locally, on the west bank the sandstones and conglomerates of the Newark series can supply modest amounts of water to wells, somewhat more than is supplied by the sections of glacial till.

Danger of contamination of the local groundwater supplies is minimal. Leaks, spills, or the leaching of any leakage near the Station would largely sink into the ground and be slowly carried to the Hudson River by the groundwater flow. Contamination of off-site groundwater supplies by radioactive materials released in normal operation at the Station site is very remote.[14]

3. Geology and Geography

The three reactors at Indian Point are built on a hard, dark gray, metamorphosed dolomitic limestone.[22] The limestone rock is well bedded and dips steeply to the southeast. It is also much fractured and jointed, which makes it irregularly permeable. There has been little solution along the joints, and the rock is not cavernous. Even without grouting, the rock is very strong and more than capable of carrying any load that will be placed on it at the site. The bedrock was covered only with a few feet of glacial till. This was removed in the construction area, as was the limestone down to grade, and any weak, fractured limestone below grade. The rock surface was then treated with a lean cement mix, and the concrete foundations were poured directly on the treated rock. The rock was not pressure-grouted.

Adjacent to the dolomite are schist and phyllite formations, and within a few miles to the east, the basic igneous intrusive rocks of the Cortlandt complex. To the west, across the river, are further exposures of limestone, schist, and phyllite, presumably the same formations as at the Station site, although less metamorphosed. On that side of the river there are also much younger Triassic rocks which do not occur on the east bank. These are the well-cemented conglomerates, sandstones, and red shales of the Newark series and the diorite and basalt similar to the rock that makes the Palisades.[22]

There are no truly major faults in or near the site. A number of earthquakes have been felt in the area over the last century or so, including one of Intensity VII (MM) in New York City in 1884 (Refer to Section XII. A).

The Indian Point site is surrounded on all sides by high ground ranging from 600 to 1,000 feet above sea level. Along the winding Hudson River, are steep, wooded slopes of the Dunderberg on the west bank and West Mountains to the northwest and Buckberg Mountain to the west-southwest on the east side of the river where the site is located. The peaks are lower but include Spitzenberg and Blue Mountains. A number of lakes are scattered between the hills and mountains. The site itself is hilly rising to about 150 feet above the river level. The site, as stated above, will have 80 acres of heavily wood land and a fresh water lake.[2]

4. Climate

Because the Hudson River is in a deep valley at Indian Point, the local and the general weather is not the same. At river level and 100 and 200 feet above river level, the winds are upstream by day and downstream by night more than a third of the time; a usual speed is 5 or 6 miles per hour (mph). The valley winds predominate during the inversions that prevail 42% of the time. The staff in its studies of gaseous effluents used the meteorological data of Report 372.3, pages 24-27.[23-25] The records for Bear Mountain, at 1,301 feet elevation, show winds from all directions during rainstorms; during thunderstorms south winds are predominant, with few winds being found from north to east.[23] Tornadoes are almost unknown in New York; the coastal hurricanes are the storms that bring the most wind.[26] According to Appendix XII-4, the Department of Commerce states that the probability per year of a tornado striking a point in the area of the Plant is 0.00048. Precipitation averages 46 inches per year and is rather uniform month by month; the measured annual range is from 36 to 63 inches. Because evaporation and soil retentivity are greatest in summer and because of snow in winter, the flow of the Hudson River is not uniform through the year but is high in spring and low in late summer. Mean ambient air temperatures near Indian Point vary from 28°F in January to 75°F in July, with extremes of -19° and 105°F.

5. Special Environmental Considerations

The Indian Point site has no unique natural environmental values such as a natural wildlife sanctuary, forested areas, geysers, or caverns. The site is surrounded by geographically interesting terrain such as the forested mountains but the facility is not expected to have any influence on the terrain as presently constituted.

The site was formerly used by the U.S. Maritime Administration to dock its reserve fleet. Prior to construction of Indian Point Unit No. 1, about 189 vessels were docked but by July 31, 1971, the entire fleet had been removed from the area. The site was formerly an amusement park that had been abandoned after its use as a park had diminished.

F. ECOLOGY OF THE SITE AND ENVIRONS

1. Terrestrial Ecosystem

The terrestrial plants at the Indian Point site are typical for the area. The forested sections are typical of an oak-maple-hemlock community. Other species, such as linden, cottonwood, sumac, hickory, dogwood, and wild cherry, are also present where they have been introduced into previously cleared areas. Wildlife at the site is composed of porcupines, woodchucks, squirrels, opossums, insects, and a variety of birds, as well as other species.[14] The site and surrounding habitats are by no means in a wilderness area, and the plants and animals are typical of those species which are adaptable to human intrusion.

2. Aquatic Biota

The aquatic biota of the area is diverse. Fig. II-14 shows a simplified food web for the Hudson River at Indian Point. A list of aquatic species found in the area by several investigators is included as Appendix II-1 of this Statement. The principal aquatic primary producers in the vicinity of Indian Point are phytoplankton. The high turbidity and deep water do not provide a good habitat for the development of extensive communities of periphyton or rooted vascular aquatics in the immediate vicinity of the Plant. However, such communities exist within the area that will be affected by operations at Indian Point. Howells and Weaver[27] studied the phytoplankton at Indian Point and found members of some 53 genera of planktonic algae.

The zooplankton of the area is represented by most major groups.[28] In general, the zooplanktonic species include protozoans, occasional medusal coelenterates, rotifers, nemertines, and microcrustaceans (including Cladocera, Ostracoda, Mysidacea, Copepoda, Amphipoda, Isopoda, and some Decapoda). Also included are the pelagic larvae and juveniles of larger forms. Included in this category are the larval stages of barnacles (Cirrepedia), larger decapods, annelids, and mollusks and early developmental stages of several fish species.

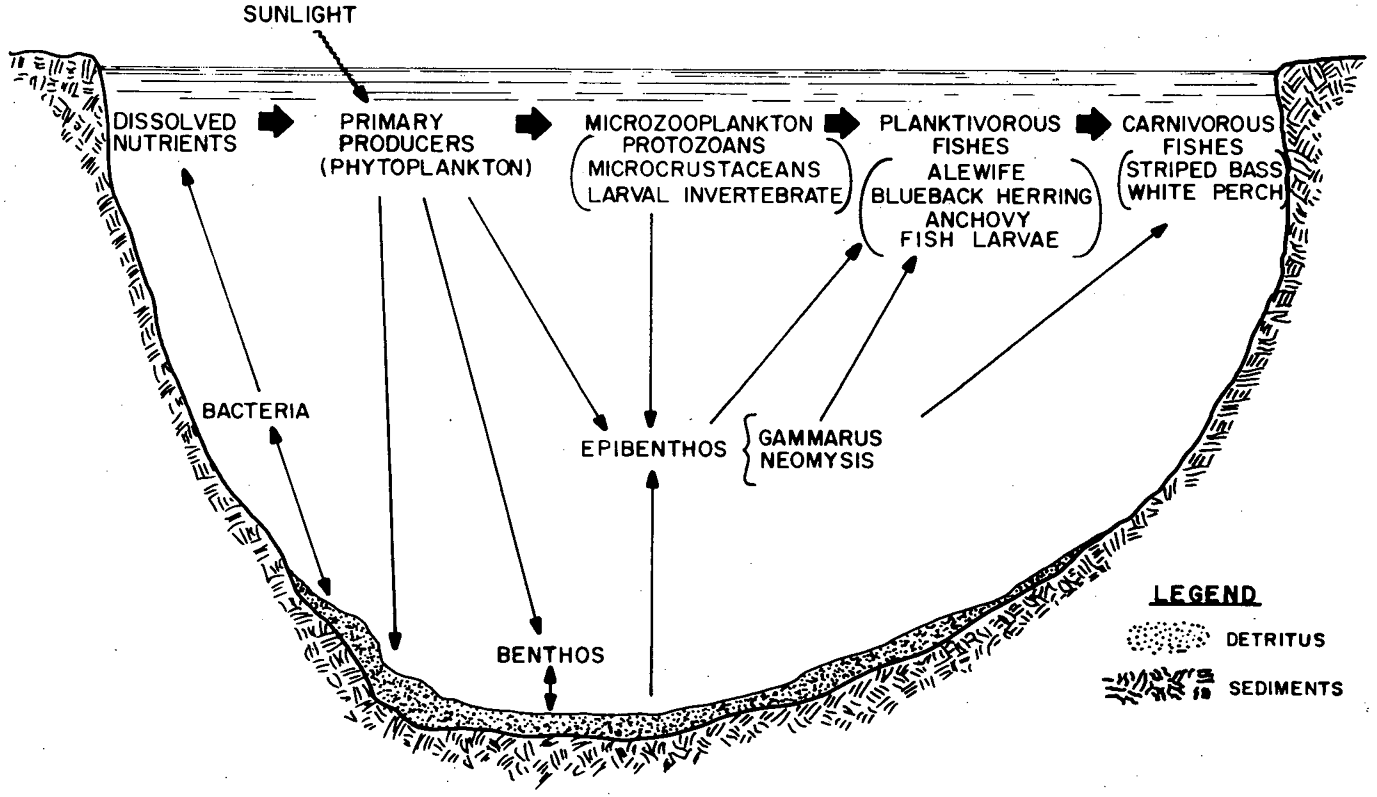


Fig. II-14
Simplified Aquatic Food Web for Hudson River at Indian Point.

a. Decomposers

Bacterial communities in the Hudson at Indian Point are important constituents of the biological community. These organisms are important in that they are responsible for the decomposition of organic matter which thereby provides the raw materials for growth of phytoplankton. Thus bacterial decomposition prevents loss of important materials from biological systems. Bacteria play an additional role by assimilating dissolved organic matter in the water. The bacteria themselves are food for much of the microscopic zooplankton and thereby contribute directly to production at higher trophic levels.[28]

For most bacteria characteristic of waters in the temperate region, the optimum temperature for growth is about 95°F. Temperatures lower than this optimum inhibit growth. In laboratory cultures with optimum temperature and nutrient supply, bacterial populations are able to double themselves within 18 to 35 minutes. If optimal conditions for growth could be maintained and there was no predation, a single minute bacterial cell could produce 2.4×10^{25} bacteria per ton of river water in 48 hours.[29] However, the generation times of bacteria in natural waters are not exceptionally short and are regulated by available food supplies. The generation times of bacteria in a series of impoundments range from 9 to 120 hours. In comparison, the maximum net production of phytoplankton in Lake Erken is about 150% of the standing crop per day.[28] This indicates that for short periods, the generation time of the phytoplankton may roughly equal that of the bacteria. The growth of bacteria in natural water does not normally outstrip the growth of phytoplankton so greatly that the bacteria continuously dominate the food supply of the zooplankton. On the contrary, it is only when the phytoplanktonic organisms die, releasing large quantities of nutrients for bacterial growth, that the bacteria may temporarily increase their role as an energy source for the zooplankton.[28]

Bacterial densities in the Hudson near Indian Point vary with the season. In the winter, the bacterial density may be as low as 1×10^6 per liter or less, while summertime densities may exceed 5×10^7 per liter.[5]

b. Primary Producers

Planktonic algae are responsible for using energy from the sun to convert carbon dioxide, minerals, and water into the organic material of which they are composed. These organisms provide the basis for the food web of aquatic systems and are the principal food of most of the zooplankton[29] and many fish species as well.[30]

At Indian Point the dominant species most of the year belong to the genus *Melosira* sp., with *Asterionella* sp. as a secondary dominant form. The abundance of these organisms varies from 5 x 10^5 to 6 x 10^6 per cubic meter of river water. As the salinity builds up in the summer, the special composition changes in favor of more salt-tolerant forms, such as *Rhizosolenia* sp., *Chaetocerus* sp., and *Thalassiosira* sp. About 25 genera of algae (principally diatoms) are present in the area at all times.[27] Some variation in species composition across the river has been observed. However, when averaged for several months, there was little variability in the percentage composition of the major groups of phytoplankton across the river. Diatoms accounted for about 70% of the phytoplankton, green algae for about 23%, blue-green algae for about 5%, and all others less than 1%.[31]

As indicated above, algae may have a short generation time. Under optimum conditions some species are capable of producing 3 generations per day. However, the normal population growth rate is regulated by temperature, light, grazing by herbivores, and available nutrients.[32]

Many algae are capable of limited movement, although the movement is small in comparison with the movement of the water in their habitat. Consequently, the turbulence and current of the river are primarily responsible for their distribution within the water.

In the Hudson, only those algae which are near the surface are able to capture energy from the sun to grow and reproduce. Since their distribution is largely regulated by the turbulent estuarine water currents, the phytoplanktonic organisms are not always in the upper photosynthetically active zone, which averages about 6 feet deep.[5] Consequently, even if all other factors were optimum, the generation time would still be much longer than predicted by laboratory analysis.

c. Consumers

(1) Zooplankton

The zooplankton is a diverse group of organisms which transform their generally less nutritious food (phytoplankton, bacteria, and organic detritus) into a form more readily utilized by larger organisms. These larger organisms include larger zooplankters, larval fish, and adults of several fish species, such as the bay anchovy, which utilize the zooplankton for food throughout their life cycle.

Many reproductive strategies are employed among zooplankton species. Protozoans generally reproduce by division of parent cells into two daughter cells. Under optimum conditions for growth, including food supply and temperature, protozoan populations can double from 1 to 3 times per day.[33]

Population growth of small crustaceans such as copepods and cladocerans is also very dependent on temperature, noticeably increasing as the temperature increases. Doubling times of 0.2 to 2.0 days have been observed for these organisms at temperatures of about 77°F.[34,35] The population turnover rate (100% replacement by a new crop) may be as little as 4 days at 77°F but up to 22 days or longer when temperatures are low. One-quarter of a 28% average loss rate per day at summer temperatures has been attributed to predation.[34]

Many of the larger zooplankters, including amphipods and euphasiids, may reproduce during only one season a year. Their resiliency or capacity to recover from population decimation may be very limited compared with the microscopic forms, which can produce one or more generations per day and reproduce throughout the year.

Heinle[36] found that the upper thermal tolerance of the copepods *Arcatia tonsa* and *Eurytemora affinis* was between 86° and 95°F when the acclimation temperatures were 68° and 77°F. Growth rate and productivity of both species increased with increased temperature up to about 80.6°F. Above that temperature the growth rate and productivity decreased.[36]

The most abundant invertebrate utilized by fish in a 1964 survey based upon examination of 190 fish stomachs, was the amphipod *Gammarus*.[37] Dipteran larvae and pupae, adult insects, and smaller crustaceans such as cladocerans, copepods, and ostracods were also important components of the stomachs. However, the individual size of the invertebrates in the stomachs varied with the sizes and ages of the fish caught.[37]

(2) Macroinvertebrates

This group of organisms includes bottom fauna, which live in or on the bottom deposits, and organisms that attach themselves to any hard surface. Larval stages of these organisms form a part of the zooplankton. Most of the larger invertebrate organisms (macrobenthos) that live in these habitats reproduce during only one season of the year, so that their ability to recover from a kill would be restricted compared with many microbenthic forms which reproduce throughout the year.

Little is known about the quantitative aspects of these organisms in the Hudson River. Generally, this fauna appears sparse both in the Indian Point area and throughout the lower part of the estuary.[37-39] In deeper portions of the Hudson River north of Indian Point and through the Hudson gorge, grab samples commonly contain no specimens of macrobenthos. The microbenthos has not been sampled.[10,11,13,37-39]

Benthic organisms common in the Indian Point area include *Balanus* sp. (barnacle), *Congeria* sp. (clam), polychaete worms, and *Gammarus* sp. (amphipod), which also occurs as a planktonic species.[10,11,13]

(3) Fish

As is typical of estuarine situations, there are a great number of species of fish (See Appendix II-1). Included within these species are residents which are found in the area throughout the year. Other species are present in the area only during periods of high discharge of fresh water and the associated low salinity. Another group composed principally of marine fishes move into the area during periods of intrusion of salt water. In addition to the resident species and those which move in and out of the Indian Point area with the salt front, there are seasonal migrants. Both anadromous* and catadromous** species pass the Indian Point area on their way to and from spawning grounds. From a biological standpoint, protection of the lower Hudson is most important in relation to the fish species that use the estuarine environment for purposes of reproduction and early development. A more detailed analysis of these species can be found in Appendix II-2. Migratory fish in the area include striped bass, shad, alewife, smelt, sturgeon, blue-back herring and eels. Principal resident fish are catfish, minnows, white perch, tomcod and sunfish. The shad and striped bass are the two most important commercial species and the striped bass, the most important sport fish.

d. Special Ecological Considerations

From an ecological standpoint, the most significant feature of the Hudson River at Indian Point is that it is an estuary. Because of this fact, the lower Hudson, including the Indian Point area, is a spawning and nursery area for species that populate not only the Hudson River but Long Island Sound and the Atlantic Ocean near New York. The most prominent such species is the striped bass (See Appendix V-3). There is considerable evidence that the Hudson is a major spawning area for the striped bass living in Long Island Sound. Besides being important commercially, the striped bass plays an important ecological role as a predatory fish. Several other anadromous species also use the Indian Point area as a spawning or a nursery area or both.

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*Anadromous fish is a species which ascends rivers from the sea for spawning.

**Catadromous fish is a species which lives in fresh water but swims to sea water to spawn.

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III. THE STATION

A. GENERAL

The Indian Point Station owned by the applicant includes three Units, each consisting of a pressurized water reactor, a turbine-generator, and auxiliary equipment. Unit No. 1 has been operating since 1962 as a combined nuclear- and oil-fired fossil plant to produce a gross output of 285 MW(e) and net output of 265 MW(e). Construction of Unit No. 2, with a net capacity of 873 MW(e), will be completed by end of 1972. Unit No. 3, with a capacity of 965 MW(e), is under construction and is scheduled to be completed by 1974. The following discussion is limited to a description of Units Nos. 1 and 2.

Waste heat from Units Nos. 1 and 2 is dissipated by once-through cooling with water from the Hudson River. In Unit No. 2, cooling water is withdrawn from the Hudson River at a maximum rate of 840,000 gallons per minute (gpm) through pumps at full capacity and at 30,000 gpm for service water purposes. Upon passing through 3 condensers, the circulating cooling water is heated up to 15 F° above ambient and discharged into a common discharge canal with Unit No. 1. The heated water is then discharged into the Hudson River through a submerged multiport discharge at a minimum velocity of 10 feet per second (fps). Dilution of the thermal discharges take place by jet entrainment, and ambient diffusion, with heat dissipation eventually by surface heat exchange into the atmosphere.

B. EXTERNAL APPEARANCE

The stack for Unit No. 1 and the concrete containment vessels for the reactor Units dominate the landscape of the Indian Point site. Part of the stack for Unit No. 1 will be removed because of safety considerations. However, the structures housing the superheater, turbine-generators, and service facilities of the Units have been designed to integrate this complex so as to present an acceptable appearance from the river side. The whole Station can be seen from this side. The Unit No. 2 containment vessel, to the north of Unit No. 1, is taller than that of Unit No. 1, but the brick-faced turbine-generator building for Unit No. 2 is contiguous with that for Unit No. 1 and has a complementary architecture. The Unit No. 3 containment vessel, to the south, will be of the same size and construction as that of Unit No. 2 (see Fig. III-1). The two will form a symmetrical arrangement around Unit No. 1, as shown

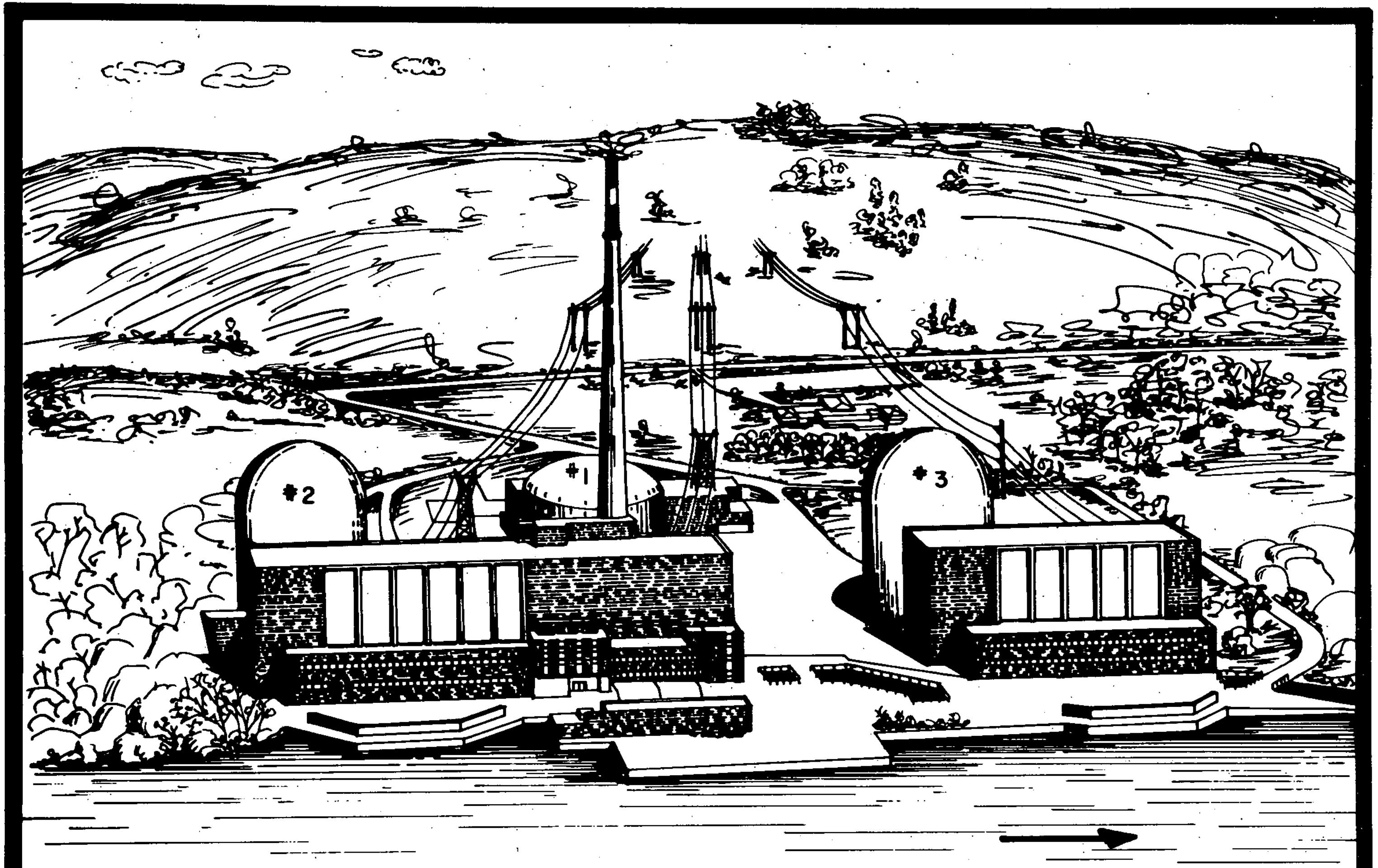

Fig. III-1
Representation of Indian Point Site.

in Fig. III-2. Decorative concrete screens and boxes planted with appropriate shrubbery will shield the pumps and other machinery of Units Nos. 2 and 3 so that no outside hardware will be visible from the river side. Similar mechanical equipment for Unit No. 1 is housed in a permanent structure. Form, color, and texture of the buildings have been considered so that the setting is enhanced and the feeling of intrusion is held to a minimum.

Landscaping of the area immediately surrounding the complex is in progress, in which advantage is taken of the hilly and rocky terrain and the adjoining wooded areas. The northern part of the site includes 80 acres of woodland, including a freshwater lake. The applicant plans to develop this area into a public park, with picnic tables and benches located in shaded spots around the lake and with nature trails leading to the shoreline of the river and the Unit No. 2 turbine-generator building. A new visitors' center with parking and toilet facilities for public use will be provided at the site. A temporary visitors' center, which has been in use since September, 1959, is located on a hill overlooking the Station and the Hudson River. Exhibits and other information will be available in the new center showing a master plan for enhancing the educational, recreational, and scenic value of the site for the visiting public.[1]

C. TRANSMISSION LINES

According to the applicant, the transmission of electricity from Unit No. 2 to the load center will not require additional rights-of-way for transmission lines. The new transmission lines are strung on existing towers or on new towers along the old right-of-way. Steel pole construction was used in the area between Unit No. 2 and the Buchanan Substation located across Broadway Road to improve aesthetic value as well as to incorporate the latest engineering knowledge (Fig. III-3). The double-circuit structures are designed to carry the Unit No. 2 output of 873 MW(e) at 345 kV to the applicant's system at the Buchanan Substation 2,100 feet away from the turbine building[2] plus the 138-kV input for the Unit No. 2 light and power facilities or the 138-kV output from Unit No. 1.

Two additional lines were strung from the Buchanan Substation to the Millwood Substation, a distance of approximately 9-1/2 miles, and two terminal positions were made at the Millwood Substation. These lines were placed on existing structures on existing rights-of-way so that additional changes from building Unit No. 2 did not

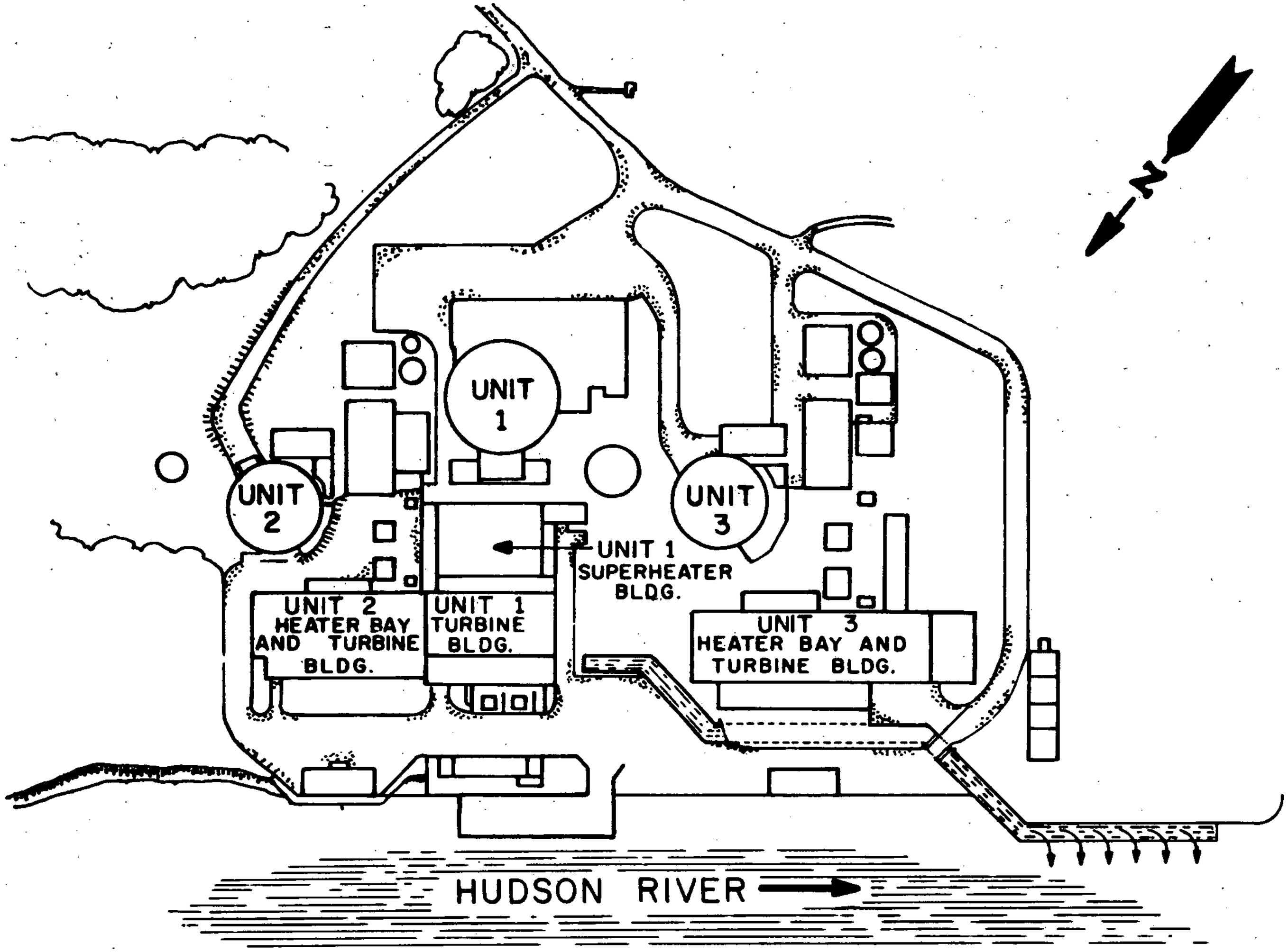

Fig. III-2
Indian Point Plant Site Layout.

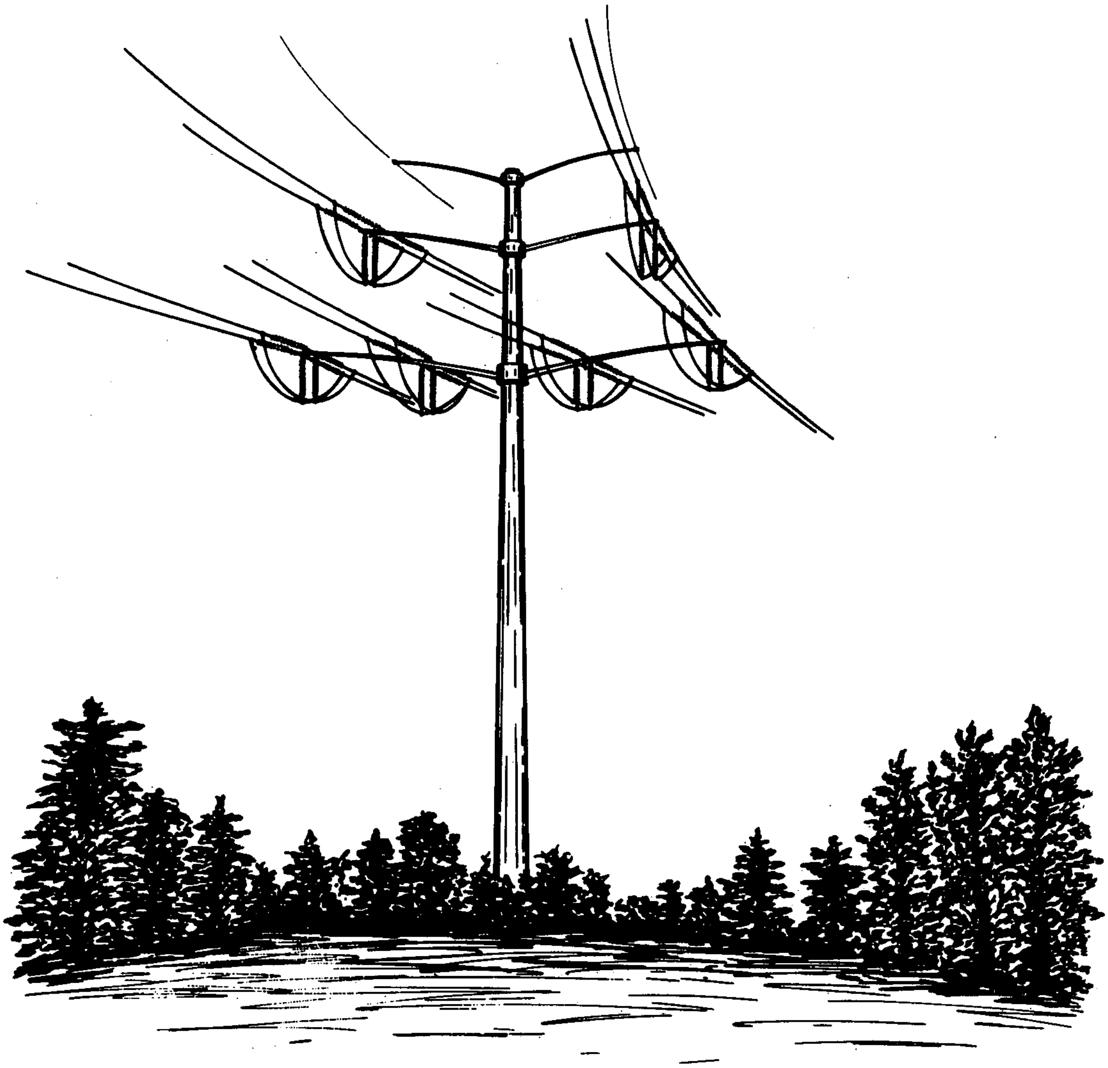

Fig. III-3
New Type
Steel Transmission Pole

result in any further modification of the environment because of construction of transmission lines. Approval from New York State for additions to the existing lines and structures was received. Furthermore, the electrical output from Indian Point Unit No. 2 will be transmitted from the Buchanan Station to the Pennsylvania-New Jersey-Maryland (PJM) interconnection.[2]

D. REACTOR AND STEAM-ELECTRIC SYSTEM

The Indian Point facility consists of three separate Units, each powered by a closed-cycle, pressurized, light-water-moderated and cooled nuclear reactor as its source of heat for generating steam to produce electricity. Unit No. 1, with a total capacity of 890 MW(t) (615 MW(t) nuclear and 275 MW(t) fossil) and a gross electrical output of 285 MW(e) (45 MW(t) is heat lost in Plant), was completed in 1962 by Babcock & Wilcox. It utilizes an oil-fired superheater to furnish about 112 MW(e) of net capacity to supplement about 153 MW(e) of nuclear power (net) by superheating the saturated steam.[3] The steam electric system uses once-through cooling at a maximum flow rate of 319,000 gpm to dissipate waste heat, including about 39,000 gpm for the service water system.

Units Nos. 2 and 3 were designed and are being built by the Westinghouse Electric Company, which has a turn-key responsibility, including the testing and initial startup of Unit No. 2. Construction of Unit No. 2, with an initial thermal output of 2,758 MW(t) and electrical output of 873 MW(e), will be essentially completed by winter 1972. A Facility Operating License No. DPR-26 was granted to the applicant to load fuel and to perform subcritical tests on October 19, 1971. Unit No. 3 has an initial thermal output of 3,075 MW(t) and an electrical output of 965 MW(e); it is approximately 70% complete, with service scheduled for 1974.

The reactor core in Unit No. 2 is fueled with slightly enriched uranium dioxide in the form of pellets which are contained in sealed zircaloy tubes, set in 193 fuel subassemblies. The fissioning of uranium-235 in the fuel rods is controlled by both a chemical shim (boron) in the form of boric acid and control rods, which consist of stainless steel-clad absorber rods of cadmium, indium, and silver. Moderator and primary coolant water pressurized at an operating pressure of 2,235 pounds per square inch gauge (psig) is pumped through four separate primary loops, each with a circulating pump and a vertical U-tube steam generator, to remove heat from the reactor. The primary coolant water is heated to a design temperature of 650°F in passage through the core to the steam generator in each loop and is pumped back to the reactor core for reheating. In the secondary system, water at a design pressure of 1,085 psig and 427°F is converted to steam at 600°F in the steam generator which drives the tandem-compound turbine-generator unit, which incorporates one high-pressure and three low-pressure turbines on one shaft. The "spent" steam is condensed in three single-pass condensers by water withdrawn from the Hudson River, and the resulting condensate is recirculated through the feedwater heaters to the steam generator. The cooling water is pumped at a maximum flow rate of 840,000 gpm through six pumps through single-pass condensers and is heated approximately 15 F° before being discharged into the discharge canal. Each reactor has an individual water intake, but all three Units discharge their circulating cooling water into a common open canal. (See Section III.E for details of the cooling system.)

The primary system — consisting of the reactor, steam generators, circulating pumps, primary coolant piping, and pressurizers — is housed in a domed, cylindrical, reinforced-concrete containment vessel lined with steel. The secondary system and additional auxiliary systems are housed separately in adjacent buildings. Another building is provided for fuel handling purposes and for storage of spent fuel (see Fig. III-2).

These systems are described in detail in the applicant's Preliminary Safety Analysis Report (PSAR) and Final Facility Description and Safety Analysis Report (FFDSAR) for Unit No. 2 and the staff's Safety Evaluation and Supplements.

E. EFFLUENT SYSTEMS

1. Heat

a. Projected Heat Load on the Hudson River

One of the major concerns in the production of electricity by steam-generator systems is the disposal of waste heat. Modern fossil-fuel plants convert thermal energy into electrical energy at an efficiency of about 38%, while light-water nuclear facilities have an efficiency of about 32%. In fossil plants, a maximum steam temperature of 1,050°F is attainable, while in current light-water reactors the maximum steam temperature used is about 600°F. Fossil plants discharge a significant portion of their waste heat (about 15%) to the atmosphere, while nuclear plants discharge virtually all waste heat into coolant water. As a result, the water discharged from a nuclear plant contains 50% more heat per unit of electricity than that from a fossil plant. The simplest and most economical method is to utilize an easily available and adequate supply of water in a once-through cooling system. This has been a satisfactory and often used method up to the present time.

The environmental features of the Hudson River are described in Section II.E. Table III-1 shows the location of existing and planned steam-electric stations on the Hudson River. The facilities closest to the Indian Point site include the existing Lovett Plant (Orange and Rockland Utilities, Inc.) about 1 mile downstream; the Bowline Point Units Nos. 1 and 2 under construction by Orange and Rockland and the applicant, about 5 miles downstream; the existing Danskammer (Central Hudson Gas and Electric Corporation); and the Roseton Plants Unit 1 and Unit 2 (under construction as a joint venture of Central Hudson Gas and Electric Corporation, Niagara Mohawk Power Corporation, and Consolidated Edison), both about 23 miles upstream. Table III-1 also shows some operating characteristics of these plants.[4] Indian Point Unit No. 2 rated at 2,758 MW(t) and 873 MW(e) discharges heat of about 6.38×10^9 British thermal units (Btu) per hour to be dissipated to the cooling water. The Roseton facility, composed of two 600 MW(e) units (the first of which is scheduled for operation in November 1972 and the second in May 1973), utilizes a submerged-jet type discharge system. Cooling water is discharged through a jet system 20 feet below mean low water (MLW) normal to the river flow at a location about 500 feet downstream from the intake and about 275 feet from shore. The Bowline Point Units Nos. 1 and 2, each with an output of 600 MW(e), are scheduled to be operational by the summer of 1972 (but had been delayed due to strikes) and by 1974, respectively. These units also use a submerged-jet discharge design. The jet system is located about 2,200 feet north of a channel connecting the intake pond entrance to the river and extends 1,200 feet out into the river. It utilizes eight jets, 25 feet on centers, that discharge at 15 fps, 15 feet below MLW.

b. New York State and Federal Thermal Discharge Criteria

New York State has established standards for the discharge of waste heat into its waterways. These standards have varied during the operating history of Indian Point Unit No. 1. In 1950 the New York State Water Pollution Control Board (NYSWPCB) established "Rules and Classifications and Standards of Quality and Purity for Waters of New York State," which were amended in 1954, 1956, and

TABLE III-1

OPERATING CHARACTERISTICS OF EXISTING AND PLANNED STEAM ELECTRIC GENERATING STATIONS ON THE HUDSON RIVER[4]

Station	Location (mile point)	Rated Capacity, all units [MW(e)]	Flow		Temperature Rise, T_p (°F)	Thermal Discharge, H (BBtu/day)[a]
			gpm	cfs		
Albany	140	400	352,000	784	11.0	46
Danskammer	66	508	308,000	686	14.5	54
Roseton	65	1,200	650,000	1,448	15.4	120
Indian Point (3 Units)	43	2,123	2,052,000	4,571	15.0	369
Lovett (5 Units)	42	503	323,000	720	14.8	57
Bowline (2 Units)	38	1,240	768,000	1,711	13.5	125
59th Street	5	221	168,000	374	6.0[b]	12
TOTAL		6,155	4,621,000	10,294		783

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[a] BBtu/day = billion Btu/day; Btu=British thermal unit.

Basis: H(Btu/day) = 1.2×10^4 x gpm x T_p(F°).

[b] Monthly average operation, summer 1969.

1959. In 1962 the NYSWPCB was abolished, and its functions were transferred to the NYS Water Resources Commission (WRC). In these standards the Hudson River at Indian Point was classified as "SB" waters. The use of SB waters is described as for "bathing and any other usages except shell fishing for market purposes." The quality standards for SB waters[5] include criteria which specify that no heated liquids be discharged:

> "alone or in combination with other wastes in sufficient amounts or at such temperatures as to be injurious to edible fish or shell fish or the culture or propagation thereof,...; and otherwise none in sufficient amounts to make the waters unsafe or unsuitable for bathing or impair the waters for any other best usage as determined for the specific waters which are assigned to this class."
> (6 NYCRR 701.4 et seq.)

The Federal Water Quality Act of 1965 encouraged the States to establish water quality standards for interstate streams and coastal waters by June 30, 1967. Due to a request from the Federal Water Pollution Control Administration (FWPCA) to upgrade State temperature standards, the Department of Health (NYSDH) reviewed the New York water quality critera. In August 1967 NYS issued a document[3] which stated:

> "To protect water resources, fishlife, and stream biota from effects of transient and long-range adverse temperature changes, careful studies of stream environment should be conducted where discharges of thermal significance are contemplated."

In July 25, 1969, revised temperature criteria were adopted as included in the New York State Compilation of Code, Rules, and Regulations (6 NYCRR 704.1(b)(4)).[5,6] These criteria are as follows:

> "The water temperature at the surface of an estuary* shall not be raised to more than 90°F at any point provided further, at least 50 percent of the cross sectional area and/or volume of the flow of the estuary including a minimum of one third of the surface as measured from water edge to water edge at any stage of tide, shall not be raised to more than 4°F over the temperature that existed before the

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*The lower Hudson River, including the Indian Point area, has been classified as an "estuary."

> addition of heat of artificial origin or to a maximum of 83°F, whichever is less. However, during July through September if the water temperature at the surface of an estuary before the addition of heat of artificial origin is more than 83°F, an increase in temperature not to exceed 1.5°F, at any point of the estuarine passageway as delineated above, may be permitted."

These are the current State temperature criteria applicable to operation of Indian Point Units Nos. 1 and 2. They have not been approved by the U.S. Environmental Protection Agency (EPA).

Upon submission of the New York State thermal criteria to the Federal Water Pollution Control Administration (FWPCA) of the U.S. Department of Interior for review and comment, FWPCA found that the criteria were unacceptable. After EPA was established in December 1970, attempts were made to resolve the disagreements between the State and Federal agencies. On November 10, 1971, EPA[7] recommended that the State thermal criteria of July 26, 1969 be revised to take into account the following recommendations for Federal approval.

(a) In accordance with Federal regulations (18 CFR 622.4(a)), public notice/public hearing procedures must be applied to further revise the New York State standards as adopted on July 25, 1969. Also, the revisions must be adopted in accordance with state laws, rules, and regulations.

(b) After the revised thermal criteria have been officially adopted by New York State, they should formally be submitted to the EPA for approval.

The revisions recommended by EPA include the following regulations on thermal discharges regarding estuaries:

> "The water temperature at the surface of an estuary shall not be raised to more than 90°F at any point. Further, in at least 50 percent of the cross-sectional area and/or volume of the flow of the estuary including a minimum of at least 1/3 of the surface as measured from water edge to water edge at any stage of tide, shall not be raised to more than 4°F over the temperature

> that existed before the addition of heat of artificial origin during the period from October through June or more than 1-1/2°F during the period July through September or a maximum of 83°F, whichever is less. Further the discharge must meet the additional requirement that no more than a distance of 1,000 feet on the surface in any direction shall be raised more than 4°F over the temperature that existed before the addition of heat of artificial origin or a maximum of 83°F, whichever is less during the period from October through June or more than 1-1/2°F during the period from July through September. Because of the studies that have been made on the estuarine portion of the Hudson River, the need for limiting the temperature rise here during July through September to 1-1/2°F is waived and the conditions specified for October through June will be permitted year-round."[7]

The disagreements between the Federal and State agencies regarding these thermal regulations have not yet been resolved. In regards to the U.S. Army Corps of Engineers Permit program, the applicant applied for a Section 10 Permit to modify the discharge structure and install a steel outfall section consisting of 12 submerged openings, which was approved on November 24, 1970 and later amended on November 4, 1971, to change from 18 to 12 feet below the standard reference level. Application for Section 13 Permit under the Refuse Act of 1899 was made by the applicant on June 24, 1971 and was revised on October 27, 1971. The application was administratively complete. Estimated date of final action for approval for the Section 13 Permit is December 31, 1972. New York State water quality certification was obtained by the applicant for both Units Nos. 1 and 2 on December 7, 1970. The applicant is furnishing to EPA the public hearing transcripts and other information on studies made by the applicant.

c. Description of the Indian Point Cooling System

Water for Unit No. 1, at the rate of 319,000 gpm,* is withdrawn from the river through an intake structure located behind the north end of a 247-foot long wharf directly in front of the reactor building. The structure consists of four intake cells, each 11 feet 2 inches wide with the bottom 26 feet below MLW. Originally a skimmer wall extended downward to limit openings to 12 feet 6 inches high, but in April 1966, the openings were

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*The flow rate normally used is about 300,000 in which 280,000 gpm is the flow through the condenser and 20,000 gpm is the normal service water flow, although there are additional pumps to increase the total maximum service flow up to 39,000 gpm.

enlarged to the present size of 20 feet 6 inches. Each of the four cells contains--in sequence--a stop log gate, deicing header, trash rack, traveling screen, chlorination system, and circulating water pumps. A fixed fine screen was added in 1967 to cover the opening of each cell and to leave no recesses in which fish might get trapped.

The original discharge consisted of an open canal that released the effluent directly into the river about 320 feet downstream of the intake. Recirculation problems caused the addition in 1966 of a 214-foot extension parallel to the bank, but it continued to function as a surface discharge system. This system was used until the New York State thermal criteria standard was changed in 1969 to limit a maximum surface temperature to 90°F. Thus, in 1971 the applicant modified the discharge system to utilize a submerged jet 18 feet below the standard reference level* and to discharge the heated cooling water normal to the river flow. The applicant has further modified the discharge structure during the past several months by changing the depth of the submerged jet from 18 feet to 12 feet and is adding control gates to regulate the discharge velocity through the ports to 10 fps as described below.[8,9]

The Unit No. 2 intake structure is located upstream of that of Unit No. 1. The reinforced concrete intake structure contains six main intake channels for six circulating water pumps and a divided service water intake channel. The Indian Point Unit No. 2 structure is designed with six large pumps, each having a capacity of 140,000 gpm capacity, and six small pumps for a total of 30,000 gpm of service water needs. At full capacity, the condenser flow is 840,000 gpm (1,872 cfs). Each main opening is 13 feet 4 inches wide by 26 feet deep, the top of which is 1 foot below the MLW level of the Hudson River, and serves as a skimmer wall to remove logs and debris floating in the river. Each channel contains fixed fine screens, de-icing headers, trash bar screens, stop log gates, traveling screens, and a chlorination system. The de-icer loop provides an outlet in front of the racks to melt the ice. Two de-icing pumps pump 80,000 gpm each of the warm circulating water through the de-icing loop into a de-icing spray header of the intake forebay. The fixed fine screens are at the mouth of the intake forebay to prevent fish from being trapped in the forebay. The applicant has been testing the use of an air bubble curtain in front of the intakes of Unit No. 1 and shall install and operate double air bubble screens in front of each of the intakes of both Units during the winter when the river water is below 40°F.[41] Figure III-4 is a diagrammatic sketch of the intake structure of Unit No. 2.

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*Standard reference level is the U.S. Coast and Geodetic Survey Sea Level Datum. The mean low water level is one foot below the standard reference level.

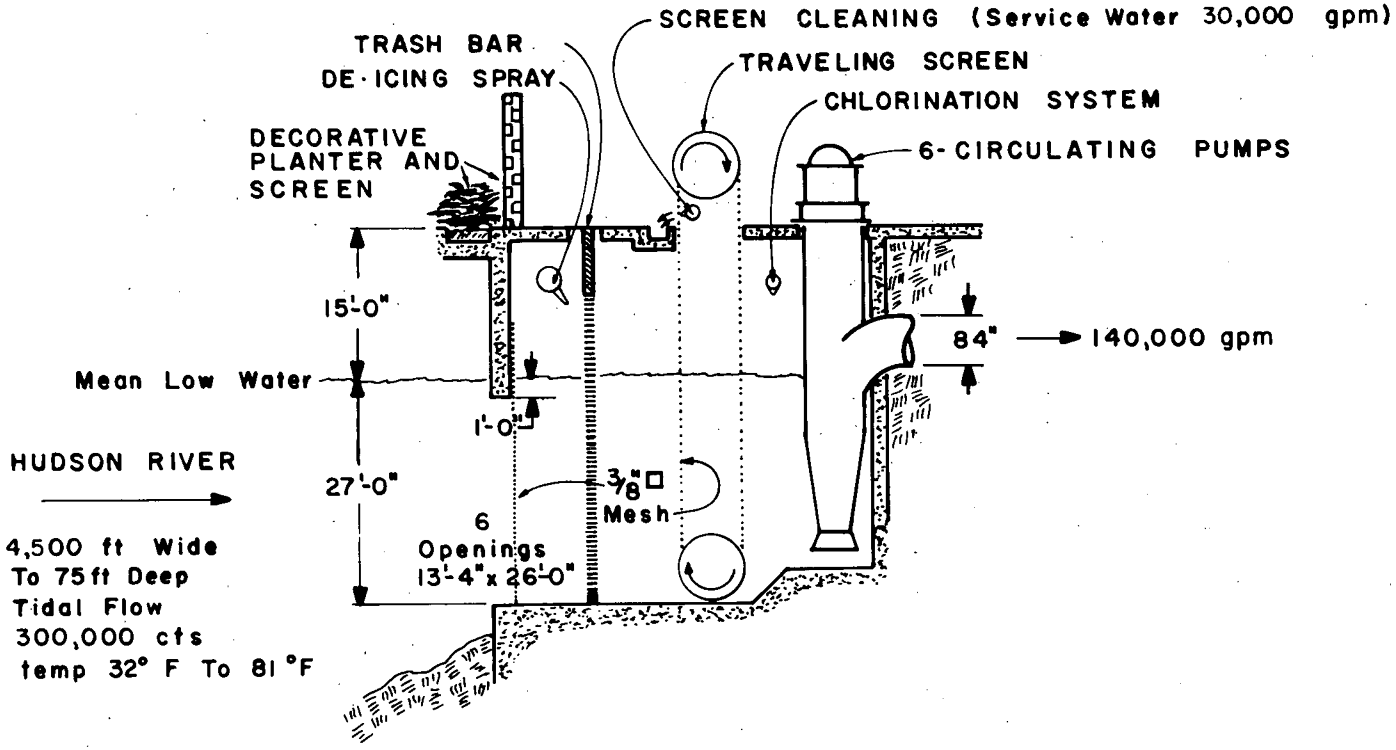

Fig. III-4
Diagrammatic Sketch of Intake Structure.
Indian Point Unit 2

A trash rack composed of vertical steel bars 1/2 inch x 3 inch on 3-1/2 inch centers is located 12 feet 4 inches from the river's edge inside each of seven cell openings to protect the circulating water pumps from logs, ice chunks, and large debris. Behind the trash racks is the provision for a fixed fine mesh screen (used on occasion) with one of the partitioned service water channels and 3/8-inch mesh mobile traveling screens. A de-icing spray header is located in the cell chamber ahead of all the screens so that heated water from the discharge canal can be recirculated at 160,000 gpm to the intake structure to melt ice that may form on or tend to clog the screens. Appropriate mobile trash rakes remove material that collects on the racks and fixed screens, and a high pressure backspray from the service water supply serves to remove material that may have impinged on the traveling screen during its up-pass.

A sodium hypochlorite system is available to treat the incoming river water to control the fouling growth on the condenser tubes. A 15% sodium hypochlorite solution injected at a rate of 5 gpm is programmed through a control panel in the Unit No. 1 intake structure and utilizes its two 4,000-gallon storage tanks and pumps. An automatic programmed control system initiates a cycle in which a slug treatment of the six water intake bays occurs in two groups of three, through the service water intake bay. However, the automatic system can be manually operated such as to inject the sodium hypochlorite solution into half of the condenser for 30 minutes and the other half for another 30 minutes. The frequency of injection will be limited to 3 hours per week, as discussed in Section V.D., for a total time of 6 hours of chlorination treatment per week for both Units.

Water for the six 900-horsepower circulating pumps is piped directly to the three steam condensers through six 84-inch diameter conduits, two going to each condenser. The water from each pump discharges into one of two inlet water boxes of the condenser. Each of the three condensers is a single-pass divided-flow waterbox construction, with 96-inch diameter inlets and outlets. They consist of 50-feet long, 1-inch O.D.,* No. 18 BWG** admiralty tubes welded into silicon bronze tube plates, resulting in 306,000 square feet of heating surface per condenser.

At full power operation, a maximum flow rate of 840,000 gpm (1,872 cfs) of cooling water will be withdrawn from the river through the six pumps, but operation at reduced flows is possible. Flow through each of three condenser water boxes is normally 280,000 gpm, but the water boxes are divided by a separation plate so that flow through each half is normally 140,000 gpm. Operation at a minimum flow of 84,000 gpm is possible. At minimum conditions, three half-sections

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*O.D. = outer diameter.

**BWG = Birmingham Wire Gauge.

must be operated at a total flow of 252,000 gpm and at maximum condition of 420,000 gpm. The recirculation system to be installed prior to winter 1972-1973 will permit a net flow to the condensers with 84,000 gpm per pump. The by-pass system shall be used at all times when the water temperature of the Hudson River in the area of the Plant is below 40°F.[41]

Velocities of the water in the intake structure will vary according to the area available for flow. At full flow of 840,000 gpm, the velocities will be 0.8 fps through the six main openings, 1.0 fps through the trash bars, 1.3 fps through the fixed fine mesh screens, and about 2.0 fps through the traveling screen panels (see Appendix III-1). At reduced flow during the winter time, when the by-pass system is in operation, the intake velocity shall be maintained at an average rate of 0.5 fps.

An open discharge canal collects all of the cooling water from Units Nos. 1 and 2 and the service water from both Plants and conveys it to the discharge facility located downstream from Unit No. 1. Figure III-5 is a diagram of the heat transfer system and canal.

The total maximum discharge can be about 2,650 cfs* (710 cfs or 319,000 gpm from Unit No. 1 and up to 1,933 cfs or 870,000 gpm from Unit No. 2), and the temperature of the cooling water will be raised about 15F°. Table III-2 indicates the variation in outfall flow rates, excess temperature increases of the heated cooling water, the peak temperature rise, and the dwell time of nonscreenable organisms from the point of entrance to the water box to the river during different pumping conditions of the intake-discharge system for Units Nos. 1 and 2.

The discharge facility is an evolution of the original discharge studies[21] and is now designed to handle the effluent from all three Indian Point Units operating at full capacity. It handles effluent from Unit No. 1 only at the present time. After the 1966 change noted above, the structure was further extended in February 1970 to a point 960 feet from the Unit No. 1 intake. In 1971, an underwater discharge system of an additional 270 feet was provided; it consists of 12 slots, each 4 feet high and 15 feet long, located with the center line 18 feet below U. S. Coast and Geodetic

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*The applicant states that a total of about 1,188,000 gpm (or about 2,650 cfs) would be used by both Units when service water is included.[1] The value of 2,650 cfs has been used in the staff's analysis.

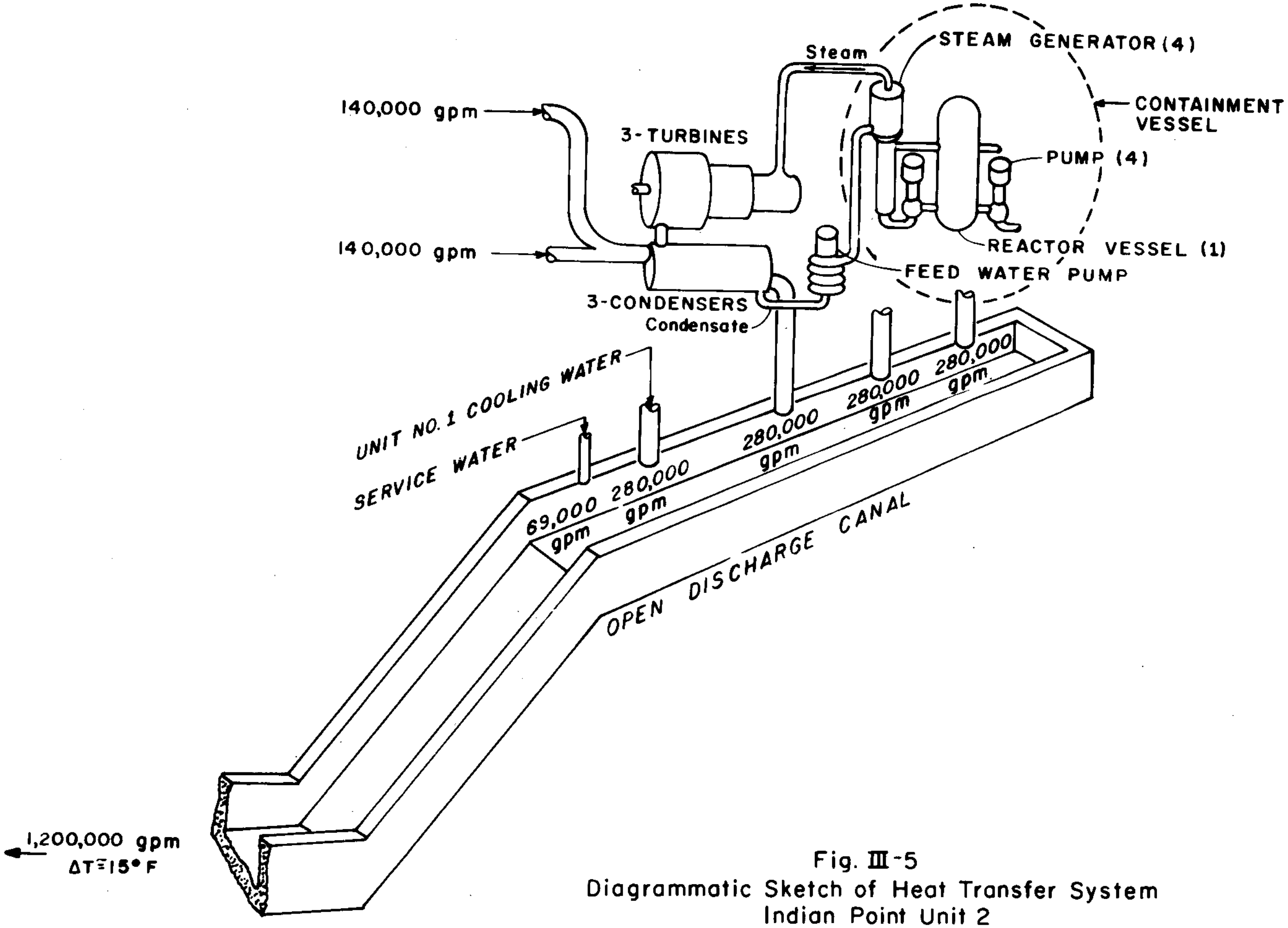

Fig. III-5
Diagrammatic Sketch of Heat Transfer System
Indian Point Unit 2

TABLE III-2

INDIAN POINT UNIT NO. 2 INTAKE - DISCHARGE SYSTEM

Thermal Input Produced By MW(t)	Pumping Conditions	Flow Intake gpm	Discharge gpm	Heat Loss to River		Daily Average Δt, °F	Dwell Time of Nonscreenable Biota
				MW(t)	Btu/Day		
(Without De-icing Loop) Unit No. 1							
890	2 pumps (full flow)	280,000	300,000	560	4.7×10^{10}	14	13 seconds* 35 minutes**
Unit No. 2							
2,758	6 pumps (full flow)	840,000	870,000	∿1870	15.3×10^{10}	15	
	(minimum flow)	504,000*	534,000			25***	18 seconds*
(With De-icing Loop)							
2,758	6 pumps (full flow)	680,000	710,000			20	40 minutes**
	(minimum flow)	344,000*	374,000			24.4***	

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* Minimum water flow from water-box inlet to outlet

** Minimum flow from water inlet box to river entrance

*** See Reference 45 for further details

Survey Sea Level Datum, so that thermal discharges will be jetted horizontally into the body of the river. Figure III-6 illustrates this design. The applicant has modified the depth of the discharge ports from 18 feet to 12 feet. This construction work was completed by early April 1972. Ten of these submerged ports are equipped with fully adjustable gates so that a design discharge velocity of 10 fps may be maintained independent of the flow. The two gates (located farthest downstream) can be operated fully open or fully closed; i.e., they are not adjustable. The gates move in a vertical motion so that the centerline depth of the adjusted openings varies according to gate position. A total discharge flow of about 1,188,000 gpm for both Units will occur with this discharge structure. When Indian Point Unit No. 1 is at full power, 560 MW(t) of heat is wasted; from Unit No. 2, 1,875 MW(t) of heat is wasted and dissipated as heated thermal discharges. Only seven ports will be used for the two Units while all the ports will be used when all three Units are in operation.

A level control weir in the discharge canal will automatically maintain a predetermined head on the discharge water to provide the required jet velocity and also to reduce the head requirements on the intake pumps.

Warmed water from the discharge canal can be recirculated to the intake structures for de-icing purposes under extreme conditions by means of two 80,000-gpm pumps located adjacent to the discharge canal.

d. The Hudson River Estuary and Its Cooling Capacity

Extensive discussion of the Hudson River hydraulics is presented in Section II.E.1. Further discussion of those aspects of particular significance to thermal discharges is presented here.

Salt water intrusion is an important feature of the flow at Indian Point since it promotes density-induced flows in excess of the freshwater flow. In addition, the salt water serves as a built-in tracer material which aids the analysis of the effects of thermal discharges.

A net tidal average seaward upper layer flow substantially in excess of the freshwater flow exists throughout the saltwater intrusion zone of partially mixed estuaries such as the Hudson. The source of this added flow at any location is a time-averaged landward flow of more saline water in the deep layers which ultimately joins the upper freshwater flow between the location of interest and the upstream limit of the salt intrusion.

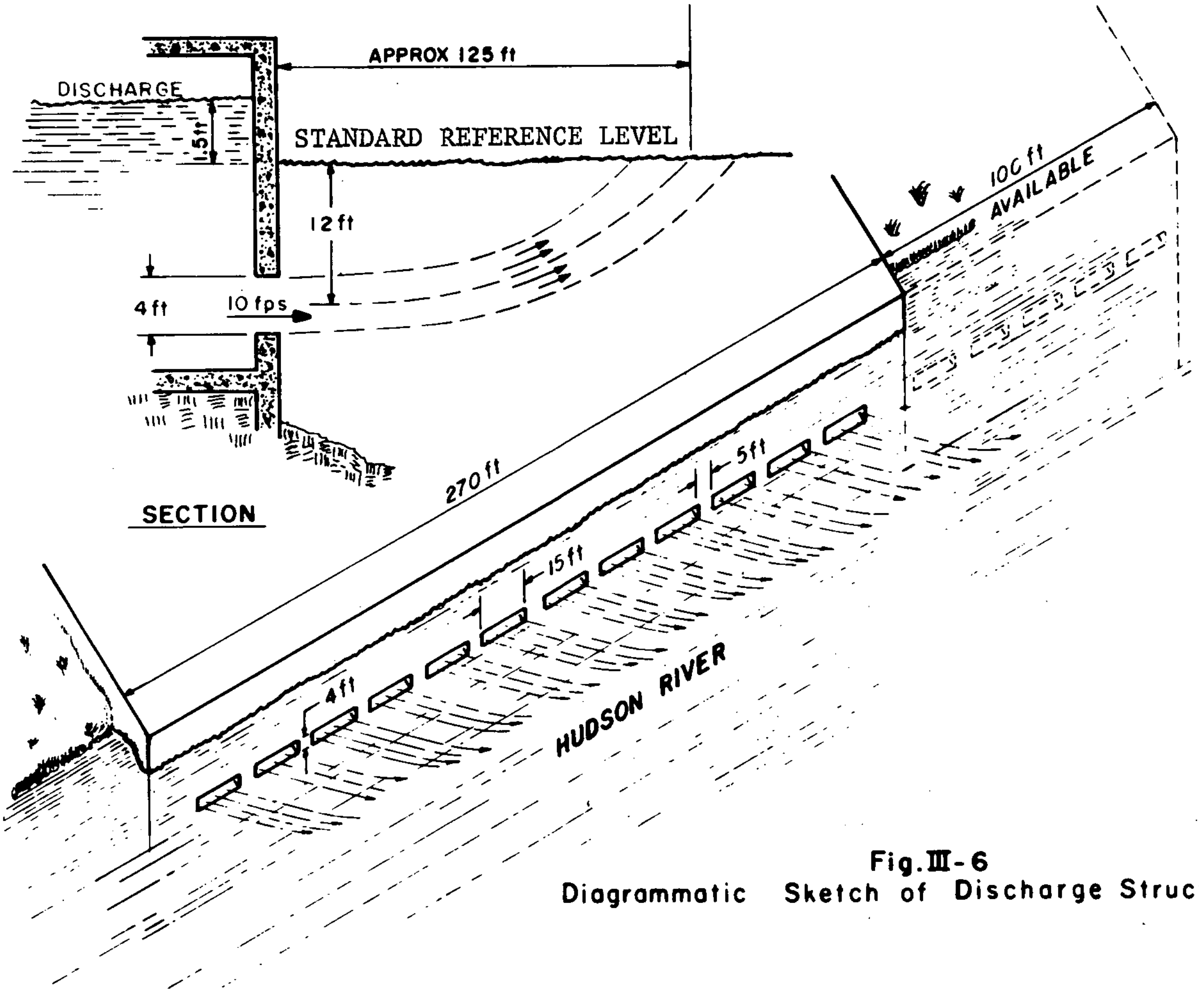


Fig. III-6
Diagrammatic Sketch of Discharge Structure

A schematic representation of the flow patterns is given in Fig. II-13, Section II.E.1.d. As described in that figure, there is no distinct interface between the two "layers" and the opposing lower and upper layer velocities do not actually exist at any one instant except may be at tital flow reversal but are the resultant flows time-averaged over a full tidal period. Establishing the correct upper layer flow at a specific location is a difficult task.

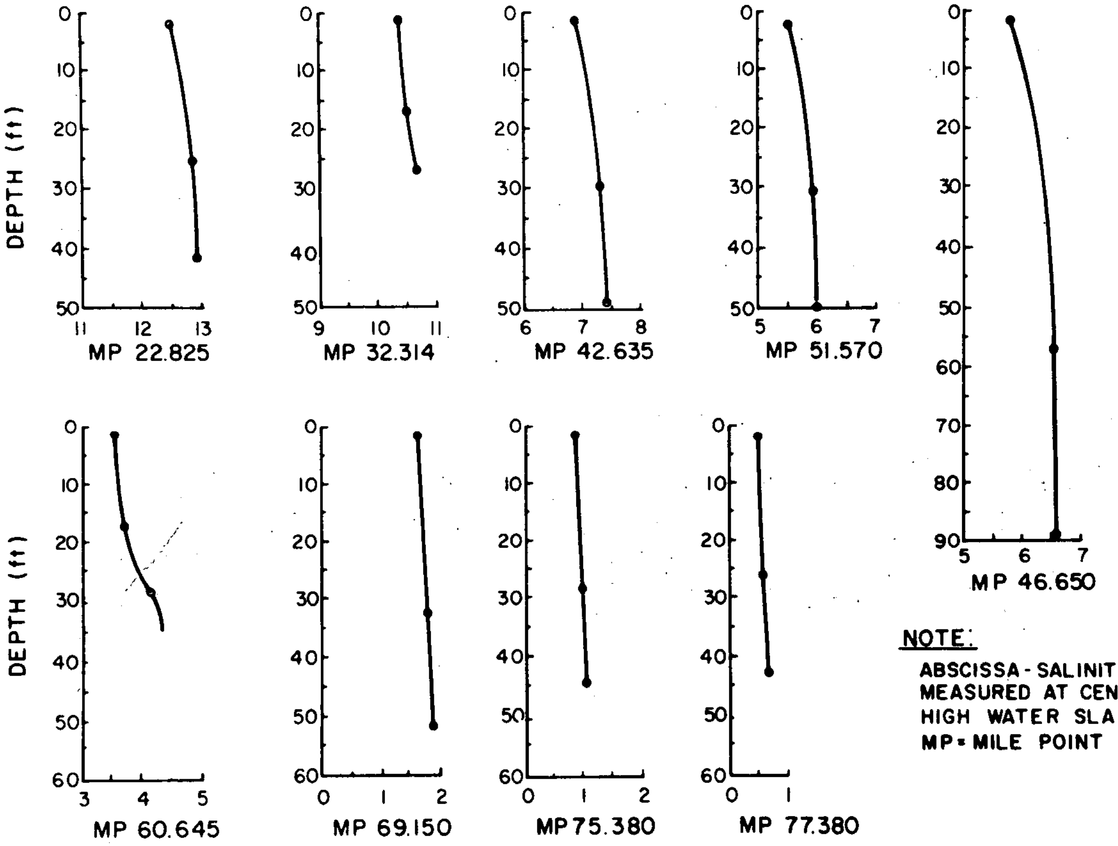
One simplified method for calculating the upper layer flow was proposed by Pritchard[42] using information on salinity and fresh water flow. The equation derived is based on a salt mass balance in any cross section under steady state conditions and can be expressed as

$$Q_u = Q_R \left[1 + \frac{S_u}{S_\ell - S_u} \right] \qquad (1)$$

where

Q_u = Flow in the upper layer in seaward direction
Q_R = Fresh water river flow
S_u = Average salinity in the upper layer
S_ℓ = Average salinity in the lower layer.

Vertical salinity gradients at nine locations are given in Reference 10 for a condition when the river flow was relatively steady at 4,000 cfs for several months. Under these conditions salinity concentration in excess of 0.1 ppt extended to approximately Mile Point 82. These salinity profiles, taken in mid-channel during high water slack, are shown in Fig. III-7. Table III-3 lists the location and the salinities of the net average upper and net average lower layers taking the surface salinity to be representative of the upper layer and the deepest data point to represent the lower layer.



NOTE:
ABSCISSA - SALINITY ppt
MEASURED AT CENTER CHANNEL,
HIGH WATER SLACK.
MP = MILE POINT

Fig. III-7 Variations of Salinity with Depth in the Hudson at Nine Locations
Fresh Water Flow, 4,000 cfs
INDIAN POINT

TABLE III-3
TOTAL SEAWARD UPPER LAYER FLOW COMPUTED FROM EQUATION (1) USING SALINITY GRADIENT DATA FROM REFERENCE 16

(Fresh water flow = 4,000 cfs)

Location (mile point)	Salinity (parts per thousand) Upper Layer	Salinity (parts per thousand) Lower Layer	Net Tidal Average Upper Layer Flow from Eq. (1)[b] (cfs)
22.8	12.50	12.95	115,000
32.3	10.35	10.55	170,000
42.6[a]	6.90	7.40	59,000
46.7	5.80	6.60	33,000
51.5	5.00	5.50	44,000
60.6	3.55	4.15	24,000
69.2	1.65	1.90	30,000
75.4	0.85	1.05	21,000
77.4	0.50	0.65	17,000

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[a] Indian Point.

[b] Believed to be biased to the high side.

The upper layer flow computed by Equation (1) for Indian Point is 59,000 cfs when the freshwater flow is about 4,000 cfs. However, the computed flow values do not increase monotonically in the seaward direction as they should and the calculated upper layer flow at Mile Point 77.4, the most upstream point of the salt front, is 17,000 cfs, rather than the established freshwater flow rate of 4,000 cfs. This suggests that all the values computed by Equation (1) may be biased on the high side.

The main reason for this bias may be that the salinity data used represent conditions at the center of the channel and thus are not necessarily representative of average conditions across the channel. In addition, use of Equation (1) for locations of low salinity and weak stratification involves division by a difference of two small values, which can magnify any possible error.

A second means for determining the magnitude of the upper layer flow is by direct velocity determination. If a true area-averaged velocity is determined for maximum flood and ebb conditions, the net nontidal flow may be computed from the difference between flood and ebb flows, with the assumption that flow velocity varies in a sinusoidal manner during the ebb and flood periods. A determination of this type is attempted in Reference 10 for three cases: (1) data taken in October 1958 when Q_R was 10,000 cfs, (2) data taken in April 1959 when Q_R was 44,000 cfs, and (3) data taken in September 1929 when Q_R was 8,000 cfs. The applicant's consultants concluded: For case 1, the presence of a density-induced flow is indicated by the velocity determinations, but they are not sufficiently accurate for quantitative determination. For case 2, the measurements, as expected, show that no density-induced flow existed at this high river flow. For case 3, the density-induced flows computed for Indian Point gave a total upper layer flow of 22,000 cfs; values at other longitudinal locations were also computed.

The staff concurs with conclusions 1 and 2, but it cannot accept the values given for case 3 as significant. Flood and ebb flows are more than 10 times as high as the net upper layer flow, and calculation of their difference would require far more extensive measurements than were undertaken in this survey to determine precisely the area-averaged velocities--an extremely difficult undertaking. Furthermore, proof of valid results must be offered by satisfaction of the material balance:

$$\begin{array}{c}\text{Net seaward}\\\text{upper layer flow}\end{array} = \begin{array}{c}\text{Landward}\\\text{lower layer flow}\end{array} + \begin{array}{c}\text{Freshwater}\\\text{flow}\end{array}$$

A proper flow material balance was not attained. However, the data of case 3 clearly indicate the presence of a density-induced flow, as does case 1.

A third means for establishing the presence of a net nontidal flow in an estuary is by inference from the value of the dispersion coefficient as calculated from the longitudinal salinity gradient. Experience[11] shows that, in fully mixed estuaries that show no saline gradient with depth, dispersion coefficients in the range 30 to 180 square feet per second (ft^2/sec) may be anticipated. In this case, salt intrusion is solely a consequence of turbulent diffusion generated by the tidal movement. On the other hand, when saline dispersal also takes place via the mechanism of the mixing flow, values for effective dispersion coefficient can be an order of magnitude higher.[11] In Reference 12, values for the dispersion coefficient, E, are computed by the applicant from the longitudinal salinity gradient. Values given for Indian Point range between 3,000 and 5,000 ft^2/sec for freshwater flows between 8,000 and 4,000 cfs. The staff believes that those values are over-estimated. The same authors in Reference 13 report a value of 2,700 ft^2/sec at Indian Point for a freshwater flow of 3,000 cfs, which still seems to be rather high (see Reference 11).

In summary, the presence of a net nontidal seaward flow in the salt-intrusion zone of the Hudson is clearly established by means of (1) observed vertical salinity gradients, (2) direct velocity measurements, and (3) high computed values for the longitudinal dispersion coefficient. However, the magnitude of the upper and lower layer flows is not yet satisfactorily established. More detailed field experiments are needed to establish these flows. A possible cause for this overestimate lies in the applicant's use of a one-dimensional time average concentration model (Equation 6 in Reference 12) for deriving this coefficient.

e. General Description of the Thermal Plume

For the purpose of discussion and analysis, the thermal plume may be conveniently divided into three zones: the submerged jet region, the near field isotherms, and the far field temperature distribution.

(1) The Submerged Jet Region

At a 12 foot depth and with a velocity of 10 fps, the jet must entrain sufficient water to reduce its excess temperature from 15°F to some value such that a maximum surface temperature of 90°F is never exceeded. Since the jet velocity is high compared with the maximum oscillating tidal velocities in the channel, published submerged jet studies[14-16] could perhaps be used with small error. The available studies treat the case of zero ambient or constant ambient velocity. No methods seem to be available for the Indian Point situation of fluctuating ambient velocity. The entrainment analysis[17] performed by the applicant on the Indian Point submerged jet contains some points of difference from the other published analyses (see Section III.E.1.g).

(2) Near Field Isotherms

This is the region that is beyond the jet zone, wherein oscillating tidal flows have a pronounced effect, yet near enough to the discharge so that the excess temperature is not yet dispersed across the channel. Again, a number of analyses are available for the near field plume for the case of zero or constant ambient velocity,[18-20] but none are available for the case of oscillating flow. Very little appears in the literature on three-dimensional near-field plumes. The computational procedure performed on the Indian Point near-field thermal plume, given in Reference 21, is geared particularly toward estimation of the percent of the width and depth of the channel covered by the 4F° isotherm.

(3) Far Field Temperature Distribution

In this region the so-called one-dimensional approximation is frequently applied.[11] The excess temperature is assumed to be distributed uniformly in the lateral direction and to diffuse upstream via the influence of the longitudinal dispersion coefficient. Movement upstream does not exceed the distance of one tidal excursion. The excess temperature extends farther downstream and decays with distance due to both dispersal and surface heat exchange.

f. Heat Dissipation Models Presented by the Applicant

The applicant has used a number of heat dissipation models to predict the thermal effects caused by the once-through cooling system used in Indian Point. Those models can be divided as follows: (1) mathematical model for the submerged discharge; (2) one-dimensional mathematical model for cross-sectional averaged temperatures at the near and far fields; (3) exponential mathematical model for the temperature distribution in a given cross section; (4) a net nontidal mathematical model for the cross sectional temperature at the Indian Point site; and (5) hydraulic models. A short description of each one of those models as presented by the applicant in the Appendices of Supplement No. 1 to the Environmental Report for Indian Point Unit No. 2 is presented here.

(1) Submerged Discharge Model[17]

A computer program was written based on 12 simultaneous equations which together describe the fluid mechanics of submerged jets. The model assumes that the initial jet momentum, induced buoyancy, and river water entrainment are the controlling mechanisms involved and that drag forces and river boundary effects can be neglected. The model is written for a single, circular, submerged jet with a conical shape of constant slope, except for one change at the end of the zone of flow establishment. The trajectory of the jet center line may change, but each cross section is considered uniform in temperature and velocity. A number of steps are used to mark various interferences with external boundaries. This model is used to show compliance with the 90°F temperature criterion.

(2) Near and Far Field Heat Dissipation Model

A one-dimensional steady-state mathematical model[21] was developed to predict the cross-sectional area-averaged temperature rise along the length of the river. The model predicts the following temperature rise:

$$\left.\begin{array}{l}\Delta\bar{T}_1\\ \\ \Delta\bar{T}_2\end{array}\right\} = \frac{f_5 \; H \; \exp\left[\begin{pmatrix}f_1\\ \\ f_2\end{pmatrix}\begin{pmatrix}f_3\\ \\ f_4\end{pmatrix}\frac{U}{2E} \quad 1 \pm \quad \sqrt{1+\frac{4K'E}{U^2}} \quad x\right]}{\rho \; C_P Q_R \; \sqrt{1+\frac{4K'E}{U2}}} \tag{2}$$

in which:

$\Delta\bar{T}_1$ = area-averaged temperature rise upstream of Indian Point, F°

$\Delta\bar{T}_2$ = area-averaged temperature rise downstream of Indian Point, F°

H = thermal discharge, Btu/day

ρ = water density, lb/ft^3

C_P = water heat capacity, Btu/(lb F°)

Q_R = river freshwater flow, ft^3/day

U = freshwater velocity, sq. miles/day

E = longitudinal dispersion coefficient, miles/day

x = distance from plane of discharge, miles

K' = temperature decay coefficient, day^{-1} (see below)

f_1 = correction factor used in the infinite receiver model (where all parameters are considered constant) to agree with the variable parameters segmented model, for temperature decay upstream of Indian Point

f_2 = same as f_1, but for downstream of Indian Point

f_3 = correction factor used to adjust the theoretical model to agree with observed data, for temperature decay upstream of Indian Point

f_4 = same as f_3, but for downstream of Indian Point

f_5 = correction factor used to adjust the theoretical model to agree with observed data at the plane of discharge

This model is based on mass, momentum, and energy conservation principles but also includes seven empirical adjustment coefficients which will be discussed in Section III.E.1.g(3).

The temperature decay coefficient is defined as

$$K' = \frac{\bar{K}B}{\rho C_p A} \text{ (TSF)} = \frac{\bar{K}B}{\rho C_p A} \frac{\Delta \bar{T}s}{\Delta \bar{T}} \qquad (3)$$

in which:

$\bar{K}$ = meteorological surface heat transfer coefficient, Btu/ft^2 F° day)

B = river width, ft

A = river cross-section area, ft^2

$\Delta \bar{T}s$ = average surface-temperature rise, F°

$\Delta \bar{T}$ = cross section area averaged-temperature rise, F°

TSF = thermal stratification factor which is defined by

$$TSF = \Delta \bar{T}_s / \Delta \bar{T} \qquad (4)$$

(3) Cross Section Temperature Distribution Model

Two expressions were assumed[25] for predicting the temperature distribution in a given cross section. The equation for the cross sectional temperature distribution is

$$\Delta T = \Delta T_m \exp(-KA) \qquad (5)$$

and that for the surface temperature distribution is

$$\Delta T_s = \Delta T_{sm} \exp(-kb), \qquad (6)$$

in which:

ΔT = temperature rise isotherm, F°

ΔT_m = maximum temperature rise at any point in the cross section, F°

A = that portion of the cross section within which the temperature rise equals or exceeds ΔT, ft^2

K = exponential decay coefficient for area or the reciprocal of the river cross-section area within which ΔT decreases by a factor of 1/e, ft^{-2}

ΔT_s = surface temperature-rise isotherm, F°

ΔT_{sm} = maximum surface temperature-rise at any point across the width of the river, F°

b = that portion of the surface width within which the surface temperature rises equals or exceeds ΔT_s, ft

k = exponential decay coefficient for surface width or the reciprocal of distance in river width within which ΔT_s decreases by i/e, ft^{-1}

Equations (5) and (6) are used to show compliance with the temperature rise isotherm criteria for both 50% cross section area and two-thirds of the river width. (See Section III.E.1.b. for the New York State thermal criteria.)

(4) Net Nontidal Flow Model[10,22]

The phenomenon of net nontidal flow is considered in having a capability for dilution far in excess of that of the freshwater river flow. Complete mixing is assumed to exist in each cross section, and the expression for the cross-section area-averaged temperature rise at the plane of discharge is

$$\Delta\bar{T} = H/\rho C_p Q_d, \qquad (7)$$

in which H, ρ, and C_p are the previously defined heat discharge, water density, and heat capacity and

$\Delta\bar{T}$ = cross-section area averaged-temperature rise, F°

Q_d = total dilution flow, cfs

In Equation (7) the applicant considers that the total dilution flow, Q_d, is the sum of the absolute values of the upper seaward flow and the lower landward flow.

(5) Hydraulic Models

Three hydraulic models have been constructed to simulate the various aspects of the Indian Point discharge.

Model I was used mainly for Indian Point Unit No. 1 to study the recirculation problems of the thermal plume which led to a discharge canal design to minimize the recirculation of heated discharge water.

The second model (model II) simulates the Hudson River about 9,000 feet above and 9,000 feet below Indian Point. It is a vertically distorted model scaled 1:250 in the horizontal dimension and 1:60 in the vertical.

The third model is an undistorted 1:50 scaled model of the submerged discharge which simulates about 900 feet along the east shore and 400 feet of the river's 4,000-foot width. The model was used for optimizing the parameters of the submerged discharge ports. In later stages it has been incorporated into Model II to study the effects of the submerged discharge on a large scale. The salt intrusion and the density-induced flows were not simulated in the model.

g. The Staff's Review of the Applicant's Heat Dissipation Models

A detailed review of the heat dissipation models presented by the applicant revealed a number of inherent uncertainties which might affect the applicant's conclusions as to the predicted thermal effects on the Hudson River. As a general comment, it should be noted that, until the recent issuance of Reference 22, the applicant's presentation of the heat dissipation models was based on the combined effects of all three Indian Point Units. In addition, the various models and arguments presented, as discussed in many sections of the Appendices of Supplement No. 1 to the Environmental Report, were written at different stages and for various purposes. This makes the review difficult.

The heat dissipation models presented by the applicant have deficiencies which require that the models be subjected to rigorous verification by field studies. Field data are inadequate to support some of the assumptions used. The magnitudes of the density-induced flows for different freshwater flows need to be determined. The applicant's mathematical models, which use an area-averaged assumption, do not take into account local salinity or flow gradients. Since the model is time averaged over the tidal period (steady-state model), it cannot predict temperature distributions during severe periods at high and low slack waters. Improvements and refinements in these models and rigorous field studies to confirm these models are needed in order to use them to predict the actual dissipation of the thermal discharges from Indian Point Units Nos. 1 and 2. Details of the staff's evaluation of the applicant's analysis of heat dissipation of thermal discharges are discussed below.

(1) Heat Load and Water Intake Temperature

The applicant takes into account that 32% of the heat generated in the reactor, based on operating experience with Unit No. 1, is converted into electricity and 5% is assumed by the applicant as in-plant losses. The rest (63%) is discharged into the river. It is the staff's opinion that 5% in-plant losses for such a large plant [about 2,100 MW(e) for Units Nos. 1, 2, and 3] is far too high. [Note: This has been corrected by the applicant in more recent studies (Ref. 22).]

The maximum river ambient temperature assumed by the applicant is 78°F to 79°F. In a Report of Inquiry on Indian Point Unit No. 1, submitted by the Commission's Division of Compliance in October 1971 (see Volume II, Fig. B-4 and attachment B-3),^{3} there is detailed information on temperature measurements made by New York University. Based on those measurements, the maximum river temperature at the Plant intake can be above 81°F in August. These temperatures were measured at three stations across the river section (east bank, mid-river, and west bank) at the Indian Point site while Indian Point Unit No. 1 and Lovett Plant were in operation (which might have affected the water temperature.) The thermal analysis should take this elevated temperature into account. [Note: The applicant has taken part of this elevated temperature into account in more recent studies (see Ref. 22) in a form of recirculation. The staff has also considered it in its analysis (Section II.E.1.h). See discussion of agencies' comments in Section XII.B.]

(2) Submerged Discharge Model

In Appendix M of Supplement No. 1 to the Environmental Report, the applicant discussed the effect of the submerged discharge of Indian Point cooling water on the temperature distribution of the Hudson River. The submerged jet discharge model involves a number of uncertain assumptions that may be critical. The jet is discharged horizontally at 10 fps and perpendicularly to the river flow. (See Fig. III-6). The analysis assumes that the jet will have a conical shape with a constant slope of 0.15 in the zone of flow establishment and 0.25 in the zone of established flow. The length of the zone of flow establishment was taken at 5.2 times the length of slot. None of these parameters are well established in the open literature. Specifying the slope of a jet expansion is another way of specifying the entrainment coefficient. This coefficient is a measure of the amount of diluting water entrained into the jet and has a direct effect on the rate of temperature decay. The value of the entrainment coefficient is not well established, and the few data available are reported as entrainment coefficients rather than as slopes of jet expansion. The sensitivity of the results of the choice of slope must be evaluated numerically. The relationship chosen for the length of the zone of flow establishment is close to that reported in the literature for a circular port and zero ambient velocity . However, based on the definition of the zone of flow establishment, it is clear that the smaller dimension of the slot (4 feet) should be used rather than its length (15 feet) in evaluating the length of this zone.[17]

The suggested model is used to calculate a uniform average temperature and velocity in each cross section along the jet. Therefore, it does not have the capability of predicting the temperature at the jet center lines, which is higher than the average. To get an approximation of the centerline temperature, the applicant assumes that a cosine distribution exists between the boundary of the jet and its center. Cosine distributions are not commonly used. Most investigators assume a Gaussian distribution, which results in a higher peak temperature for the same average value. The difference between the two approaches might be about 15%, which in the staff's case comes close to an additional 1F° temperature rise. In addition, the choice of a 3F° temperature rise at a jet boundary is not clear nor is the location of the "jet boundaries" defined.

The submerged discharge analysis is based on a single circular jet model. Since the actual discharge is composed of 12 ports, each 4 feet by 15 feet, centered 20 feet apart, a problem of mutual jet interference exists. The initial distance between adjacent edges of two jets at the discharge point is 5 feet. However, since the applicant's model is based on a circular jet, an equivalent diameter of 8.75 feet was used. This creates an initial clear distance between jets of 11.25 feet compared to 5 feet in the actual design. Using the applicant's procedures but for only 5 feet initial clearance, the staff gets interference at about 16.7 feet distance, compared to about 40 feet reported, and a dilution ratio of 1.5 at that point, compared to 2.37 reported. The temperature rise at that point (again using the applicant's procedures) becomes 12.4F°. If this is added to an intake temperature of 81°F, a maximum surface temperature of about 93°F results. [Note: Recently the spacing between the ports has been changed from 5 feet to 6 feet with center-to-center distance of 21 feet instead of 20 feet. Also, the applicant has recently specified that only alternate ports will be used; so actual clearance between the ports at the base is now 27 feet compared to 5 feet assumed in this discussion. This will almost eliminate the possibility of jet interference.]

The applicant has assumed that no additional entrainment will occur after the point of jet interference. The staff believes that this assumption is overly conservative. Dilution will continue beyond the point of jet interference and will therefore further reduce temperatures along the jet; however, evaluation of the new entrainment coefficient or the new slope of the jet expansion will require special investigation.

The staff has therefore found it desirable to perform an independent analysis of the submerged jet temperature distribution. A parametric study shows that the dilution of the heated jet is sufficiently large so that the 90°F criterion is not exceeded even under various pessimistic assumptions (see Section III.E.1.h.). The applicant has also improved its model in more recent studies and confirms its previous conclusions.[22,42]

(3) Near- and Far-Field Heat Dissipation Model

As discussed in Appendix K of Supplement No. 1 to the Environmental Report, this model was originally developed for showing compliance with the early New York State thermal criteria. However, in order to show compliance with the new State regulations, a less conservative model was needed. The adjustments made to the original model by arbitrarily using correlation factors so that the results will agree with only one set of observed data from operation of Indian Point Unit No. 1 and extrapolating the model to predict the effects of Units No. 1 and 2 together is unjustified.

The correction factors f_1 to f_5 are inserted in Equation (2) in a seemingly arbitrary way. The model correction factors, f_1 and f_2, used to convert the more complicated variable parameters of a segmented model to an infinite, constant-parameter model, are based on comparison of the two models for one set of conditions. Why the two models should differ by the same factors for other sets of conditions is not clear. The correction factors f_3, f_4, and f_5 used to correct the mathematical model to the observed data are also based on one set of field conditions (April 1967) which are quite different from the examined ones. The observed data are for a surface discharge, 482 MW(t) waste heat load, 17F° condenser temperature rise, winter meteorological conditions (April 1967) (Appendix J of Supplement No. 1), and river flow of 40,000 cfs. The case examined is for a submerged discharge, about 2,500 MW(t) waste heat load (five times as much), 14F° condenser temperature rise, summer meteorological conditions, and river fresh water flow of 4,000 cfs (a tenth as much). The differences are too large to justify such an extrapolation. In addition, since the observed data are not under controlled laboratory conditions, it is difficult to be sure that some unexpected conditions did not exist when the field measurements were taken. The large size of the factors f_3 and f_4 (about 15), also makes the adjustment questionable. The factor f_5 has a direct effect on the results, and a change in this factor can change the conclusion from an acceptable to an unacceptable temperature rise.

The longitudinal dispersion coefficient, E, is supposed to take into account all the turbulent diffusion and mixing caused by various movements (tidal movements, net nontidal flows, density mixing, etc.). In spite of many investigations, there is no reliable method for predicting E. The applicant derives an expression for E based on a comparison between measured salinity profiles and a steady-state diffusion differential equation for salinity concentration.

However, the values calculated by this method (around 12 square miles/day), and reported in Fig. B-6 in Appendix J, seem to be too high (see Section III.E.1.d.). More investigation and field data are needed to establish the correct value of this longitudinal dispersion coefficient.

The thermal stratification factor (TSF)[21] is defined as the ratio between the surface average temperature rise and the cross-sectional area average-temperature rise. In reality, none of those temperatures are uniform. Experimental field measurements are the only way to get proper values for the TSF. The only field measurements for both surface and cross section temperatures are those taken on July 1966 and April 1967 by Northeastern Biologists, Incorporated (NBI). A TSF of 3.0 was found for the July 1966 conditions and 6.0 for the April 1967 conditions. The applicant uses the lower value of 3.0 for adjusting the mathematical model in the January 1968 report (Appendix J to Supplement No. 1). For the February 1969 report (Appendix K to Supplement No. 1), the applicant uses a linear interpolation between a minimum value of 1.0 for an effluent channel temperature increase of 3.4F° (complete vertical mixing) and a maximum value of 3.0 for an effluent channel temperature increase of 14F°. Although this compromise seems to be reasonable, the basic value of 3.0 is the result of field measurements which were taken under conditions quite different from the ones for maximum severity. The field measurement data on Unit No. 1 were taken for surface discharge, for a waste heat load of 482 MW(t), and a 17F° condenser temperature rise. The maximum severity conditions are submerged discharge, 2,500 MW(t) waste heat load (five times as much), and 14F° condenser rise with Unit No. 2 in operation. The differences in all three conditions might result in a TSF lower than the July 1966 data. The extrapolation of the results, taken under this single set of conditions, to such a wide variety of conditions is not justified, especially because of its major effects on calculated results (see Section III.E.1.h.).

(4) Cross-Sectional Temperature Distribution Model

This model is combined by the applicant with the cross sectional average temperature model for evaluating temperature distributions and isotherms, in particular to check the extent of the 4F° isotherm. Such an evaluation calls for a three-dimensional transient model which does not exist in the literature and is indeed difficult to develop. Thus, the applicant's model is of necessity highly intuitive and simplified and must rely heavily on field data; however, the only field data used are those collected in April 1967 (Appendix J to

Supplement No. 1). Again, a single set of data is used to make extensive extrapolations which are unjustified for the same reasons that were previously discussed in the one-dimensional far-field model. (See Section III.E.1.h for parametric studies.)

(5) Net Nontidal Flow Model

The net nontidal flow phenomenon is suggested by the applicant as being the main reason for disagreement between the mathematical model and the observed data from July 1966 and April 1967. The model is proposed as an alternative to the one-dimensional dispersion model discussed in Section III.E.1.g(3). As mentioned before, the phenomenon evidently does exist and should be taken into account. However, the concept that the amount of water available for dilution is the sum of the upper layer seaward flow and lower layer landward flow[10,22] is unjustified. The warmer and lighter discharged water tends to stratify to the upper layer and therefore the lower layer flow might be largely inactive in the dilution process (depending on the degree of vertical mixing). When it is, it will tend to carry the heated water upstream and return the upper layer to the intake. Even so, the phenomenon is certainly very helpful in diluting the warm discharged water and should be included in any realistic model of the Hudson River. However, more field data are needed to evaluate quantitatively the upper layer flow and the degree of stratification for different times of the year and under various fresh water flow conditions.

h. Staff Assessment of Temperature Distribution at Plane of Discharge

The staff recognizes the applicant's difficulties in trying to show compliance with the NYS thermal criteria. Many of the problems raised by the staff in the Draft Statement were further discussed by the applicant in supplementary reports and letters.[22,42] These responses provided satisfactory answers to some, but not all, of the questions. At the same time, however, some of the applicant's assumptions - such as no additional jet dilution after the point of jet interference - are indeed conservative.

An ideal solution would require a time-dependent three-dimensional model which is not available at the present time. The available alternatives are either to use simplified models in a conservative manner or to rely extensively on field data. The staff feels that both approaches should be combined for the best advantage.

The staff has found it desirable to perform an independent analysis for the submerged jets and to use the applicant's model (since other models were not available at this time) to perform an extensive parametric study to evaluate the surface and cross-sectional temperature distribution at the plane of discharge. Field data are needed to make a more realistic judgement on the correct parameters to be used.

(1) Submerged Jet Temperature Distribution

Analysis of the submerged jet for predicting its temperature distribution and maximum surface temperature is based on two submerged jet models. One is Hirst's model[16,23] for a single round jet discharging into an infinite volume of receiving water. This model assumes Gaussian velocity and temperature distributions across the plume and uses a variable entrainment coefficient. It is able to take into account ambient stratification in both temperature and/or salinity, ambient velocity, and various discharge angles in either two- or three-dimensional plume trajectories. The second model, by Koh and Fan,[15] is for a multiple-port diffuser discharging into an infinite, stagnant body of receiving water. This model assumes a single round jet up to the point of interference of the jets and then switches to an infinite slot jet model.[24] The velocity and temperature distributions across the plume are considered to be Gaussian, and the entrainment coefficients are taken into account as input for constant values for round and slot jets. The combined capabilities of these two models made it possible for the staff to check the effects of various assumptions and to compare probable, optimistic, and pessimistic cases. The plume cases studied, along with their parameters and resulting characteristics, are summarized in Table III-4 for the single-jet model and in Table III-5 for the multiple-port model. In all cases, the jets were assumed to be discharged at 10 fps in a horizontal direction, normal to the river flow, at a depth of 12 feet, and at a temperature of 15F° above ambient. In each model, a base case was chosen as being the most probable. The various parameters studied were as follows:

1. Jet diameter: 4.0, 8.7, and 12.7 feet
2. Jet salinity: 0.0, 7.0, 9.0, 6.75, and 9.75 parts per thousand (ppt)
3. Ambient salinity: 0.9, 7.0, 9.0, and 10.0 ppt

Table III-4. Single, round jet model[a]

Case	Jet diameter (ft)	Jet temperature (F°)	Jet salinity (ppt)	Ambient temperature (°F)	Ambient salinity (ppt)	Ambient velocity (ft/sec)	Ambient temperature gradient (F°/ft)	Ambient salinity gradient (ppt/ft)	Entrainment coefficient	Maximum surface temperature (F°)	Travel time (sec)	Maximum temperature at point of jets interference	
												L[b] = 6 ft	L = 27 ft
Base	8.7	96	7.0	81	7.0	0.0	0.0	0.015	Ref. 16	86.9	15	96.0	90.0
1	8.7	96	0.0	81	0.0	0.0	0.0	0.015	Ref. 16	86.9	15	96.0	90.0
2	8.7	96	9.0	81	9.0	0.0	0.0	0.015	Ref. 16	86.9	15	96.0	90.0
3	8.7	95	7.0	80	7.0	0.0	0.0	0.015	Ref. 16	85.9	15	95.0	89.0
4	8.7	97	7.0	82	7.0	0.0	0.0	0.015	Ref. 16	87.9	15	97.0	91.0
5	8.7	96	7.0	81	7.0	0.5	0.0	0.015	Ref. 16	84.7	18	96.0	90.0
6	8.7	96	7.0	81	7.0	1.0	0.0	0.015	Ref. 16	83.3	22	96.0	89.9
7	8.7	96	7.0	81	7.0	1.5	0.0	0.015	Ref. 16	82.7	29	96.0	89.7
8	8.7	96	7.0	81	7.0	2.0	0.0	0.015	Ref. 16	82.5	37	96.0	89.5
9	8.7	96	7.0	81	7.0	0.0	0.0	0.0	Ref. 16	86.8	16	96.0	90.0
10	8.7	96	7.0	81	7.0	0.0	0.05	0.015	Ref. 16	86.1	15	96.0	89.8
11	4.0	96	7.0	81	7.0	0.0	0.0	0.015	Ref. 16	84.3	19	96.0	85.7
12	12.7	96	7.0	81	7.0	0.0	0.0	0.015	Ref. 16	88.9	15	96.0	92.8
13	8.7	96	7.0	81	7.0	0.0	0.0	0.015	0.082	86.0	16	96.0	90.0
14	8.7	96	7.0	81	7.0	0.0	0.0	0.015	0.057	87.0	15	96.0	90.0
15	8.7	96	7.00	81	7.00	0.0	0.0	0.015	0.030	88.9	14	96.0	90.0
16	8.7	97	7.75	82	8.00	0.0	0.0	0.0	0.05	88.5	15	97.0	91.0

[a] All jets are discharged in horizontal direction at 10 fps. Plume boundaries are considered to be at a radius where ΔT is 5% of its centerline value. Case 16 is pessimistic but still possible, while the base case is the most probable.

[b] L = distance between ports.

Table III-5. Multiport thermal plume characteristics[a] for various parametric assumptions[15,24]

Case	Jet diameter (ft)	Jet temperature (F°)	Jet salinity (ppt)	Ambient temperature (F°)	Ambient salinity (ppt)	Entrainment coefficient for a circular port	Entrainment coefficient for a slot port	Spacing between port centerlines (ft)	Maximum jet surface temperature (F°)	Surface dilution at jet centerline	Surfacing jet width (ft)	Horizontal distance to surfacing point (ft)
Base	4.0	96	7	81	7	0.057	0.082	4.5	85.7	2.26	62	122
1	4.0	95	7	80	7	0.057	0.082	4.5	84.7	2.26	62	122
2	4.0	97	7	82	7	0.057	0.082	4.5	86.7	2.24	61	120
3	4.0	96	0	81	0	0.057	0.082	4.5	85.7	2.24	61	120
4	4.0	96	6.75	81	7	0.057	0.082	4.5	85.7	2.27	63	124
5	4.0	96	9.75	81	10	0.057	0.082	4.5	85.8	2.22	60	118
6	4.0	96	7	81	7	0.057	0.082	10.0	84.5	3.03	50	112
7	4.0	96	7	81	7	0.057	0.082	31.0	83.5	4.2	31	101
8	4.0	96	7	81	7	0.082	0.16	4.5	84.6	2.89	101	113
9	4.0	96	7	81	7	0.03	0.057	4.5	86.3	1.99	48	126
10	4.0	97	7.75	82	8	0.03	0.057	4.5	87.4	1.96	47	122

[a] All jets are discharged in horizontal direction at 10 fps into a stagnant nonstratified body at a depth of 12 feet below the standard reference level. Plume boundaries are considered to be at a radius where ΔT is 5% of its centerline value. Case 10 is pessimistic but still possible, while the base case is the most probable one.

4. Ambient velocity: 0.0, 0.5, 1.0, 1.5, and 2.0 fps

5. Ambient temperature gradient: 0.0 and 0.05 F°/ft

6. Ambient salinity gradient: 0.0 and 0.015 ppt/ft

7. Entrainment coefficient[16] for round jet: 0.08, 0.057, and 0.082

8. Entrainment coefficient for slot jet: 0.057, 0.082, and 0.16

9. Recirculation, which is expressed as ΔT above 80°F ambient: 0.0, 1.0, and 2.0F°

10. Port spacings: 4.5, 10.0, and 31.0 feet between centers

The various jet diameters simulate the 4 feet by 14 feet rectangular port into a single round jet with the same minimum opening (4 feet), same diameter (8.7 feet), or same perimeter (12.7 feet). The low entrainment coefficients (0.057 and 0.03) simulate disturbances from the bottom slope and outfall walls to achieve normal ambient entrainment into the plume as compared to infinite water volume. The spacing of 4.5 feet in the multiport model simulates an infinite slot jet, which is certainly conservative. In the single-jet model (Table III-4), no jet interference can be simulated, and therefore the maximum surface temperatures and travel times shown in the table are not exactly correct. The maximum temperatures at the points of jet interference are shown for 6 feet and 27 feet clear distance between the ports. Temperatures are further reduced beyond the interference point as analyzed in the multiport model (Table III-5).

From Tables III-4 and III-5 it can be seen that in no case is the final surface temperature above 90°F. The most probable case is represented by the "base" case in both models. From those cases, it seems that the maximum surface temperature will be about 86°F to 87°F. The last case in each table represents a pessimistic possibility which results in a maximum surface temperature of about 88°F to 89°F.

Other conclusions that can be derived from this parametric study are that the jet will surface at about 110 feet from the river bank and about 25 feet downstream. The trajectory length of the jet is estimated to be about 120 feet, and the travel time of an organism along the plume center line is about 30 sec. The width of the jet seems to be about 60 feet at the point where it surfaces For a total outfall length of 250 feet, the total surfacing area would be about 15,000 ft^2 and total water volume would be about a million cubic feet.

(2) Surface and Cross Section Temperature Distribution

The following is an extensive parametric study based on the dispersion model proposed by the applicant.[21] As stated in Section III.E.1.g, the staff feels that the correction factors used by the applicant in its model are unjustified; therefore the correction factors are assumed to be equal to 1.0 (f_5 = 1.0). The other points of uncertainties are treated here as parameters, each with a range of possible values being investigated. The various parameters studied and their corresponding ranges are as follows:

1. River freshwater flow, Q_R: 4,000 and 7,000 cfs
2. Longitudinal dispersion coefficient, E: 4, 5, 6, 7, 8, 9, 10, and 12 sq miles/day
3. Thermal stratification factor, TSF: 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5
4. Intake recirculation factor: 0.075, 0.1, 0.125, and 0.15
5. Submerged jet dilution: 1.5, 2.0, 2.5, 3.0, and 3.5
6. Surface heat exchange coefficient: 90 (fall) and 130 (summer), Btu/(day)(ft^2)(F°)

A computer program was prepared to study the numerous combinations possible with the above ranges of parameters. Part of this study is summarized in Table III-5a. The output shown in the table includes average and maximum cross section area temperatures, average and maximum surface temperatures, and percentages of cross section area and surface width within the 4F° temperature-rise isotherms. This parametric study showed: (1) the cross-sectional area within the 4F° isotherm will be on a tidal average basis less than 50% of the total cross section of the river even under a pessimistic set of assumptions; (2) the predicted surface temperature distribution is very sensitive to the values of the parameters used; and (3) there are many possible cases where the surface width within the 4F° isotherm exceeds even on a tidal average basis two-thirds of the total river width at Indian Point.

Table III-5a. A parametric study of temperature distribution at the Indian Point discharge plane [$\bar{k} = 130$ Btu/(day)(ft^2)(°F)]

Case	River freshwater flow (cfs)	Dispersion coefficient (sq. miles/day)	Thermal stratification factor	Intake recirculation factor	Submerged jet dilution	Temperature of cross-section area (°F)		Surface temperature (°F)		Fraction of total area within 4°F isotherm	Fraction of river width within 4°F isotherm
						Avg.	Max.	Avg.	Max.		
1	4000.	4.00	1.00	0.075	3.00	4.1	16.1	4.1	5.4	0.36	0.52
2	4000.	4.00	1.00	0.100	3.00	4.5	16.5	4.5	5.5	0.40	0.74
3	4000.	4.00	1.00	0.125	3.00	5.0	16.9	5.0	5.6	0.45	1.36
4	4000.	4.00	1.50	0.075	3.00	3.4	16.1	5.1	5.4	0.30	2.38
5	4000.	5.00	1.00	0.075	3.00	3.7	16.1	3.7	5.4	0.33	0.39
6	4000.	5.00	1.00	0.125	3.00	4.6	16.9	4.6	5.6	0.40	0.79
7	4000.	5.00	1.50	0.075	3.00	3.1	16.1	4.7	5.4	0.27	0.94
8	4000.	6.00	1.00	0.125	3.00	4.2	16.9	4.2	5.6	0.37	0.58
9	4000.	6.00	1.50	0.075	3.00	2.9	16.1	4.3	5.4	0.25	0.62
10	4000.	6.00	1.50	0.100	3.00	3.1	16.5	4.7	5.5	0.27	0.94
11	4000.	6.00	2.00	0.075	3.00	2.5	16.1	5.0	5.4	0.22	1.63
12	4000.	6.00	2.00	0.100	3.00	2.7	16.5	5.5	5.5	0.24	7.81
13	4000.	7.00	1.00	0.125	3.00	4.0	16.9	4.0	5.6	0.34	0.48
14	4000.	7.00	1.50	0.075	3.00	2.7	16.1	4.0	5.4	0.23	0.49
15	4000.	7.00	1.50	0.100	3.00	2.9	16.5	4.4	5.5	0.25	0.67
16	4000.	7.00	1.50	0.125	3.00	3.3	16.9	4.9	5.6	0.28	1.17
17	4000.	7.00	2.00	0.075	3.00	2.3	16.1	4.6	5.4	0.20	0.93
18	4000.	7.00	2.00	0.100	3.00	2.6	16.5	5.1	5.5	0.22	1.75
19	4000.	8.00	1.50	0.100	3.00	2.7	16.5	4.1	5.5	0.24	0.54
20	4000.	8.00	1.50	0.125	3.00	3.1	16.9	4.6	5.6	0.26	0.82
21	4000.	8.00	2.00	0.075	3.00	2.2	16.1	4.4	5.4	0.19	0.67
22	4000.	8.00	2.00	0.100	3.00	2.4	16.5	4.8	5.5	0.21	1.05
23	4000.	8.00	2.50	0.075	3.00	2.0	16.1	4.9	5.4	0.17	1.36
24	4000.	10.00	1.50	0.125	3.00	2.8	16.9	4.2	5.6	0.24	0.56
25	4000.	10.00	2.00	0.075	3.00	2.0	16.1	3.9	5.4	0.17	0.46
26	4000.	10.00	2.00	0.100	3.00	2.2	16.5	4.3	5.5	0.19	0.63
27	4000.	10.00	2.00	0.125	3.00	2.4	16.9	4.8	5.6	0.21	1.05
28	4000.	10.00	2.50	0.075	3.00	1.8	16.1	4.4	5.4	0.15	0.69
29	4000.	10.00	2.50	0.100	3.00	1.9	16.5	4.8	5.5	0.17	1.11
30	4000.	10.00	3.00	0.075	3.00	1.6	16.1	4.8	5.4	0.14	1.22

Table III-5a (continued)

Case	River freshwater flow (cfs)	Dispersion coefficient (sq. miles/day)	Thermal stratification factor	Intake recirculation factor	Submerged jet dilution	Temperature of cross-section area (°F)		Surface temperature (°F)		Fraction of total area within 4°F isotherm	Fraction of river width within 4°F isotherm
						Avg.	Max.	Avg.	Max.		
31	4000.	12.00	1.50	0.125	3.00	2.6	16.9	3.8	5.6	0.22	0.43
32	4000.	12.00	1.50	0.150	3.00	2.9	17.3	4.4	5.7	0.25	0.65
33	4000.	12.00	2.00	0.100	3.00	2.0	16.5	3.9	5.5	0.17	0.47
34	4000.	12.00	2.00	0.125	3.00	2.2	16.9	4.4	5.6	0.19	0.69
35	4000.	12.00	2.00	0.150	3.00	2.6	17.3	5.1	5.7	0.22	1.36
36	4000.	12.00	2.50	0.075	3.00	1.6	16.1	4.0	5.4	0.14	0.50
37	4000.	12.00	2.50	0.100	3.00	1.8	16.5	4.4	5.5	0.15	0.70
38	4000.	12.00	2.50	0.125	3.00	2.0	16.9	5.0	5.6	0.17	1.24
39	4000.	12.00	3.00	0.075	3.00	1.5	16.1	4.4	5.4	0.13	0.71
40	4000.	12.00	3.00	0.100	3.00	1.6	16.5	4.9	5.5	0.14	1.14
41	7000.	4.00	1.50	0.075	3.00	3.1	16.1	4.6	5.4	0.27	0.88
42	7000.	4.00	1.50	0.100	3.00	3.4	16.5	5.1	5.5	0.29	1.62
43	7000.	5.00	1.50	0.075	3.00	2.8	16.1	4.2	5.4	0.25	0.60
44	7000.	5.00	1.50	0.100	3.00	3.1	16.5	4.7	5.5	0.27	0.90
45	7000.	6.00	1.50	0.075	3.00	2.6	16.1	4.0	5.4	0.23	0.47
46	7000.	6.00	1.50	0.100	3.00	2.9	16.5	4.4	5.5	0.25	0.65
47	7000.	6.00	2.00	0.075	3.00	2.3	16.1	4.7	5.4	0.20	0.99
48	7000.	6.00	2.00	0.100	3.00	2.6	16.5	5.2	5.5	0.22	2.01
49	7000.	7.00	1.50	0.100	3.00	2.7	16.5	4.1	5.5	0.24	0.53
50	7000.	7.00	2.00	0.075	3.00	2.2	16.1	4.4	5.4	0.19	0.70
51	7000.	7.00	2.00	0.100	3.00	2.4	16.5	4.8	5.5	0.21	1.12
52	7000.	8.00	1.50	0.100	3.00	2.6	16.5	3.9	5.5	0.22	0.45
53	7000.	8.00	1.50	0.125	3.00	2.9	16.9	4.4	5.6	0.25	0.65
54	7000.	8.00	2.00	0.075	3.00	2.1	16.1	4.2	5.4	0.18	0.55
55	7000.	8.00	2.00	0.100	3.00	2.3	16.5	4.6	5.5	0.20	0.81
56	7000.	8.00	2.50	0.075	3.00	1.9	16.1	4.7	5.4	0.16	1.02
57	7000.	10.00	1.50	0.100	3.00	2.4	16.5	3.5	5.5	0.20	0.36
58	7000.	10.00	1.50	0.125	3.00	2.6	16.9	4.0	5.6	0.23	0.48
59	7000.	10.00	2.00	0.075	3.00	1.9	16.1	3.8	5.4	0.16	0.41
60	7000.	10.00	2.00	0.100	3.00	2.1	16.5	4.1	5.5	0.18	0.55

Table III-5a (continued)

Case	River freshwater flow (cfs)	Dispersion coefficient (sq. miles/day)	Thermal stratification factor	Intake recirculation factor	Submerged jet dilution	Temperature of cross-section area (°F)		Surface temperature (°F)		Fraction of total area within 4°F isotherm	Fraction of river width within 4°F isotherm
						Avg.	Max.	Avg.	Max.		
61	7000.	10.00	2.00	0.125	3.00	2.3	16.9	4.7	5.6	0.20	0.86
62	7000.	10.00	2.50	0.075	3.00	1.7	16.1	4.3	5.4	0.15	0.61
63	7000.	10.00	2.50	0.100	3.00	1.9	16.5	4.7	5.5	0.16	0.92
64	7000.	12.00	1.50	0.100	3.00	2.2	16.5	3.3	5.5	0.19	0.31
65	7000.	12.00	1.50	0.125	3.00	2.4	16.9	3.7	5.6	0.21	0.40
66	7000.	12.00	2.00	0.100	3.00	1.9	16.5	3.8	5.5	0.16	0.43
67	7000.	12.00	2.00	0.125	3.00	2.1	16.9	4.3	5.6	0.18	0.61
68	7000.	12.00	2.50	0.075	3.00	1.6	16.1	3.9	5.4	0.14	0.46
69	7000.	12.00	2.50	0.100	3.00	1.7	16.5	4.3	5.5	0.15	0.63
70	7000.	12.00	2.50	0.125	3.00	1.9	16.9	4.9	5.6	0.17	1.06
71	7000.	12.00	3.00	0.075	3.00	1.4	16.1	4.3	5.4	0.12	0.65
72	7000.	12.00	3.00	0.100	3.00	1.6	16.5	4.8	5.5	0.14	1.00

Evaluating the range of realistic values for each parameter is a very difficult task. To reduce the number of possibilities, it is reasonable to assume a constant submerged jet dilution factor of 3.0, a constant intake recirculation of 0.1, and a constant minimum freshwater flow of 4,000 cfs. The longitudinal dispersion coefficient, E, and the thermal stratification factor, TSF, both have a larger range of uncertainty. In the staff's opinion, field experiments are clearly needed to establish the correct values for these parameters. If desired, however, likely values of 6.0 to 7.0 sq. miles/day for the longitudinal dispersion coefficient and 1.5 to 2.0 for the TSF could be chosen. The above approximations are covered by cases 10, 12, 15, and 18 in Table III-5a. In these cases the cross-sectional area within the 4F° isotherm is about 25% of the total cross section of the river, whereas the surface width within the isotherm ranges between two-thirds to full-river width. However, cases (e.g., 19, 22, and 26) which show more favorable results are also possible. For the case[22] called "drought-fall conditions," a surface heat exchange coefficient of 90 Btu/(day)(ft^2)(F°) was used as compared to 130 used in Table III-5a for the summer months. The predicted temperatures were, of course, higher. Table III-5a also includes the case of 7,00-cfs freshwater flows. This was the average low flow in the summer during the years 1918-1964. For this flow, the more reasonable assumptions are covered by cases 46, 48, 49, and 50. Here, too, the conclusions are the same: the 50% cross-sectional area criterion is easily satisfied, but satisfying the two-thirds (river width) criterion is in doubt. Any further conclusions are restricted by the actual data available for the various parameters used.

It might be worthwhile to indicate that the same parametric study was used for predicting the temperature distribution when only 50% power is assumed. It seems that, except for a very few pessimistic cases, both cross-sectional area and surface-width criteria will be satisfied for the 50% power condition.

The second model used by the applicant is the "density-induced circulation" model, which is based on upper layer flows rather than river freshwater flows. The limitations of this model are mainly lack of reliable values for the flows involved and for the amount of stratification which exists between the two layers. Table III-5b summarizes part of a parametric study made for this model. The upper layer flow varies from 10,000 to 30,000 cfs. The longitudinal dispersion coefficient is not used in this model. Here again, the results are very sensitive to the values of flows and thermal stratification factors, both of which need to be evaluated by field experiments.

Table III-5b. A parametric study of temperature distribution at the Indian Point discharge (density-induced circulation model)

Case	River freshwater flow (cfs)	Dispersion coefficient (sq. miles/day)	Thermal stratification factor	Intake recirculation factor	Submerged jet dilution	Temperature of cross-section area (°F)		Surface temperature (°F)		Fraction of total area within 4°F isotherm	Fraction of river width within 4°F isotherm
						Avg.	Max.	Avg.	Max.		
1	10000.	0.0	1.00	0.075	3.00	4.0	16.1	4.0	5.4	0.35	0.49
2	10000.	0.0	1.00	0.100	3.00	4.4	16.5	4.4	5.5	0.39	0.67
3	10000.	0.0	1.00	0.125	3.00	4.9	16.9	4.9	5.6	0.44	1.17
4	10000.	0.0	1.50	0.075	3.00	4.0	16.1	6.0	5.4	0.35	1.00
5	12500.	0.0	1.00	0.100	3.00	3.5	16.5	3.5	5.5	0.30	0.35
6	12500.	0.0	1.00	0.125	3.00	3.9	16.9	3.9	5.6	0.34	0.47
7	12500.	0.0	1.00	0.150	3.00	4.5	17.3	4.5	5.7	0.39	0.73
8	12500.	0.0	1.50	0.075	3.00	3.2	16.1	4.8	5.4	0.28	1.13
9	15000.	0.0	1.00	0.150	3.00	3.8	17.3	3.8	5.7	0.32	0.43
10	15000.	0.0	1.50	0.075	3.00	2.7	16.1	4.0	5.4	0.23	0.49
11	15000.	0.0	1.50	0.100	3.00	2.9	16.5	4.4	5.5	0.25	0.67
12	15000.	0.0	1.50	0.125	3.00	3.3	16.9	4.9	5.6	0.28	1.17
13	15000.	0.0	2.00	0.075	3.00	2.7	16.1	5.3	5.4	0.23	5.03
14	17500.	0.0	1.00	0.150	3.00	3.2	17.3	3.2	5.7	0.28	0.31
15	17500.	0.0	1.50	0.125	3.00	2.8	16.9	4.2	5.6	0.24	0.58
16	17500.	0.0	1.50	0.150	3.00	3.2	17.3	4.9	5.7	0.28	1.01
17	17500.	0.0	2.00	0.075	3.00	2.3	16.1	4.6	5.4	0.20	0.83
18	20000.	0.0	1.00	0.150	3.00	2.8	17.3	2.8	5.7	0.24	0.25
19	20000.	0.0	1.50	0.150	3.00	2.8	17.3	4.3	5.7	0.24	0.58
20	20000.	0.0	2.00	0.075	3.00	2.0	16.1	4.0	5.4	0.17	0.49
21	20000.	0.0	2.00	0.100	3.00	2.2	16.5	4.4	5.5	0.19	0.67
22	20000.	0.0	2.00	0.125	3.00	2.5	16.9	4.9	5.6	0.21	1.17
23	22500.	0.0	1.00	0.150	3.00	2.5	17.3	2.5	5.7	0.21	0.22
24	22500.	0.0	1.50	0.150	3.00	2.5	17.3	3.8	5.7	0.21	0.43
25	22500.	0.0	2.00	0.100	3.00	1.9	16.5	3.9	5.5	0.17	0.46
26	22500.	0.0	2.00	0.125	3.00	2.2	16.9	4.4	5.6	0.19	0.66
27	22500.	0.0	2.00	0.150	3.00	2.5	17.3	5.0	5.7	0.21	1.25
28	25000.	0.0	1.50	0.150	3.00	2.3	17.3	3.4	5.7	0.19	0.34
29	25000.	0.0	2.00	0.125	3.00	2.0	16.9	3.9	5.6	0.17	0.47
30	25000.	0.0	2.00	0.150	3.00	2.3	17.3	4.5	5.7	0.19	0.73
31	25000.	0.0	2.50	0.075	3.00	1.6	16.1	4.0	5.4	0.14	0.49

Table III-5b (continued)

Case	River freshwater flow (cfs)	Dispersion coefficient (sq. miles/day)	Thermal stratification factor	Intake recirculation factor	Submerged jet dilution	Temperature of cross-section area (°F)		Surface temperature (°F)		Fraction of total area within 4°F isotherm	Fraction of river width within 4°F isotherm
						Avg.	Max.	Avg.	Max.		
32	25000.	0.0	2.50	0.100	3.00	1.8	16.5	4.4	5.5	0.15	0.67
33	25000.	0.0	2.50	0.125	3.00	2.0	16.9	4.9	5.6	0.17	1.17
34	27500.	0.0	1.50	0.150	3.00	2.1	17.3	3.1	5.7	0.17	0.29
35	27500.	0.0	2.50	0.100	3.00	1.6	16.5	4.0	5.5	0.14	0.48
36	27500.	0.0	2.50	0.125	3.00	1.8	16.9	4.5	5.6	0.15	0.71
37	30000.	0.0	1.50	0.150	3.00	1.9	17.3	2.8	5.7	0.16	0.25
38	30000.	0.0	2.00	0.150	3.00	1.9	17.3	3.8	5.7	0.16	0.43
39	30000.	0.0	2.50	0.125	3.00	1.6	16.9	4.1	5.6	0.14	0.53
40	30000.	0.0	2.50	0.150	3.00	1.9	17.3	4.7	5.7	0.16	0.86
41	30000.	0.0	3.00	0.075	3.00	1.3	16.1	4.0	5.4	0.11	0.49
42	30000.	0.0	3.00	0.100	3.00	1.5	16.5	4.4	5.5	0.13	0.67
43	30000.	0.0	3.00	0.125	3.00	1.6	16.9	4.9	5.6	0.14	1.17

It must be mentioned again that both models are for steady state condition and therefore are not able to predict the temperature distributions at the more severe periods of low and high slack water. For this purpose, some use could be made of the transient one-dimensional model reported by Harleman.[11]

i. Summary and Recommendations

The staff has performed an independent analysis for the submerged jets and concluded that in spite of several deficiencies in the applicant's model, the major conclusions are indeed correct; the maximum surface temperature is expected to be about 86 to 87°F and therefore, the 90°F maximum surface temperature criteria will probably be met.

The applicant's model for predicting temperature distribution in the near and far field is essentially a steady-state one-dimensional model. Therefore, the model cannot be used to predict the expected temperatures at the more severe periods of the tidal cycles (i.e., high and low slack water) and to show compliance with thermal criteria at "any stage of the tide."

The use of an exponential function for generating a three-dimensional temperature distribution from an average one-dimensional model is questionable. The use of correction factors extrapolated from the Indian Point Unit No. 1 field data is unjustified.

Since an alternative three-dimensional transient model was not available, the staff has used the applicant's model to perform an extensive parametric study and found that the results are very sensitive to the various parameters used. The most important parameters are the thermal stratification factor (TSF), the longitudinal dispersion coefficient (E), and the density-induced flows involved in the salt intrusion zone of the estuary.

The staff believes that field data are clearly needed to establish the correct values to be used for the above parameters. However, if one attempts to make an estimate based on the applicant's model and the presently available data, it seems that the following predictions might be possible: (a) the cross-sectional area within the 4F° temperature rise isotherm at the point of discharge might be on a tidal average about 25% of the total cross-sectional area, (b) the river width within the 4F° temperature rise isotherm at the point of discharge might be even on a tidal average basis between 60% to 100% of the total river width, and (c) some other assumptions resulting in more favorable predictions are possible but are not probable and cannot be defended with the presently available data.

A great deal of the uncertainty with respect to the thermal effects from the effluent from Indian Point Units Nos. 1 and 2 rests upon lack of field data for the longitudinal dispersion coefficient, the values of the apparent upper and lower layer flows during the 9 months of the year during which the "two-layered flow" flow situation exists in the Hudson River, and the amount of stratification in the estuary with and without the thermal discharges. The staff is of the opinion that the best, and perhaps only, way to resolve this uncertainty is by obtaining accurate temperature maps of the plume at times when Plant discharges and runoff flows are relatively constant. It is urged that the applicant obtain such sets of measurements as soon as possible - perhaps the first set during the 50% testing period.

Other temperature profile measurements should be obtained during 100% power operation at several times during the year in order to obtain values over a representative range of runoff flows and meteorological conditions. This data can be very useful in improving and refining the proposed models as well as establishing the correct parametric values required for using them.

2. Radioactive Wastes

The operation of a nuclear reactor results in the production of radioactive fission products, the bulk of which remain within the cladding of the fuel rods. During operation of the reactor, small amounts of fission products may escape from the fuel cladding into the primary coolant; also, some radioactive materials are produced as a result of neutron activation of corrosion products, of water, of dissolved chemicals, and of air in the coolant. Some of these materials in low concentrations may be released into the atmosphere as gases or into the Hudson River to unrestricted areas as liquids by carefully controlled processes after appropriate treatment, monitoring, and sampling and analysis.

The radioactive waste treatment systems presently incorporated in the Indian Point Plant Unit No. 2 are described in the Final Facility Description and Safety Analysis Report (FFDSAR),[26] the applicant's Environmental Report, Supplement No. 1,[1] and Supplement No. 2,[2] and staff's Safety Evaluation Report and Supplements. The quantity of radioactivity that may be released to the environment during operation of both Units at full power will be in accordance with the Commission's regulations as set forth in 10 CFR 20 and 10 CFR 50.

Staff evaluation of Unit No. 2 is based on the systems described in the FFDSAR and assumes that (1) changes in the waste evaporator have been completed and that (2) changes in the steam generator blowdown and ventilation systems will be completed before the end of the first refueling outage.

a. Liquid Wastes

The liquid waste system is designed to reduce radioactive materials in liquids discharged from the Indian Point Unit No. 2. The system is divided into two parts: the chemical and volume control system (CVCS), which will process radioactive water discharged from the reactor system; and the waste disposal system, which will collect and treat liquids from the secondary loop, including equipment and floor drains.

(1) Chemical and Volume Control System

Two process systems are located within the CVCS of Unit No. 2 (Fig. III-8). The proper functioning of these systems will greatly reduce the burden placed upon the waste disposal system. Most of the radioisotopes present in the waste effluents originate in the reactor coolant.[27] To maintain a low level of radioactivity in the primary coolant, a part of this coolant will be withdrawn to the CVCS and processed through one of two mixed-bed demineralizers to remove ionic impurities, fission products, and corrosion products except cesium, yttrium, molybdenum, and tritium. (These isotopes are removed slowly or not at all by the demineralizers and are assumed to pass through without any removal for the purpose of this analysis.) On an intermittent basis the effluent from the demineralizers will be processed through a second demineralizer to reduce all radioactive isotopes except tritium.[28] In the later stages of core life-time, the coolant effluent from the mixed-bed demineralizers will be routed to one of two deborating demineralizers. The effluent from both demineralizers will be filtered and returned to the volume control tank for reuse or sent to the holdup tanks for reuse after processing through the boric acid evaporator.

The second part of the CVCS will process liquids that drain from reactor coolant pump seals, accumulators, pressurizer relief tanks, and valve and flange leak-offs and the excess coolant let down during reactor startup. These liquids will be collected in one of three holdup tanks and processed on a batch basis. Liquid from one of the holdup tanks will be passed through one of four evaporator-feed cation demineralizers and will be filtered, degassed, and sent to a boric acid evaporator. The distillate

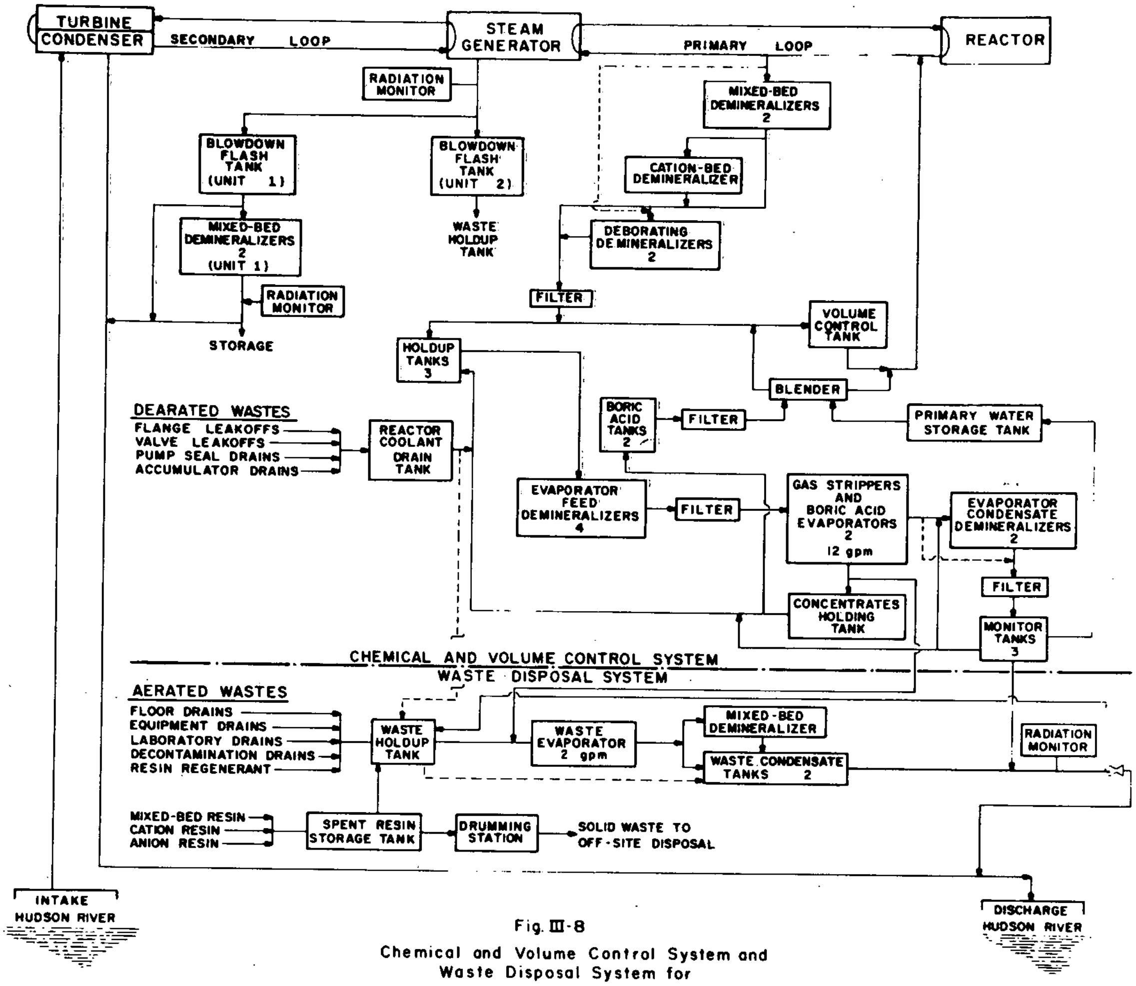

Fig. III-8

Chemical and Volume Control System and Waste Disposal System for Indian Point Unit 2 from the evaporator will be processed through a demineralizer, filtered, and transferred to one of the three monitor tanks. The contents of the tanks will be sampled and analyzed. The system is provided with recycle capability if the monitor tank activity is above permissible discharge limits. If the quality of the distillate is such that it can be reused, it will be transferred to the primary coolant storage tank. The boric acid concentrate will be either reused or discarded to the batch tank in the waste disposal system and removed as solid waste. The values in Table III-6 are based on an assumed release of four primary system volumes per year and an overall decontamination factor (DF) of 10^5 for the demineralizer-evaporator combination for all isotopes except iodine and tritium. A 10^3 DF for iodine was used.

(2) Waste Disposal System

The waste disposal system will process liquids from equipment drains and leaks, laboratory drains, decontamination drains, demineralizer regeneration, and floor drains (also shown in Fig. III-8). These liquid wastes will be collected in a waste holdup tank and analyzed for radioactivity. Liquid wastes that require no further cleanup will be transferred to the waste condensate tank for monitored discharge into the Hudson River via the discharge canal. Liquids requiring further treatment will be processed in batches through a waste evaporator to the waste condensate tank. After sampling and analysis, the condensate will be released to the discharge canal. Any solution in excess of preset limits of radioactivity will be processed through a polishing demineralizer or returned to the waste holdup tank. The concentrates from the waste evaporator will be packaged as solid waste.

The applicant is planning to install a steam generator blowdown purification system which will process the blowdown from both Unit No. 1 and Unit No. 2. This system will contain a flash tank, a filter, and a non-regenerable mixed-bed demineralizer. The demineralizer effluent will be monitored and released into the discharge canal. The present system contains a monitored blowdown tank which is vented to the atmosphere. Blowdown liquids are released without treatment to the discharge canal. The anticipated release from steam generator blowdown shown in Table III-6 is based on a continuous primary-to-secondary system leakage of 20 gpd and a 10-gpm steam generator blowdown.

TABLE III-6

ANTICIPATED ANNUAL RELEASE OF RADIOACTIVE MATERIAL IN LIQUID EFFLUENT FROM INDIAN POINT UNIT NO. 2 (INITIAL SYSTEM)

Nuclide	Steam Generator Blowdown (Ci/yr)	Chemical Volume Control System (Ci/yr)	Waste Disposal System (Ci/yr)
Rb-86	0.018	*	*
Sr-89	0.015		
Sr-90	0.0005		
Y -91	0.019		
Zr-95	0.002		
Nb-95	0.002		
Mo-99	5.51	0.005	0.018
Te-99m	0.61	0.004	0.016
Ru-103	0.002		
Te-127m	0.012		
Te-129m	0.11		
I -130	0.009	0.002	0.006
Te-131	0.031		
I -131	8.1	0.59	2.06
Te-132	0.62		0.002
I -132	0.12	0.056	0.19
I -133	3.46	0.56	1.92
Cs-134	7.1	0.004	
I -135	0.62	0.14	0.45
Cs-136	2.05	0.001	0.005
Cs-137	6.06	0.003	0.012
Ba-140	0.016		
Ca-140	0.003		
Ce-141	0.003		
Ce-144	0.002		
Pr-143	0.002		
Co-60	0.099		
Cr-51	0.018		
Mn-54	0.015		
Mn-56	0.045		
Fe-55	0.048		
Fe-59	0.019		
Co-58	0.47		
TOTAL	∿35	∿ 1.4	∿ 4.7

H -3 $\leq$ 1000 Ci/yr

*Isotopes with computed amounts less than 0.001 curies per year were not reported but are included in the total.

The effluent from the Plant laundry and contaminated showers will be processed in the Unit No. 1 system. Laundry wastes are expected to be a minor source of radioactivity.

Based on staff evaluation of the liquid waste systems for Unit No. 2, the radioactivity in the liquid discharged to the Hudson River was calculated to be approximately 40 Ci/yr, excluding tritium, for the initial system and a fraction of 5 Ci/yr, excluding tritium, for the modified system (Tables III-6 and 7). However, to compensate for expected operational occurrences and equipment shutdowns, the values for the modified system were normalized to 5 Ci/yr. From operating experience of operating PWR-type nuclear reactors, the tritium release was estimated to be about 1,000 Ci/yr. The applicant's estimated releases based on the modified waste system and a fuel leak of 0.5% of the full power operating fission product source term were 4,200 Ci/yr of tritium and 0.025 Ci/yr for all other radionuclides.

(3) Releases from Unit No. 1

The anticipated annual release of liquid radwastes from the initial system Unit No. 1 is given in Table III-8. At the present time the liquid wastes generated within Unit No. 1 are collected in 75,000-gallon tanks and released to the discharge canal after an additional delay of about 5 days. The amounts of radioactivity released from Unit No. 1 in the past have been reported in References 29-34; these are summarized for the years 1962-1971 in Table III-9.

(4) Combined Effluents from Unit No. 1 and Unit No. 2

The 40 Ci/yr expected to be released from Unit No. 1 and the 5 Ci/yr from Unit No. 2 will be diluted with an average of about 1 million gpm flow of the circulating cooling water. If the blowdown release from Unit No. 2 is added to the other releases, then the annual releases from the Indian Point Station into the Hudson River are estimated to be 81 Ci. When all Plant modifications become fully effective, this would be 10 Ci/yr (see Table III-13).

b. Gaseous Waste

During operation of the facilities, radioactive materials released to the atmosphere in gaseous effluents include low concentrations of fission product noble gases (krypton and xenon),

TABLE III-7

CALCULATED ANNUAL RELEASE OF RADIOACTIVITY IN LIQUID EFFLUENT FROM INDIAN POINT PLANT UNIT NO. 2 (MODIFIED SYSTEM)

Nuclide	Ci/yr	Nuclide	Ci/yr
Rb-86	0.0033	I -131	0.89
Rb-88	0.081	I -132	0.084
Sr-89	0.00041	I -133	0.48
Sr-90	0.000015	I -135	0.096
Sr-91	0.00014	Cs-134	1.17
Y -90	0.00011	Cs-136	0.48
Y -91m	0.00074	Cs-137	0.89
Y -91	0.033	Ba-137m	0.022
Y -93	0.00024	Ba-140	0.00046
Zr-95	0.000068	La-140	0.00031
Zr-97	0.000013	Ce-141	0.000075
Nb-95	0.000066	Ce-143	0.000024
Nb-97m	0.000013	Ce-144	0.000043
Nb-97	0.000015	Pr-143	0.000060
Mo-99	0.4	Pr-144	0.000043
Tc-99m	0.33	Nd-147	0.000024
Ru-103	0.000049	Pm-147	0.000006
Ru-106	0.000015		
Rh-103m	0.000049	Cr-51	0.0012
Rh-105	0.000015	Mn-54	0.00043
Rh-106	0.000045	Fe-55	0.0013
Te-125m	0.000041	Fe-59	0.00041
Te-127m	0.00032	Co-58	0.012
Te-129	0.00044	Co-60	0.0013
Te-129m	0.0032	Np-239	0.00039
Te-129	0.0021		
Te-131m	0.0012	Total	∿ 5 Ci/yr
Te-131	0.00023		
Te-123	0.021	H -3	∿ 1,000 Ci/yr
I -130	0.0015		

TABLE III-8

ANTICIPATED ANNUAL RELEASE OF RADIOACTIVE MATERIAL IN LIQUID EFFLUENT FROM INDIAN POINT UNIT NO. 1 (INITIAL SYSTEM)

Isotope		Ci/yr
I -137		15.5
I -132		1.01
I -133		6.56
I -134		0.79
I -135		3.53
Cs-137		0.41
Sr-89		0.05
Sr-90		0.01
Co-58		1.18
Co-60		0.49
F -18		3.38
Na-24		5.03
Cu-64		0.42
Mn-54		1.63
	Total	40.00

H-3 1,500 Ci/yr

TABLE III-9

SUMMARY OF LIQUID RADIOACTIVE RELEASES FROM INDIAN POINT UNIT NO. 1

Year	Activity Released[3] (Ci) H-3	Other	Total	Plant[34] Capacity Factor (%)
1962 (5 mo.)	--	0.13	0.13	28
1963	--	0.16	0.16	38
1964	--	13	13	25
1965	490	26	510	46
1966	130	43	170	50
1967	370	28	390	68
1968	800	35	830	65
1969	1100	28	1100	72
1970	410	7.8	420	14
1971	725	81	810	60

halogens (mostly iodines), tritium contained in water vapor, and particulate material including both fission products and activated corrosion products.

The primary source of gaseous radioactive waste is from the degassing of the reactor coolant. This is principally from the exhaust of cover gas from liquid-waste holdup tanks and from the venting of the CVCS and other equipment. Additional sources of gaseous waste activity include the auxiliary building exhaust, the vent from the steam generator blowdown tank, the turbine building exhaust, the reactor building containment air, and the condenser air ejectors. The gaseous waste system for Unit No. 2, shown in Fig. III-9, contains a vent header which will collect radioactive gases vented from the various holdup tanks, pressure relief tanks, and the CVCS. The gases will be compressed and stored in one of four large decay tanks. The control arrangement is such that one decay tank is filled at a time. When the fourth tank is being filled, the first tank will be emptied. Evaluation of the applicant's data indicates that the four large decay tanks have sufficient capacity to permit a holdup time of 45 days at Unit No. 2. The four separate decay tanks of Unit No. 1 (Fig. III-9) have sufficient capacity for 60 days. Prior to being released, the contents of each tank will be sampled and analyzed. The decision to discharge the gas to the Plant vent through high-efficiency particulate air (HEPA) filters or to return it to the CVCS for reuse and additional decay will be based on the analysis of radioactivity level. Provisions have also been included for transferring gas between tanks. Besides the four large gas-decay tanks, there are six smaller tanks. These tanks are reserved for use during degassing of the reactor coolant and purging of the volume control tank. The gas released from the decay tanks will be combined with ventilation air from the auxiliary building and discharged to the atmosphere through the Plant vent. The discharge point for Unit No. 2 is about 193 feet above the building grade; for Unit No. 1, it is from about 10 feet above the top of the superheater stack, 255 feet above building grade.

The vapor from the steam generator blowdown will be vented directly to the atmosphere during the first fuel cycle. Following the first fuel cycle, the steam generator will be tied into Unit No. 1. The vapor from the Unit No. 1 flash tank will go to the Unit No. 1 turbine condenser where the iodine will be scrubbed out. When Unit No. 1 is not operating, the flash tank vapor will be released directly to the atmosphere through the existing roof vent. From the operating history of Unit No. 1, the staff assumed that the steam generator blowdown vapor from Unit No. 2 would be released directly one-third of the time.

The containment building, primary auxiliary building, and the fuel storage building are designed for handling of radioactive materials. The separate exhaust systems have also been designed to ensure that air flow is from areas of low potential to areas having a greater potential for accidental release of airborne activity. The atmosphere in the primary auxiliary building is discharged through prefilters and HEPA filters to the Plant vent. In addition, a fan has been provided for diluting the concentration of activity in the air discharged by the Plant vent system. Charcoal adsorbers are to be added to the containment and primary auxiliary building exhausts for iodine removal.

Following power operation, use of the containment treatment system for pre-access cleanup may be necessary during shutdown. The treatment system consists of a prefilter, HEPA filters, and charcoal adsorber through which the containment air will be circulated. Before entry by personnel, the containment building atmosphere will be vented without further treatment through the containment purge exhaust system and discharged to the Plant vent. Air will be exhausted from the fuel storage building through a prefilter and HEPA filters prior to being released to the Plant vent. This system also will be modified by the addition of a charcoal adsorber for removal of radioiodines. Atmospheric discharges from the condenser air ejectors, which remove radioactive gases that have collected in the condenser as a result of primary-to-secondary leakage, will be continuously monitored and released without treatment through a vent stack located on the roof of the turbine building. Turbine building ventilation air will be discharged separately without treatment.

The staff's estimates of the anticipated annual release of radioactive nuclides in the gaseous effluent, based on the radioactive waste systems described in the FFDSAR for Unit No. 2 and on existing equipment in Unit No. 1, are summarized in Table III-10. Table III-11 contains a summary of airborne radioactive releases from Indian Point Unit No. 1[3] and shows that essentially all of the iodine released to the atmosphere as gas is due to the blowdown. The staff's calculated release

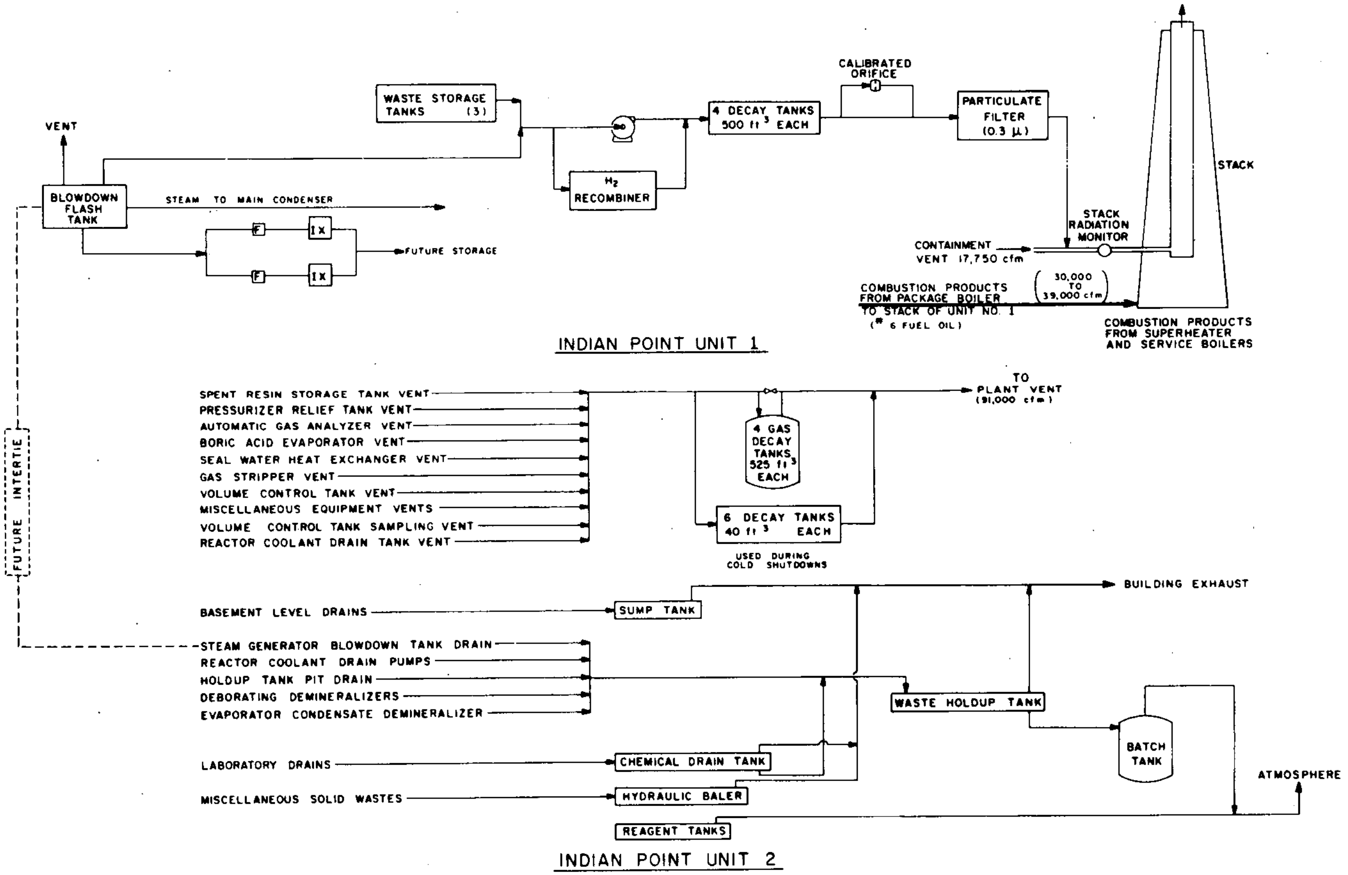

Fig. III-9 Gaseous Effluent Flowsheet for the Indian Point Station.

TABLE III-10

ANTICIPATED ANNUAL RELEASE OF RADIOACTIVE NUCLIDES IN GASEOUS EFFLUENT FROM INDIAN POINT UNITS NOS. 1 AND 2 (INITIAL SYSTEM)

	Discharge rate (Ci/yr)				
	Unit No. 1	Unit No. 2			
Isotope	Total (60-day decay)	Containment Purge	Gas Processing System	Steam Generator Leak	Unit No. 2 Total
Kr-85	180	13	790	2	800
Kr-87	2	0.04		3	3
Kr-88	6	0.31		10	10
Xe-131m	8	10	63	3	76
Xe-133	1,000	1,000	390	680	2,100
Xe-135	2	0.35		3	3
Xe-138	1	0.007		2	2
I-131	0.37	0.018		0.62	0.64*
I-133		0.018		0.31	0.33

*This release will be limited to 0.18 Ci/yr by the Technical Specifications.

TABLE III-11

SUMMARY OF AIRBORNE RADIOACTIVE RELEASES FROM INDIAN POINT UNIT NO. 1

	Reported Releases*		
	Noble and Activation Gases (Ci)	Iodines and Particulates (Ci)	Plant Capacity Factor (%)
1962	--	--	28
1963	0.007	--	38
1964	13	--	25
1965	23	--	46
1966	56	--	50
1967	23	Neg.	68
1968	55	Neg.	65
1969	600	0.025	72
1970	1,800	0.075	14
1971	380	0.21	60

*The data for 1962 to 1966 were taken from the Semi-Annual Operating Reports of Consolidated Edison. The data for 1967 to 1971 were obtained from the Commission's Division of Compliance records.

of 0.64 Ci/yr of iodine-131 exceeds the Technical Specification for Unit No. 2, which require that discharge of iodine-131 to be less than 0.18 Ci/year.

In Supplement No. 1 to the Environmental Report,[1] the applicant described several proposed modifications to the gaseous waste system. The proposed changes include the installation of an iodine removal system (charcoal adsorbers) in the Plant vent, to reduce any gaseous release of radioiodine from the containment purge or auxiliary building, and an intertie between Unit No. 2 and Unit No. 1 steam generator blowdown lines. As the result of these modifications, the staff estimates of the gaseous releases of radioactivity from Unit No. 2 to the atmosphere are 2,700 Ci/yr of noble gases and 0.18 Ci/yr of iodine-131 (Table III-12). The combined releases from Units Nos. 1 and 2 will be 3,900 Ci/yr of noble gases and 0.42 Ci/yr of iodine-131 (Table III-13). Testimony presented by the applicant before the Licensing Board on July 13, 1971, indicates that the proposed modifications will be completed by the end of the first fuel cycle.

c. Solid Wastes

Radioactive solid wastes will consist mainly of spent demineralizer resins, evaporator concentrates, and filters. Concentrates from the waste evaporator will be put into steel drums and mixed with a solidifying agent such as vermiculite and cement. Spent resins will be packaged the same way after "cooling" in the waste-resin storage tank for 1 to 6 months. The sluice water will be separated from the resin and returned to the waste holdup tank. Each drum will be stored in a shielded area prior to being shipped offsite. Miscellaneous solid wastes such as paper, rags, clothing, and glassware will be compressed in 55-gallon drums by a baler. The filled drums will be stored in a shielded area in the drumming room until shipped offsite. All solid waste will be packaged and shipped to a Federally-licensed burial ground in accordance with the Atomic Energy Commission's and Department of Transportation's regulations. Based on the applicant's estimate, it is expected that 100 to 150 drums of solid waste will be transported offsite each year from the initial systems. The quantity of solid waste from the modified system is expected to be significantly greater and contain approximately 5,000 Ci/yr from Unit No. 2. Details of transportation of wastes and their impact are discussed in Section V.F.

TABLE III-12

CALCULATED ANNUAL RELEASE OF RADIOACTIVE NUCLIDES IN GASEOUS EFFLUENT FROM INDIAN POINT NUCLEAR GENERATING UNIT 2 (MODIFIED SYSTEM)

	Discharge Rate (Ci/year)[a]					
			Gas Processing System	Steam Generator Leak		
Isotope	Containment Purge	Auxiliary Building	for 45-Day Decay	Air Ejector	Blowdown Tank Vent[b]	Total
Kr-83m	-	1	-	1	-	2
Kr-85m	-	6	-	6	-	12
Kr-85	2	1	870	1	-	870
Kr-87	-	3	-	3	-	6
Kr-88	-	11	-	11	-	22
Xe-131m	1	2	81	2	-	86
Xe-133m	-	9	-	9	-	18
Xe-133	88	530	470	530	-	1600
Xe-135m	-	1	-	1	-	2
Xe-135	-	17	-	17	-	34
Xe-137	-	1	-	1	-	2
Xe-138	-	2	-	2	-	4
Total Noble Gases	91	580	1500	580	-	2700
I-131	0.027	0.001	-	0.13	0.20	0.36[c]
I-133	0.027	0.001	-	0.066	0.07	0.14

---

[a] Less than 0.5 Ci/yr of noble gas or less than 0.0005 Ci/yr of iodine.

[b] Assumes direct venting to the atmosphere one-third of the time, based on average Plant factor for Unit No. 1 since 1967 omitting 1970; 67% passes through Unit No. 1 condenser.

[c] Release will be limited to 0.18 Ci/yr by Technical Specifications.

TABLE III-13

CALCULATED RADIOACTIVITY RELEASES IN EFFLUENTS FROM INDIAN POINT NUCLEAR GENERATING PLANTS UNITS NOS. 1 AND 2

Unit No.	Power (MWe)	Effluent Radioactivity (Ci/yr)			
		Liquids		Gases	
		Tritium	All Others	Noble Gases	Iodine-131
		Initial Process Basis			
1	615	1,500	40	1,200	0.37
2	2,758[a]	1,000	41	3,000	0.67[b]
Total		2,500	81	4,200	1.0
		Modified Process Basis			
1	615	1,500	5	1,200	0.06
2	3,215	1,000	5	2,700	0.36[b]
Total		2,500	10	3,900	0.42

[a] This is the stretch power output of Unit No. 2.

[b] Limited to 0.18 Ci/yr by the Technical Specifications.

3. Chemical Discharges and Sanitary Wastes

a. Chemical Wastes

Several routine operations of the Indian Point Unit No. 2 will contribute to the discharge of chemical wastes into the environment as a result of operation of the Plant: leakage from the primary coolant system, steam generator blowdown, regeneration of demineralizers, and cleaning of the condenser tubes. The different water treatment procedures carried out by the applicant are governed by the use of several systems (primary, secondary, condenser, and service water) rather than by operating at different power levels. Thus the chemical additions and discharges are the same for both partial and full power operation with minor exceptions. Liquid radioactive wastes are discussed above in Section III.E.2. Some of these operations were initiated at the onset of operation during subcritical testing and will continue during zero power testing and power escalation up to 50% and 100% of rated power.

In practice, the cooling water circulating through the once-through condenser system and service water system for a total maximum flow of 870,000 gpm of Unit No. 2 serves to dilute any discharged chemicals. The applicant will monitor these Plant effluents for chlorine, pH, salinity, dissolved oxygen, and copper to assure that the water discharged into the Hudson River will meet the limits established by the New York State Department of Environmental Conservation. In addition, the applicant plans to conduct a continuous environmental monitoring program in the area of the Indian Point site.

A list of chemicals utilized in the various Plant systems and the amounts and concentration limits at the confluence of the discharge canal water with the Hudson River are given in Table III-14. In addition to thermal discharge standards established by New York State, the State Department of Environmental Conservation has established water quality standards depending on water use. Applicable criteria classifies the Hudson River at Indian Point as "Class SB" (NYS Part CRR 701.4)[5] as shown in Table 2.3-2 of the applicant's Supplement No. 1. All discharges will be subject to regulation by the New York State Department of Environmental Conservation pursuant to section 1203 of the Public Health Law and to Federal regulations under Section 21(b) of the Water Quality Improvement Act of 1970 and Section 13 of the Rivers and Harbors Refuse Act of 1899. The applicant has applied for the permits for Section 13. The estimated date of final action is December 31, 1972. Since the regulation is phrased in terms of general criteria rather than

TABLE III-14
THE DISCHARGE OF CHEMICALS TO THE HUDSON RIVER FROM INDIAN POINT UNITS NOS. 1 AND 2[a]

Chemical Discharged	Max. Sustained Releases, lb/day		Conc. at Discharge Point to Hudson River[b] (ppm)		Proposed Limits from Both Units[c] (ppm)	NYS Allowable Conc. of Chemical Discharges (ppm)
	Unit No. 1	Unit No. 2	Unit No. 1	Unit No. 2		
Lithium hydroxide[d]	2.5	2.5	<0.01	<0.001	0.01	d
Boric acid (Boron)[d]	600	600	0.2	0.06	9	d
Sodium hydroxide	156	12	1.2	<0.1	10	e
Sulfuric acid (SO_4)	450	-	3	-	10	e
Sodium phosphate (PO_4)	15	24	0.001	0.0007	1.54	-
Hydrazine	24	5	0.006	0.0005	0.1	-
Cyclohexylamine	2.5	12	0.0006	0.001	0.1	-
Morpholine	2.5	12	0.0006	0.001	0.1	-
Sodium sulfate	Neutralization product of NaOH and H_2SO_4		2.5	-	10	-
Sodium carbonate	1,000/batch	-	8.5[f]	-	5[f]	-
Sodium hypochlorite (Cl_2)	15%	15%	0 to 0.5[i]	0 to 0.5[i]	0.5	0.5
Potassium chromate (Cr VI)	Intermittent use	30	-	0.008	0.05	0.05
Detergent[g]	3.0	-	0.01	-	1.0	-

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[a] Sulfate, caustic soda, and soda ash together represent 5 to 10% of the permissible concentrations of the total dissolved solids (TDS) that can be discharged into receiving waters.

[b] Discharge during full power operation with 319,000 gpm for Unit No. 1 and 870,000 gpm flow for Unit No. 2 of condenser coolant in the discharge canal.

[c] Values normalized to a nominal flow of condenser coolant in the discharge canal of 100,000 gpm.

[d] These releases would occur only in the event of evaporator breakdown.

[e] These represent the concentration of dissolved solids that can be discharged into the river.

[f] Soda ash used in a 2% solution for 12 hours to wash the Unit No. 1 flue gas passages of the superheaters, economizers and air preheaters, four times per year and discharged continuously during the cleaning period at 17 gpm into a flow of 20,000 gpm of service cooling water during Unit No. 1 shutdown.

[g] Alkyl benzene sulfonate.

[h] Chlorination treatment schedule: 30 minutes for each inlet water box 3 times per week.

[i] Intermittent discharge following chlorination treatment.

specific numbers, the applicant is proposing to meet certain discharge limits with respect to concentrations of various chemicals at the confluence with the Hudson River which it believes satisfy the criteria. The basis for these limits was obtained in part from bioassay work performed by the Raytheon Company and New York University as consultants for the applicant.

During the operation of the two Units at Indian Point, certain chemicals must be used to maintain the desired water quality required in the primary and secondary water systems. Some of the chemicals will be contained in closed-loop systems and will eventually be disposed of as solid waste, while other chemicals will be discharged in liquid effluents into the Hudson River through a discharge canal common to both Unit No. 1 and Unit No. 2. The chemical wastes will be diluted by the cooling water. During shutdown, 20,000 gpm of cooling water will be utilized in Unit No. 1 and 30,000 gpm of cooling water in Unit No. 2 for dilution of chemical wastes. In full operation, up to 319,000 gpm from Unit No. 1 and 870,000 gpm from Unit No. 2 for a total of about 1.2 million gpm of water flow will be used to dilute the chemical wastes. For this analysis, a more conservative approach was used in order to discuss the more adverse conditions when dilution of the wastes would be less (see Table III-14). Chemical discharges are not power dependent, but the concentration levels are flow dependent. Details of the chemical discharges from Unit No. 1 are described in Section D, Volume II of Reference 3.

(1) Releases from Primary System

The standard chemicals utilized in the primary systems to control pH and oxygen levels include lithium hydroxide and hydrazine. These chemicals will be added to the primary cooling to obtain the desired water chemistry. The CVCS is designed to maintain the chemistry and purity of the primary coolant, the desired boric acid concentration, and the volume of water and pressure in the primary system.

Lithium hydroxide is used for pH control in the primary system. Normally, leakage from the primary system would be processed through the CVCS or the waste disposal system. Based on the assumption of an evaporator breakdown in the waste disposal system, the maximum concentration that could be expected under the conditions of evaporator breakdown* occurring simultaneously in each of the two

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*Chemical releases during evaporator breakdown are on an intermittent basis. Such releases should not be construed as occurring on any routine basis during normal operation.

Units to be about 2.2 ppm with a maximum waste disposal flow rate of 25 gpm, yielding a possible sustained release of 5.0 lb/day from the two Units. The concentration entering the Hudson River at the confluence of the discharge water is expected to be less than 0.01 ppm during normal operation.

A maximum of 2,000 ppm of boron will be used for reactivity control in the primary coolant. A breakdown of both boric acid evaporators would possibly necessitate the release of 600 lb of boric acid per day from each Unit at a maximum discharge rate of 25 gpm. A maximum concentration of 50 ppm of boric acid at the confluence of the discharge water into the Hudson River has been proposed. The expected concentration of boric acid would be less than 10 ppm.

Potassium chromate is used as a corrosion inhibitor in the closed cooling water system of Indian Point Unit No. 2. No discharged is planned, but some leakage at a maximum concentration of 100 ppm with a maximum discharge flow rate of 25 gpm could result in a concentration of 0.05 ppm (as the hexavalent chromium) at the discharge point to the river. A maximum sustained release of 30 lb/day would occur.

Sources of chemical wastes during operation of Indian Point Unit No. 2 will include concentrates which are blown down to the discharge water to which has been added sulfuric acid to control the pH, for use as makeup for various Plant systems. The concentrates from the flash evaporator blowdown have a pH between 7.0 and 8.5. No measurable release of sulfuric acid is anticipated from Indian Point Unit No. 2. Sodium hydroxide is also used during normal operation of the primary system demineralizers to regenerate the spent resins as hydroxyl or anion forms once every 4 to 7 days for 2 hours. Excess sodium hydroxide is drained to the waste disposal system where it is processed by the waste evaporator. It is also used for pH control in the waste evaporator. The waste distillate would be ultimately discharged at the rate of 25 gpm into the discharge canal. If evaporator breakdown occurs, the maximum concentration of sodium hydroxide that would be discharged would be about 5,000 ppm at a discharge flow rate of 25 gpm at the rate of 12 lb/day. The proposed maximum concentration in the discharge canal water is 10 ppm during normal operation.

The Plant laundry that serves both Units will use 3 pounds of detergent daily. This detergent, Colgate Low Foam, consists of 26.5% sodium phosphate, 28% sodium sulfate, 10% sodium carbonate, 6%

silicates, 15.5% benzene sulfates, 10% nonionics, and 4% water. The laundry water may be discharged at a rate of 25 gpm or processed through the waste disposal system.

(2) Releases from Secondary and Auxiliary Systems

Releases from the secondary and auxiliary systems involve sodium phosphate, which is used to control the steam generator acidity, as well as in combination with sodium hydroxide which is used in the treatment of the house service boilers of Units Nos. 1 and 2. In Unit No. 2 the phosphate concentration level (expressed as phosphate) of no more than 250 ppm at any one time nor 10 ppm on a sustained basis will be obtained at a maximum discharge rate of 200 gpm such that the concentration at the point of discharge into the river is 1.5 ppm. At the maximum flow rate of 200 gpm, the expected sustained release (expressed as PO_4) is 24 lb/day from Unit No. 2 and 15 lb/day from Unit No. 1.

Hydrazine, which is needed to control oxygen in the steam generators, will be kept at a concentration of 2.0 ppm during normal operation. The expected maximum flow rate is 200 gpm, and the expected sustained release is 5 lb/day during normal operation, resulting in a concentration of 0.0005 ppm at the point of discharge into the Hudson River. However, a discharge of 100 ppm hydrazine may occur once per year at the end of the refueling outage. Hydrazine is also discharged once a year from Indian Point Unit No. 1 during refueling at a flow rate of 40 gpm. The maximum possible release rate would be 24 lb/day at a maximum concentration of 50 ppm.

Neither cyclohexylamine nor morpholine, used to adjust feedwater and steam pH, will exceed a concentration in the steam generator blowdown of 5 ppm released on a sustained basis at a maximum flow rate of 200 gpm. The nuclear boilers in Indian Point Unit No. 1 are blown down continuously at a maximum rate of 40 gpm containing a maximum concentration of 5 ppm cyclohexylamine. The expected sustained release of either amine is 12 lb/day from Indian Point Unit No. 2 and 2.5 lb/day from Unit No. 1. The proposed maximum concentration of either amine discharged from both Units will be 0.1 ppm at the discharge point into the river. During normal operation, the expected concentration will be below 0.01 ppm.

Sodium hydroxide is also used at Indian Point Unit No. 1 for acidity control in the house service boilers and make-up water evaporator and for regeneration of the water treatment mixed-bed ion exchangers. The combined sustained released is expected to be 36 lb/day from the boiler blowdown and evaporator blowdown. The regeneration of the mixed-bed ion exchangers scheduled to occur would yield a total release of 120 lb/day. Although no measurable releases of sulfuric acid are anticipated from Indian Point Unit No. 2, sulfuric acid is used in the water treatment cation and mixed-bed ion exchanger regenerations for Indian Point Unit No. 1. These regenerations occur approximately once every 4 days for a duration of 2 hours. Of these 2 hours, 1 hour is used for neutralization of caustic by sulfuric acid. However, a 4% sodium hydroxide solution would yield a total release of 120 lb/day. The excess sulfuric acid is neutralized prior to discharge during the mixed-bed regeneration process. However, release of sulfuric acid at a concentration level of 3% is discharged at the rate of 450 lb/day at a flow rate of 30 gpm during cation-bed regeneration of Unit No. 1. The proposed maximum total concentration of sulfuric acid is 10 ppm at the point of discharge into the river, but the expected concentration will be 3 ppm.

Soda ash is used four times per year to wash flue-gas passages in the superheater of Indian Point Unit No. 1. A 2% solution is used for 12 hours and is discharged continuously during this period at a rate of 17 gpm. The proposed maximum concentration of soda ash at the discharge point is 5 ppm.

In the discharge canal, the applicant also has an Automatic Environmental Systems Unit (AES) into which water from the discharge canal is pumped and which monitors pH, dissolved oxygen, salinity, temperature, and cupric ions once per hour. The probe for cupric ions has an actual effective lower limit sensitivity for copper of the order of 1 ppm.[35,36]

For chlorination of the cooling water with sodium hypochlorite in the condenser tubes of Unit No. 2, two procedures are indicated in the applicant's Enrivonmental Report. An automatic programmed control system is arranged to initiate a cycle once a day or more often. Each cycle will consist of slug treating the six circulating water intake bays in two groups of three and then the service water intake bay. Another procedure is to chlorinate each condenser with a 15% sodium hypochlorite solution (320 lb/day average) at a rate of 5 gpm at a different time for approximately 1 hour, three times a week. These two procedures would result in different total amounts of sodium hypochlorite released on a weekly basis. However, in either case, the concentration of residual chlorine in the water discharged into the Hudson River will be required to be below 0.5 ppm to meet State standards.

Table III-14 summarizes the maximum concentrations of treatment chemicals that would be expected to be in the discharge canal at the point of discharge to the Hudson River. These values are compared with the New York State regulations governing the concentration of chemicals in the effluents discharged to receiving waters. The applicant has proposed that the chemical discharges with respect to concentrations released to the confluence with the Hudson River will meet the discharge limits for the "Class SB" standards applicable to the Hudson River at Indian Point and established by New York State. Table III-15 shows the concentrations of chemicals already present in the Hudson River during different flow conditions.[1]

b. Sanitary Wastes

Sanitary wastes from Unit No. 2 will be treated by the facility now used for Unit No. 1. The facility contains communutors, septic tanks, and sand filter beds. The existing facility appears to be adequate to process wastes from Unit No. 2 on the basis of capacity, design parameters, and site percolation tests. Description of the capacity is presented in Table 2.3-4 of the applicant's Supplement No. 1 to the Environmental Report. The facility has been approved by the New York State Department of Health and the Westchester County Health Department. Septic tank sludge will be removed by commercial means when the sludge level reaches one-fourth of the tank volume.

In the future, should the load on the sanitary system exceed the percolation rate, the applicant states that the effluent will be chlorinated and discharged into the river. See Section V.D. on the problem of toxicity of chlorine and the staff's analysis of effects of chlorine on biota.

4. Other Wastes

Energy is derived from burning fossil fuel, as well as nuclear fuel, at the Indian Point facility. Steam produced in the secondary loop of Unit No. 1 is further heated in a superheater before the steam enters the turbine. Nuclear fuel provides about 153 MW(e) and oil provides about 112 MW(e) of the 265 MW(e) (net) produced by Unit No. 1. In addition, Unit No. 1 contains three service boilers and Unit No. 2 contains two. Combustion products from all these units are discharged through the superheater stack of Unit No. 1. The rated capacity[36] of the superheater is 842,000,000 Btu/hr. The three boilers in Unit No. 1 are each rated at 50,600,000 Btu/hr, and those in Unit No. 2 are each rated at 60,000,000 Btu/hr.[36,37]

TABLE III-15

CHEMICAL ANALYSIS OF THE HUDSON RIVER NEAR INDIAN POINT, OCTOBER 1964, TO SEPTEMBER 30, 1967[a]

	Concentration, ppm		
	Minimum	Maximum	Average
Silica (SiO_2)	2.6	3.9	NA[b]
Iron (Fe)	0.05[c/]	0.12	NA
Aluminum (Al)	NA	NA	NA
Manganese (Mn)	0.00	0.02	NA
Calcium (Ca)	19	82	35.6
Magnesium (Mg)	3.9	184	45.8
Sodium (Na)	5.5	1,700	39.7
Potassium (K)	0.8	60	17.2
Bicarbonate (HCO_3)	54	82	67.3
Sulfate (SO_4)	23	420	127.2
Chloride (Cl)	8.5	3,020	749.1
Nitrate (NO_3)	0.2	1.8	0.7
Phosphate (PO_4)	NA	NA	0.3[d]
Dissolved solids	NA	NA	NA
Hardness (as $CaCO_3$)	64	966	295.5
Dissolved oxygen	5.5[e]	11.5[e]	8.4[e]
Biochemical oxygen demand (5-day, 20°C)	1.4[e]	4.6[e]	2.7[e]
Salinity	100	7,200[f]	950

	Physical Parameters		
	Minimum	Maximum	Average
Temperature, °F	34.7	77.0	51.8
pH	7.1	7.5	7.3
Color	0	25	15

[a] Data collected by U.S. Geological Survey at Tompkins Cove, N. Y. (MP 42.5) unless otherwise noted.

[b] NA - Not available or results too few to average.

[c] USGS Station at Verplanck, N.Y.

[d] from NYU studies.

[e] from intake at IBM facility (MP 71.6).

[f] from QLM studies.

The capacity of the superheater alone exceeds 250,000,000 Btu/hr, which means that atmospheric discharges from the Indian Point plant would lie within the scope of 42 CFR 466[38] if it were a new plant. A new plant would be limited to the discharges listed in Table III-16 according to regulations of the Clean Air Act. However, "These proposed regulations do not include provisions for implementation of Section III(d) of the Act, under which States would be expected to establish standards for existing stationary sources of certain pollutants."[38] The maximum quantity of each pollutant estimated on the basis of oil consumption at full load is listed in Table III-16 for the superheater only and for the superheater plus the five package boilers. These calculations are based on the listed rates of consumption of No. 6 fuel oil with a heat rating of 18,400 Btu/lb. They are also based on two sulfur concentrations, namely, the fuel now in use, with a nominal 1% sulfur, and the fuel to be used in the future,[1] containing no more than 0.37% sulfur. In connection with this reduction, the staff notes that the New York City code on air pollution control[39] requires a reduction of sulfur content in No. 6 (bunker) fuel oil from 1% to 0.3% by October 1, 1971.

The expected particulate discharge listed in Table III-16 is less than 30% of the maximum proposed in 42 CFR 466 for new plants; the discharge of sulfur dioxide exceeds the maximum by nearly 40% with a fuel oil containing 1% sulfur but will be only half the limit after the change to oil with 0.37% sulfur has been made. The nitrogen oxide discharged is 20% in excess of those specified in 42 CFR 466. Since Indian Point Unit No. 1 is not a new plant, the proposed regulations can serve only as a guideline.

The applicant has questioned the appropriateness of referring to the proposed "Standards for New Stationary Sources" (42 CFR 466) and the New York City air pollution code. Both of these are quoted for the purpose of providing a basis for comparison with emissions of particulate matter, sulfur dioxide, and nitrogen oxides from all fossil-fuel sources at the Indian Point site.

Chemicals and hazardous materials, such as ammonia, hydrazine, or organic solvents, will be stored and handled according to common industrial safety practices. Nonradioactive and radioactive materials in the laboratories will be handled with the normal precautions and safety practices required to protect operating personnel and workers from any health hazards.

TABLE III-16

ATMOSPHERIC DISCHARGES FROM FOSSIL-FUEL COMBUSTION AT INDIAN POINT

	Discharge (lb/million Btu)		
		Indian Point	
Component	Limits set by 42 CFR 466[a]	Superheater only	Superheater plus 5 boilers
Particulate	0.2	0.055	0.055
SO_2	0.8	0.41 or 1.1[b]	0.41 or 1.1[b]
Nitrogen oxides	0.30	0.36	0.36
Oil consumption (lb/hr)		44,564[c]	59,832[c]

[a] Reference 38 which contains proposed standards for new fossil-fuel plants.

[b] The lower value is based on 0.37% S, the higher value on 1.1% S in the fuel oil.

[c] See Reference 37.

Other waste, such as trash, shop and construction debris, non-radioactive HEPA filters, and septic tank sludges, will be disposed offsite by a commercial service. Large materials from the water intake trash racks are collected, along with the small materials flushed off the intake traveling screens, in a wire basket and disposed as solid refuse by a commercial service.

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IV. ENVIRONMENTAL IMPACT OF SITE PREPARATION AND STATION CONSTRUCTION

A. SUMMARY OF CONSTRUCTION

Construction of Indian Point Unit No. 1 was completed in 1962 and that of Unit No. 2, which started in December 1965, will be completed by about summer 1972. The construction of Unit No. 3 is about 70% complete. This Unit is scheduled to be operational in 1974. For Unit No. 2 the first major milestone of completion of Plant construction was achieved on June 29, 1970 when the applicant conducted a hydrostatic test of the reactor coolant system. Hot functional tests were also completed on March 3, 1971. Prior to core loading the applicant conducted major testing of vapor containment and structural integrity of the Plant's physical facilities. On October 19, 1971, the applicant received a Facility Operating License No. DPR-26 to load fuel and to conduct subcritical tests. On July 14, 1972 an Initial Decision to authorize the applicant's request for testing the reactor system up to 20% of rated power with the balance up to 50% power deferred to the Commission was made by the presiding Atomic Safety and Licensing Board. The applicant has received all the necessary Federal, State, and local permits and licenses for the necessary construction work as described in Chapter I, Section B.

B. IMPACTS ON LAND, WATER AND HUMAN RESOURCES

1. Area and Water Use Involved

The major impact on land use occurred during the construction of the major facilities on the site, beginning with the construction of Unit No. 1 in 1956. Plant construction of all 3 Units has only modified approximately 35 acres of the 239-acre site. The original site was the Palisades amusement park which was abandoned when the use of the park decreased. The applicant purchased the abandoned site in the mid 1950's for use as a site for a power plant. Furthermore, the site was close to the applicant's major load center of New York City so transmission line losses would be kept to a minimum. Construction of Unit No. 2 did not require purchase by the applicant of additional rights-of-way to build transmission towers. Thus, the particular site selected for Unit No. 2 resulted in a minimal adverse impact on the land actually used to build the facility, the land used for building transmission lines, or alternate sites to build a nuclear power plant. The site was zoned for heavy industrial use.[1]

During construction, few impacts of any significance resulted in land use since no changes were needed for rebuilding or relocating highways, expressways, railroad lines or gas lines. Heavy construction equipment and other materials were transported to the site on highways already in existence or up the Hudson River by barge, thereby not causing any relocation of main arteries of transportation. Much of the construction work and impacts resulting from construction are limited to the confines of the site itself.

The main boundaries of the site have essentially not been altered from construction activities going on within the site. As construction becomes completed, and the work forces and equipment begin to diminish, orderly restoration of the site will begin to accelerate. For the remaining period of construction, prompt vegetative measures and landscaping work will be continued in order to reduce erosion in the area disturbed by the construction effort.

The applicant plans to complete landscaping and development of the site for recreational purposes within a year after construction of Unit No. 3 is completed.

The size of the site is sufficient to reduce any noise levels from construction at the site boundaries so as not to create a noise problem for off-site residents. A temporary relocation of wildlife may have resulted from the noise and congestion of construction activities. However, about one half of the site still remains in its natural state. This has kept any disturbance of wildlife habitat to a minimum. Upon completion of the construction work, a natural reestablishment of wildlife in the area may result, particularly because of the 80-acre forested park and lake area being established by the applicant for public use.[2]

The thermal modeling and ecological monitoring studies (see Chapters III and V) conducted by the applicant during the past several years have indicated that to meet the New York State thermal criteria standards, the intake and discharge structure had to be modified from being a surface discharge structure in which the heated cooling water was discharged parallel to the eastern bank of the Hudson to being a submerged jet discharge in which the cooling water was discharged normal to the river through a submerged structure of 12 ports located about 18 feet below the U.S. Coast and Geodetic Survey Sea Level Datum level of the Hudson River. At the present time the submerged jet discharge structure has been changed from 18 to 12 feet. As described in Section III.E.1, the submerged discharge structure has 12 ports through which the cooling water is discharged at 10 fps. All field work preparatory to receipt of adjustable gates is complete. Fabrication of the gates is also complete. Installation of the gates began after the river thawed in early April 1972[3] and is now completed.

Of the 12 ports, 10 ports will have adjustable gates such as to control the flow volume and rate through the ports. Two ports, the most southerly gates, can be either completely opened or completely closed since they are not adjustable. Positioning of their gates (opened or closed) will be dependent on operation of the Units Nos. 1 and 2 to maintain a discharge velocity of 10 fps. During operation of Units Nos. 1 and 2, it is expected that only every other port (a total of 7) will be used to discharge heated water. When Unit No. 3 is operational, the applicant plans to use all of the ports.

The intake system is also being modified for Winter 1972-1973 to reduce the intake flow velocity from 0.8 fps to 0.5 fps through the openings of the inlet forebay of the condenser system.[5] This reduction will be accomplished by recirculation of the cooling water in which the flow velocity will be reduced from 140,000 gpm per pump to 84,000 gpm per pump. The reduction of flow by recirculation of the discharge water may aid in reducing any potential fish kill from impingement on the protective fixed and traveling screens, as described in Section V.D. Reduction in flow will be accomplished primarily during the winter months when the river water is colder and when the white perch is greatest in abundance in the vicinity of Indian Point.

During construction, some diesel powered machinery was used, thereby causing some combustion products to be released to the atmosphere. This effect would be the same on any other large construction project. The air pollution created would be intermittent and localized. Furthermore, during modification of the intake-discharge system, destruction of some benthos resulted from dredging and filling. This work was to modify the structure authorized by the U.S. Department of the Army, Corps of Engineers.

After components are constructed, certain initial Plant operations such as flushing out equipment are carried out. Some of the initial startup operations involve non-routine releases of chemicals into the Hudson River. In Section 2.3.4 of the applicant's Supplement No. 1 to the Environmental Report, below the limits proposed by State and Federal regulations. These processes, concentrations and amounts of chemicals discharged are outlined in Table IV-1. It is expected that discharges will be conducted in a batch process. Although the discharges are to be kept within State and Federal limits, the applicant should use due precaution in discharging large amounts of chemicals at any one time because of the toxic effects of some of these chemicals on fish and other aquatic biota.

2. Manpower Effects

Since most workers commuted from nearby communities to the Plant site, the impact of manpower on the local environment was negligible. At times traffic around the site increased particularly when the peak manpower of about 1,200 workers was present at any one time on the site for construction of Unit No. 2. As construction is being completed, the average manpower of 1,000 used for Units Nos. 2 and 3 will decrease. Thus, the congestion is temporary and will not occur after construction is completed.

A relatively small work force of about 400 people, primarily from the local surrounding areas, will be needed to operate and maintain the reactor facilities after construction of all three Units is finished.[4]

3. Environmental Considerations

Detailed analysis of the environmental impact of the site preparation and Plant construction would have only limited value at the time of this Statement since the construction of Indian Point Unit No. 2 is largely completed. The applicant has indicated in its Environmental Report[1] and Supplement No. 1[2] that the disturbed ground around the construction site will be "landscaped in an attractive manner, ... to improve the aesthetic and recreational value of the site." The exact extent of the landscaping effort was not defined, although excavated material was used to level the site area.[2]

According to the applicant, "effort was exercised to eliminate from view unsightly operating equipment" by erecting masonry walls to block the view of certain equipment from river traffic and the opposite shore. The applicant stated that "attention had been given to the form, color, and texture of the buildings so that the setting is enhanced and the feeling of intrusion is held to a minimum."

TABLE IV-1

POSSIBLE NON-ROUTINE CHEMICAL DISCHARGES DURING PLANT STARTUP

	Process	Intermittent Concentration ppm	Maximum Discharged Amount lb/day
Phosphates*	Steam generator pH control	250	12
Hydrazine*	Steam generator oxygen control	100	24
	Primary system oxygen control	100	170
Lithium Hydroxide** (as lithium)	Primary system pH control	10	17
Potassium Chromate** (as chromium)	Corrosion inhibitor	50	94
Boric Acid** (as boron)	Chemical shim for primary system	500	850
Sulfuric Acid	pH control of flash evaporator blowdown	non-measurable	
Sodium Hydroxide	pH control of spray tank Regeneration of demineralizer Waste evaporator pH control	10	0.5
Sodium Hypochlorite	Once-through condenser 3 times per week	0.5	

*Morpholine and/or cyclohexylamine will be discharged simultaneously.

**For a batch of 200,000 gallons of primary coolant which might have to be discharged at a rate of 300 gpm into the Hudson River at any one time.

Because of ongoing construction of Unit No. 3, much of the site is still under the influence of the operation of construction equipment. Consequently, the removal of construction equipment, debris, and temporary structures, and the final landscaping have not been completed. The time schedules for their completion depend upon the time schedule for the construction of Unit No. 3. During construction, prompt vegetative measures, landscaping work, and cleanup of debris will be done wherever possible to reduce erosion in the area disturbed and denuded in the construction operations.

The applicant has developed a master plan to enhance the benefits of the site through preservation of the 80-acre forested area, restoration by landscaping and planting areas of the site disturbed during construction and encouragement of the educational aspects of the site by building a new visitors' center.

The 80-acre plot will be maintained for use of the visiting public in which picnic tables and benches, nature trails, enlarged parking and recreational facilities will be available to the public. After about 14 acres of land were given by the applicant to the local community, a public marina along the Hudson River is being developed by the Village of Buchanan. Expanded and improved facilities, including a new visitors' center for public use, will not be foreclosed by operation of Unit No. 2. As of August 1970, about 400,000 visitors had visited the original visitors' center overlooking the site on top of a hill.

In short, Unit No. 2 is largely constructed, and consideration of the environmental impact of the remaining site preparation and construction is overshadowed by the ongoing construction of Unit No. 3 at the same site.

C. CONTROLS TO REDUCE OR LIMIT ENVIRONMENTAL IMPACTS

Landscaping with native species and replanting of the areas disturbed by the construction effort will enhance the appearance of the Indian Point Station. The development of the 80-acre forested plot with the lake will improve the recreational facilities for the public. Removal of construction debris, temporary facilities and other equipment after completion of construction, will add to the attractiveness of the site. The applicant's master plan to enhance the benefits of the site and the reestablishment of the natural area along the picturesque Hudson River will improve the usefulness and appearance of the site.

Modification of the intake-discharge structure and improvements of operating techniques to minimize ecological damage of aquatic biota of the Hudson River are essential to assure that the natural ecosystem will be preserved in the long-term during operation of the Unit No. 2 in conjunction with Unit No. 1 during the 40-year Plant lifetime.

REFERENCES FOR CHAPTER IV

1. Consolidated Edison of New York, Inc., "The Applicant's Environmental Report - Operating License Stage," August 6, 1970.

2. Consolidated Edison of New York, Inc., Supplement No. 1 to the Environmental Report for Indian Point Unit No. 2, September 9, 1971.

3. Letter dated February 16, 1972 from H. Woodbury, Consolidated Edison Company of New York, Inc., to L. R. Rogers, U. S. Atomic Energy Commission, including Information on the Status Report on the Installation of Gates on the Outfall Structure.

4. Letter dated October 28, 1971 from W. J. Cahill, Jr., Consolidated Edison Company of New York, Inc., to P. A. Morris, U. S. Atomic Energy Commission, on Responses to Questions on Environmental Aspects of Indian Point Units Nos. 1 and 2.

5. Letter dated November 10, 1971, from L. Trosten, LeBoeuf, Lamb, Leiby, and MacRae, to A. MacBeth, Natural Resources Defense Council, Inc., on Answers to Set I Questions.

V. ENVIRONMENTAL IMPACTS OF INDIAN POINT UNIT NO. 2 OPERATION WITH UNIT NO. 1 OPERATION

In this chapter, the effects on the environment of Indian Point Unit No. 2 operation in combination with Unit No. 1 operation are described and assessed. A wide range of factors was considered in the environmental review. Indian Point Unit No. 2 is essentially completed and has been operating under Facility Operating License No. DPR-26, authorizing loading of fuel and conducting subcritical testing, as granted on October 19, 1971. The impacts of major concern on the environment are those due to the operation of the once-through condenser cooling system. The impacts of mechanical shock, entrainment and impingement effects, and the thermal, chemical, and radioactive discharges on man and his environment are the major points of this consideration for operation at 100% of rated power. The summary of the impacts of Plant operation in conjunction with Unit No. 1 is presented in Chapter VII. Basic information for assessing the biological impact and supporting the conclusion reached in Section V.D is presented in Appendix V-1. The topic on entrainment and particularly in relation to striped bass is further described in Appendices V-2 and V-3 besides in Section V.D.

A. LAND USE

The use of 239 acres of land zoned for industrial use on the Hudson River for operation of Indian Point Unit No. 2 should not produce appreciable alterations in the public use of the general environment surrounding the site beyond those caused by operation of Unit No. 1.

1. Aesthetics

The major impact on land use in regard to operation of the Indian Point Unit No. 2 occurred during Plant construction and construction of the transmission lines for Unit No. 1 and construction of Unit No. 2 facilities. The major aesthetic impacts on the land resulting from operation of Unit No. 2 are the use of uncultivated, abandoned land on which construction of man-made facilities such as buildings, parking lots, transmission lines, and electrical switchyards result in breaking the river profile with the three reactor containment vessels symmetrically placed on the site along the riverbank. The vessels and buildings have been architecturally designed to present a pleasant attractive appearance, particularly when the site is viewed from the river. The applicant has developed a master plan to enhance the appearance of the site through landscaping and planting, developing an 80-acre woodland recreational facility, including a fresh water lake, and building a new visitors' center to encourage educational aspects of the facility for public information on peaceful uses of atomic energy. Page 2.3.1-2 of the applicant's Supplement No. 1 to the Environmental Report[1] shows the layout of the buildings, park, and lake area on the overall master plan. Following completion of construction of Unit No. 3 and subsequent cleaning up, restoration, and landscaping, the attractiveness of the site should improve. At that time the area for the Station facilities utilizing once-through cooling will comprise about 35 acres of the site.

Considering the fact that the original site was an abandoned amusement park, development of the site for purposes such as construction of nuclear power plants might be considered to be more beneficial than construction of some other facility which could destroy the entire site. Furthermore, since the site is zoned for industrial use, the land is well used for a beneficial purpose of providing needed power to the metropolitan New York area. Another area, the Trap site, about 1 mile south of the Station will also be beautified.

The remainder of the site will be developed for multiple public use. About 14 acres of the site adjacent to Lents Cove were transferred by the applicant to the Village of Buchanan to be developed into a marina. This will increase the beneficial impact on recreation, including boating, fishing and other water-associated recreational activities. The applicant has been in contact with the Westchester County Department of Planning to assure that any uses of the land area for the site will be consistent with the county's long-range plans for development of the area.

2. Access

The perimeter of the Indian Point site is posted and the immediate area of the Plant facilities is fenced in under restricted access control. The visitors' center and the recreational facilities including the lake and nature trails will be available to the public.

The Palisades Interstate Park located across the river from Indian Point site should not be affected by operation of Indian Point Unit No. 2 and Unit No. 1.

3. Noise Impact

Because of the size of the site, the operation of Unit No. 2 with once-through cooling should not create noise levels resulting in an annoyance to the offsite residents. The forested topography of the site acts as an acoustical shield, thereby absorbing most of the noise from the Station operation.

4. Historical Impact

As stated in Section II.D., use of the land for a power plant site will have no effect on any historical landmarks in the general vicinity of the Hudson River. The closest historic landmarks are the Stony Point Battlefield Reservation on the west side of the Hudson River about 2 miles from the Plant[1] and the Palisades Interstate Park, west of the Stony Point area. In Appendix XII-10, the New York Historic Trust "regrets the already unsatisfactory visual impact of Indian Point construction on the historic environment" of the two landmarks and further hopes there will be "no additional damaging effects on those surroundings." After construction is complete and the site extensively landscaped and developed into a park, the visual impact of the site with no additional physical facilities should be improved. The Commission's condition imposed on the applicant that a closed-cycle cooling system be designed and installed will, however, impose a further visual impact on the environs which must be considered by the applicant in the consideration of this alternative.

5. Climatic Effects

The atmosphere will ultimately absorb most of the waste heat from operation of Unit No. 2 and Unit No. 1, using water from the Hudson River as the intermediary during the dispersion of the thermal discharge in the circulating cooling water, primarily on the surface of the river. Because of the prevailing winds which blow up and down the river valley and the high probability of inversion occurring, the dispersion of the thermal discharges on the surface may cause some fogging for short periods of time, depending on the meteorological conditions. Based on many years of observation at power stations,[2] no serious atmospheric effects are expected from heat dissipation by the once-through cooling. In Appendix XII-4, the Department of Commerce concurs with the Commission in expecting no substantive weather modification with the once-through cooling system during heat dissipation into the atmosphere by the heated river water. Wispy steam fog over the thermal plume may occur, depending on the plume size. Church[3] has indicated that steam fog water is 5 millibars or more and the air temperature is at or below freezing. The air layer next to water surface will be heated and the moisture added; mixing of the air with the unmodified air just above the plume can lead to vapor saturation and condensation. Further vertical mixing tends to evaporate the steam fog. However, any observed steam fog is not expected to be thick nor to rise but a short distance off the river surface. Observation of steam fog over thermal discharges indicate that the visible plume will be thin and wispy and that the fog will rarely penetrate more than 10 to 50 feet inland before disappearing. It is not expected that the density of the fog will be sufficient to interfere with shipping or other modes of transportation on the river. Some of the water droplets will be removed by vegetation and other surfaces as they move across the shoreline, causing a local increase in humidity and dew.

6. Transmission Facilities

A single 345-kV transmission line will deliver the output of the Indian Point Unit No. 2 to the Buchanan Substation located within 200 feet of the Indian Point site. No added right-of-way was required, and the line is parallel to an existing 138-kV transmission line used to deliver light and power to Unit No. 2. Another 138 kV-line delivers the output from Unit No. 1 to the substation. The 345-kV circuit for Unit No. 2 will be supported by three tapered steel poles. Line design and construction are reported to conform to the guidelines for protection of aesthetic and other environmental values set forth in the report of the Working Committee on Utilities of the President's Council on Recreation and Natural Beauty dated December 27, 1968, and the Federal Power Commission's Order No. 414 dated November 27, 1970.[4]

B. WATER USE

Evaluation of the environmental impact of the operation of Indian Point Unit No. 2 must include the simultaneous operation of Units Nos. 1 and 2 and their additive effects. This is especially important in reference to the effects of all the liquid wastes released into the Hudson River. The following discussion only includes the impact of Plant operation on man's use of water and does not include biological considerations, which are discussed in Section V.D.

The thermal discharges to the Hudson River will be large. About 1,200,000 gpm of river water, representing a large fraction of freshwater flow of the Hudson in summer and a low fraction during the late winter runoffs, as described in Section II.E, will be withdrawn and used to carry away waste heat from both Units Nos. 1 and 2. The discharge of this water must be in compliance with the New York State thermal criteria. The staff feels that these regulations are adequately conservative to protect the nonbiological aspects of the Hudson River at Indian Point. Thus, the applicant's use of the Hudson River should not interfere with other industrial or community utilization of this resource, except as related to the thermal load of the river. In Appendix XII-4, the Department of Commerce has stated that "the facility is also not expected to have any significant hydrological interactions" because of the water use by the Plant. As discussed below in regard to the thermal load, the operation of this Plant using once-through cooling may preclude the construction of similar units nearby in the future. It is therefore important to quantify, if possible, the extent of the thermal effects of the operation of Units Nos. 1 and 2 in detail so that plans for future thermal discharges into the river can be properly evaluated.

The planned discharges of chemical and radioactive wastes as planned and discussed in Sections III.E.2 and III.E.3 are sufficiently diluted that they should not affect other present industrial or community uses of the Hudson. Table III-14 outlines the concentrations and amounts of chemicals that will be discharged during normal operating conditions. It is conceivable that during the life span of this facility, increased industrial usage of the Hudson in the Peekskill area could increase the load of polluting chemicals to significant levels, especially during periods of low freshwater flow. If such a situation develops, the discharge of all waste chemicals should be coordinated in which environmental factors will be considered to minimize any temporarily excessive pollution loads. The applicant's use of the Hudson for convenient disposal of waste materials should reflect consideration of the environmental consequences of these discharges and should not be continued if found to be detrimental to the quality of the Hudson River water. The applicant shall be required to monitor all chemical, thermal, and radioactive discharges in order to demonstrate that the discharges are in compliance with State and Federal regulations throughout the year. The ecological monitoring requirements and limitations on chemical and other discharges will be included in the Technical Specifications for the Plant.

Operation of Units Nos. 1 and 2 should not cause contamination of groundwater by either industrial or sanitary wastes. If such contamination did occur, the contaminated groundwater would end up in the Hudson, where it would be further diluted. Because of the location of the Plant, the use of groundwater by other business concerns in the area would be unaffected.

Appendix V-1 and Section V.D.1.c. outline the effects of Plant operations on water quality, including dissolved oxygen and the chemicals added during Plant operation and discharged either continously or intermittently into the Hudson River. The use of sodium hypochlorite to clean the once-through condensers results in the most important impact on water quality criterion of toxicity to biota. Residual chlorine will be limited to the New York State regulations of 0.5 ppm in the Station's effluent and is not expected to affect any present or future use of the river water directly by man. Details of chlorine toxicity to aquatic biota are discussed below in Appendix V-1.

The other chemicals such as boric acid, phosphates, chromates, sodium hydroxide, and sulfuric acid, which are listed in Table III-14, will be discharged in most cases in a batch process and will be low enough in concentrations such as to result in no important increases in concentration of those chemicals already present in the Hudson River during operation of Units Nos. 2 and 1. Table III-15 shows the natural concentrations of salts, and with Table III-14, one can determine the incremental amount of chemicals added to the system for operation purposes. These discharges will be monitored by the applicant to verify that they meet the Federal and New York State water quality regulations. The toxic effects of these chemicals on aquatic life are described below.

Furthermore, discharges of chemical and radioactive effluents into the Hudson River as planned and described in Chapter III should not affect other present commercial or industrial uses of the Hudson River by industry or communities during the period of operation of Indian Point Unit No. 2 at 100% power.

C. AIR USE

The operation of Indian Point Unit No. 2 would not greatly increase the level of nonradioactive air pollutants in the area. It would, however, allow the applicant to reduce the number of old fossil-fueled plants in operation and thereby decrease the pollution load of the air in the areas where plants are shut down. The major contributions to air pollution are the combustion products listed in Table III-16 discharged from Unit No. 1 through its oil-fired superheaters. In Appendix XII-2, the Department of Agriculture has expressed concern of the effect of sulfur dioxide from fossil-fuels on the vegetation in the area. The incremental addition of sulfur dioxide from Unit No. 2 has been estimated to be about 8 x 10^{-4} ppm or 2.7% of the Federal Quality Air Standards from burning oil (0.3% S) in the package biolers used intermittently. The major source of sulfur dioxide is from the superheater of Unit No. 1 which will produce 25% of the Federal Air Quality Standard. Since Unit No. 1 has been in operation for 10 years it appears that no significant effect on the vegetation has occurred. Furthermore, no chlorine gas will be used to cause any effects on nearby vegetation. Sodium hypochloride solution which produces residual chlorine in solution will be used to clean the condensers.

D. BIOLOGICAL IMPACT OF STATION OPERATION OF UNITS NOS. 1 AND 2

A large quantity of ecological information has been gathered concerning the Hudson River. Much of this information is applicable to the Indian Point site and is briefly summarized in Section II.F and Appendices II-1 and II-2 of this Statement. A significant proportion of this information has been obtained through research sponsored by the applicant through contracts with Raytheon Company, New York University, Ichthyological Associates, Northeastern Biologists, Bechtel Corporation, Alden Research Laboratories, and Quirk, Lawler, and Matusky Engineers. At present, investigators from the NYU Institute of Environmental Medicine and from Texas Instruments, Inc. are conducting biological sampling programs related to the operation of the Indian Point Units.

Information to answer most of the principal ecological questions associated with the operation of Indian Point Units Nos. 1 and 2 is not yet available. The proposed studies as outlined in the applicant's Environmental Report will answer some of these questions. However, other studies should be included, and these are discussed along with their purposes in Section V.D.3 on Non-Radiological Biological Monitoring Program.

The major adverse impact of the Plant including both Units will be on the aquatic environment. Large numbers of fish will likely be killed through impingement on the screens that protect the condensers. A large quantity of plankton will be entrained in the condenser cooling water where they will be exposed to potential physical, chemical, and thermal damage. The release of heated effluent water including chemical and liquid radioactive water will cause a change in the physical environment that may affect the biota. Detrimental effects of Plant operations may be manifested directly by killing organisms or making them less capable of reproduction or indirectly by affecting interactions between species.

Staff evaluation of the probable biological effects of the operation of the Indian Point Units Nos. 1 and 2 is based on an analysis of information from three sources: (1) field studies conducted at other steam generating power plants, (2) laboratory and field investigations of the probable biological effects of Plant effluents, and (3) information that has been gathered in conjunction with the operation of Indian Point Unit No. 1.

The analysis is divided into two sections:

Section V.D.1 identifies and evaluates the factors that may cause biological damage from the combined operation of Indian Point Units Nos. 1 and 2.

Section V.D.2 applies the important factors identified in Section V.D.1 to the biological community at Indian Point.

1. Sources of Potential Biological Damage

a. Radiation Effects

Although there is a voluminous amount of literature relating to the effects of radiation on organisms, very few studies have been conducted on the effects of chronic low-level radiation on natural aquatic populations. The more recent and pertinent studies have been reviewed by Auerbach et al.[5] and Templeton, Nakatani, and Held.[6] In general, the results of the studies summarized in these two reviews support the prediction that radiation effects would be difficult to detect at the dose levels normally encountered around power reactors:

> "In assessing the effect of low doses of ionizing radiation, sophisticated means of detection must be used and sensitive biological endpoints are

> necessary as criteria for ascertaining radiation damage. In experimental practice when dose rates are lowered to 1 rad per day or less, the number of factors affecting the organism are sufficient to mask any effects that might be present. Such commonly used endpoints as survivorship, fecundity, growth, development, and susceptibility to infection have not as yet been shown to be unequivocally affected by such low dose rates. Evaluating the impact of doses of less than 1 rad per day on organisms and populations under field conditions is a challenge of considerable magnitude."[5]

Aquatic organisms are exposed to both internal and external radiation.[7,8] The dose from external radiation, termed submersion dose, is due to the radiation from radionuclides in the organisms' surroundings. For planktonic or pelagic organisms, this part of the total dose results from radionuclides dissolved in the water. For benthic and epibenthic organisms, part of the external dose comes from the radionuclides dissolved in the water, and another part comes from radionuclides adsorbed onto or concentrated in their substrate. The radiation dose resulting from dissolved radionuclides can be calculated if the concentrations of the various radionuclides in the water are known.

However, the external dose resulting from radionuclides that are in the substrate of the organism is much more difficult to determine. This difficulty arises from the various behavioral characteristics of the organisms involved which modify the magnitude of the dose from radiation originating in the substrate. In addition, the level of contamination of the substrate by a radionuclide may vary with physical parameters within the environment. For example, manganese-54 adsorbs onto the substrate during periods when fresh water is predominant at Indian Point but is released during periods when salt water moves into the area.[9] As a result of these complications, the external dose from radionuclides concentrated in the substrate is difficult to estimate from the projected releases.

In addition to radiation from external sources, aquatic organisms are exposed to radiation from radionuclides within their tissues. Doses resulting from this source of exposure are potentially much greater (an estimated factor of 100 or more in this case) than doses from external sources, except perhaps for benthic or epibenthic organisms living in association with substrates in which radionuclides have been concentrated. Organisms accumulate radionuclides either directly from the water through epithelial tissue or by assimilation of their food. Transient releases of radionuclides into the environment are followed by transient peaks of radioactivity along the food-chain pathways.[5] Knowledge of these pathways and of the rates of assimilation and turnover of radionuclides is essential for prediction of time-dependent concentrations in the biota. However, chronic releases will result in steady-state concentrations in the biota, and, in these instances, factors can be used to approximate the eventual equilibrium levels of radioactivity.[5]

Radiation doses to aquatic organisms living in the Hudson River at Indian Point and at the discharge have been estimated by the staff. These estimates shown in Table V-1 are based on the assumption of no recycling of released radionuclides through the cooling water intake.

Internal doses in millirads per year for each radionuclide were calculated from Equation (1). The sum of the separate radiation doses for the various radionuclides was used to provide the total internal dose.

$$D = E \cdot k \cdot X \cdot C, \qquad (1)$$

where:

D = dose, millirads per year
E = effective absorbed energy[10] for man, Mev
k = constant = 1.87×10^7
X = bioaccumulation factor
C = concentration of radionuclide in the effluent canal, μCi/ml

The bioaccumulation factors listed in Table V-2 were obtained from the literature and are derived by dividing the radionuclide concentration in the organism per unit wet weight by the radionuclide concentration in the water to which the organism is exposed. Values more suitable to the Hudson River estuary may be obtained by careful analysis of the data gathered in conjunction with the operation of Unit No. 1.[9,11-15] Bioaccumulation factors vary greatly in different environments as a result of changing physical, chemical, and biological conditions. However, in most cases the maximum values obtained from the literature for freshwater ecosystems were used in the dose calculations. These factors often represent extreme cases and very

Table V-1. Internal radiation doses (millirad/year) to aquatic organisms living in the Indian Point effluent canal

(The nuclide concentrations are based on estimated annual releases from Unit No. 2
and continued operation of Unit No. 1 at past levels.)

Radionuclides	Initial Unit No. 2 radwaste treatment				Modified Unit No. 2 radwaste treatment			
	Concentration (μCi/ml)	Aquatic plants	Invertebrates	Fish	Concentration (μCi/ml)	Aquatic plants	Invertebrates	Fish
H-3	1.2E–06	2.3E–01	2.3E–01	2.3E–01	1.2E–06	2.3E–01	2.3E–01	2.3E–01
Na-24					2.5E–09	2.0E+01	3.4E+00	4.1E+00
Cr-51	9.0E–12	4.2E–04	2.1E–04	8.4E–04	6.0E–13	2.8E–05	1.4E–05	5.6E–05
Mn-54	8.2E–10	2.7E+02	1.1E+03	2.0E–01	8.1E–10	2.7E+02	1.1E+03	1.9E–01
Fe-55	2.4E–11	1.5E–02	9.3E–03	8.8E–04	6.5E–12	4.0E–03	2.5E–03	2.4E–04
Fe-59	9.5E–12	7.2E–01	4.6E–01	4.3E–02	2.1E–13	1.6E–02	9.9E–03	9.3E–04
Co-58	8.2E–10	2.4E+01	1.4E+01	4.7E+00	6.0E–10	1.7E+01	1.0E+01	3.4E+00
Co-60	2.6E–10	1.8E+01	1.1E+01	3.6E+00	2.5E–10	1.7E+01	1.0E+01	3.4E+00
Rb-86	9.0E–12	1.2E–01	2.4E–01	2.4E–01	1.7E–12	2.2E–02	4.3E–02	4.3E–02
Sr-89	3.2E–11	1.0E+00	1.3E+00	5.0E–02	2.5E–11	7.8E–01	1.0E+00	3.9E–02
Sr-90	5.2E–12	3.2E–01	4.3E–01	1.6E–02	5.0E–12	3.1E–01	4.1E–01	1.5E–02
Sr-91					7.0E–14	8.2E–03	1.1E–02	4.1E–04
Y-90					5.5E–14	9.2E–03	9.2E–04	9.2E–05
Y-91	9.5E–12	1.0E+00	1.0E–01	1.0E–02	1.7E–11	1.8E+00	1.8E–01	1.8E–02
Zr-95	1.0E–12	3.1E–02	3.1E–03	2.1E–04	3.4E–14	1.0E–03	1.0E–04	7.0E–06
Zr-97					6.5E–15	3.8E–04	3.8E–05	2.6E–06
Nb-95	1.0E–12	9.5E–03	9.5E–04	9.5E–05	3.3E–14	3.1E–04	3.1E–05	3.1E–06
Mo-99	2.8E–09	2.8E+00	2.8E+00	2.8E+00	2.0E–10	2.0E–01	2.0E–01	2.0E–01
Ru-103	1.0E–12	1.6E–02	1.6E–02	8.4E–04	2.5E–14	4.1E–04	4.1E–04	2.1E–05
Ru-106					7.5E–15	3.9E–04	3.9E–04	2.0E–05
Rh-105					7.5E–15	5.0E–05	5.0E–05	2.5E–06
Te-125m					2.1E–14	5.8E–05	3.5E–04	2.3E–05
Te-127m	6.0E–12	4.4E–01	2.7E–01	1.8E–02	1.6E–13	9.6E–04	5.8E–03	3.8E–04
Te-127					2.2E–13	9.9E–04	6.0E–03	3.9E–04
Te-129m	5.5E–11	1.1E+00	6.9E+00	4.5E–01	1.6E–12	3.3E–02	2.0E–01	1.3E–02
Te-131m					6.0E–13	1.8E–02	1.1E–01	7.2E–03
Te-132	3.1E–10	1.0E+01	6.5E+01	4.2E+00	1.1E–11	3.7E–01	2.3E+00	1.5E–01
I-130	8.5E–12	4.1E–02	2.0E–01	1.0E–02	7.5E–13	3.6E–03	1.8E–02	9.1E–04
I-131	1.3E–08	2.2E+01	1.1E+02	5.4E+00	8.2E–09	1.3E+01	6.7E+01	3.4E+00
I-133	6.3E–09	2.0E+01	9.8E+01	4.9E+00	3.5E–09	1.1E+01	5.5E+01	2.8E+00
I-135	2.4E–09	1.2E+01	5.9E+01	2.9E+00	1.8E–09	8.8E+00	4.4E+01	2.2E+00
Cs-134	3.6E–09	1.8E+03	8.0E+02	7.3E+01	5.6E–10	2.9E+02	1.3E+02	1.1E+01
Cs-136	1.0E–09	3.1E+02	1.4E+02	1.3E+01	2.4E–10	7.3E+01	3.2E+01	2.9E+00
Cs-137	3.2E–09	8.9E+02	3.9E+02	3.6E+01	6.5E–10	1.8E+02	7.9E+01	7.2E+00
Ba-140	8.0E–12	1.7E–01	6.9E–02	3.4E–03	2.3E–13	4.9E–03	2.0E–03	9.9E–05
La-140					1.6E–13	5.5E–02	5.5E–03	5.5E–04
Ce-144	1.0E–12	2.4E–01	2.4E–02	2.4E–03	2.2E–14	5.2E–03	5.2E–04	5.2E–05
Pr-143					3.0E–14	1.8E–03	1.8E–04	1.8E–05
Nd-147					1.2E–14	9.0E–04	9.0E–05	9.0E–06
Np-239					2.0E–13	1.1E–03	3.0E–04	1.1E–02
Total dose		3.4E+03	2.8E+03	1.6E+02		9.0E+02	1.5E+03	4.2E+01

Table V-2. Bioaccumulation factors for elements in aquatic plants, invertebrates, and fishes

Nuclide	Concentration factor					
	Plants	Reference	Invertebrates	Reference	Fish	Reference
Sr	3,000	7	4,000	7	150	7
Y	10,000	8	1,000	8	100	8
Mo	100	8	100	8	100	8
Tc	100	8	25	8	1	8
Te	1,000	*a*	6,100	*a*	400	*a*
I	200	7	1,000	7	50	7
Cs	25,000	7	11,000	7	1,000	7
Ba	500	8	200	8	10	8
Cr	100	16	50	16	200	16
Mn	35,000	7	140,000	7	25	8
Co	2,500	7	1,500	8	500	8
Zn	4,000	8	40,000	8	1,000	8
H	1	8	1	8	1	8
Ce	10,000	8	1,000	8	100	8
Fe	5,000	8	3,200	8	300	8
Rb	1,000	8	2,000	8	2,000	8
Zr	1,500	16	150	16	10	16
Nb	1,000	8	100	8	10	*b*
Na	160	8	27	8	32	8
Ru	2,000	8	2,000	8	100	8
Rh	2,000	8	2,000	8	100	8
La	10,000	8	1,000	8	100	8
Pr	10,000	8	1,000	8	100	8
Nd	10,000	8	1,000	8	100	8
Np	1,000	8	290	8	10,000	8

[a] Calculated by the staff from stable element analysis listed in the *Farley Nuclear Power Station Environmental Report,* Georgia Power and Light Co., 1972.

[b] Bioaccumulation factor for this radionuclide considered by staff to equal bioaccumulation factor for Zr-95 in fish.

likely overestimate the bioaccumulation of radionuclides and therefore the internal dose that will result from the releases at Indian Point. The use of the effective absorbed energy for man also tends to overestimate the dose.

The bioaccumulation factor multiplied by the radionuclide concentration in the water (in μCi/ml) provides an estimate of the body burden of the radionuclide (in μCi/gm in the organism). The concentration in the organism's body multiplied by the effective absorbed energy and the constant κ gives the internal radiation dose to the organism in mrad/yr for that particular radionuclide. The discharge concentrations and internal radiation doses of Table V-1 were estimated by assuming that the radionuclides released from Indian Point Units Nos. 1 and 2 are diluted by about 2.0×10^{15} cc/yr (2,230 cfs of water) in the discharge canal.

The estimated total doses (see Table V-1) to the aquatic organisms living in the undiluted effluent are higher than those that the organisms would receive from background radiation but considerably less than the levels which would produce observable effects. As a result of these considerations, no discernible radiation effect is expected in the aquatic community of the Hudson River as a result of Indian Point activities.

b. Dissolved Oxygen

In the Hudson River estuary near Indian Point, there is a relatively low load of decomposing organic matter.[17] Raytheon Company[18] found that dissolved oxygen in the Hudson River water in the Indian Point area ranged from low summer values of 3 ppm to high winter values of 11 ppm. The dissolved oxygen concentration in the coolant water discharged from Indian Point Unit No. 1 was found to be slightly less than that in the intake water. Although recent information presented by the applicant during testimony indicates a sampling error in calibration of instrumentation used for dissolved oxygen analysis, Raytheon Company[18] noted a distinct drop in dissolved oxygen across Unit No. 1 and intermittent low levels of dissolved oxygen in the river near the site. As an example, Raytheon cited that in early November 1969, the dissolved oxygen in the effluent (3.7 ppm) was 34% less than that in the intake water. Since the dissolved oxygen intake concentration of 5.3 ppm and the effluent concentration of 3.7 ppm observed in both instances were less than 50% of the theoretical saturation value, the rise in water temperature does not seem to entirely account for the decrease, thus lending credence to the applicant's opinion that the Raytheon data were in error. In either event, it cannot necessarily be assumed that the change in dissolved oxygen which might occur across the condensers of Unit No. 1 would be the same for Unit No. 2.

Any reduction in dissolved oxygen caused by condenser passage would not seem likely to affect the Hudson River as a whole, since the water which has been through the condensers will be spread at the surface, where it will be exposed to maximum exchange with the atmosphere. However, because the increased temperature of the discharged water will increase the metabolic oxygen demand of aquatic organisms, oxygen concentrations may occasionally be lower in the discharge plume than in the ambient water. At certain times of the year when dissolved oxygen levels are low as a result of natural occurrences, such further reductions resulting from Plant operations could be harmful to the aquatic community. Since low ambient concentrations of dissolved oxygen at Unit No. 1 were reported by Raytheon Company[18] during September of 1969 (as low as 2.7 ppm), the staff believes that the operation of Units Nos. 1 and 2 will at times cause reductions of dissolved oxygen levels below tolerable limits. The much greater condenser flow and higher temperature rise for Unit No. 2 make the dissolved oxygen problem potentially more severe. The applicant shall be required to monitor for changes in the dissolved oxygen concentration and provide for corrective actions to minimize any reduction because of Plant operation.

c. Chemical Discharges

Many of the chemicals that will be released during Plant operations are toxic to aquatic organisms. The toxicity of these chemicals is discussed in Appendix V-1. The magnitude of the response of the biota to toxic chemicals depends on the concentration of the chemical, the duration of exposure, and variations in species sensitivity. Table V-3 compares the equilibrium concentrations of chemical releases with minimum concentrations found in the literature which produce toxic effects. As indicated in the table, potential problems could exist only with releases of boron, chromate, and sodium hypochlorite.

(1) Boron

The 50-ppm concentration of boric acid (9.45 ppm of boron) in Table III-14 represents a maximum release rate which might occur

TABLE V-3. COMPARISON OF MINIMUM TOXIC LEVELS OF CHEMICALS WITH THE MAXIMUM DISCHARGE CONCENTRATIONS IN PARTS PER MILLION

Chemical	Effluent Concentration (ppm)	Minimum Toxic Level (ppm)
Phosphate	1.54	50
Hydrazine	0.1	0.7
Boron	9.45	0.1
Chromate	0.05	0.01
Residual chlorine	0.5	0.0034
Soda ash	5.0	68

following evaporator breakdown and would not be sustained for an indefinite period of time. The maximum sustained releases of this compound will be 1,200 lb of boron per day, which could result in a concentration of up to 0.055 ppm in the river. This level would probably never be reached in the Hudson and is well below toxic levels. Consequently, releases of boron should not cause detrimental effects on the biota.

(2) Chromates

The releases of chromates to the Hudson are also expected to be intermittent rather than continuous. Such intermittent releases are expected to be infrequent and, as a consequence, should not raise the concentration of chromates in the Hudson to a point where toxic effects would occur.

(3) Residual Chlorine

Figure V-1 and Table V-4 summarize chlorine toxicity data on aquatic life, mostly freshwater fish. The staff presumes that toxicity would be similar for estuarine forms, although there has been no adequate summary of estuarine organism responses. These data do not include any additive or synergistic affects which may occur as a result of thermal and mechanical shock. The applicant claims[1] that the condenser systems of Unit No. 2 will be chlorinated three times a week for 1 hour at each exposure, and that of Unit No. 1 will be similarly treated on alternate days resulting in a combined output of 6 hours/week. Implementation of this proposed schedule will require manual override of the installed automatic chlorination system, which is capable of a maximum interval of 24 hours between chlorination injections.[1] During chlorination, high mortalities of organisms that pass through the Plant are expected and may approach 100% for many species. The concentrations in the thermal plume will also exceed levels known to affect sensitive organisms.

The length of time that organisms will be exposed to toxic levels of residual chlorine is presently unknown. During past operations of Unit No. 1, the applicant has determined that the 1 ppm chlorine demand in the Hudson River water causes the free chlorine concentration to be reduced to less than 0.1 ppm before discharge. Unfortunately, the magnitude of chloramine production and subsequent rate of decay are unknown. However, data from Unit No. 1 should not be extrapolated to Unit No. 2 because chlorinated water was retained

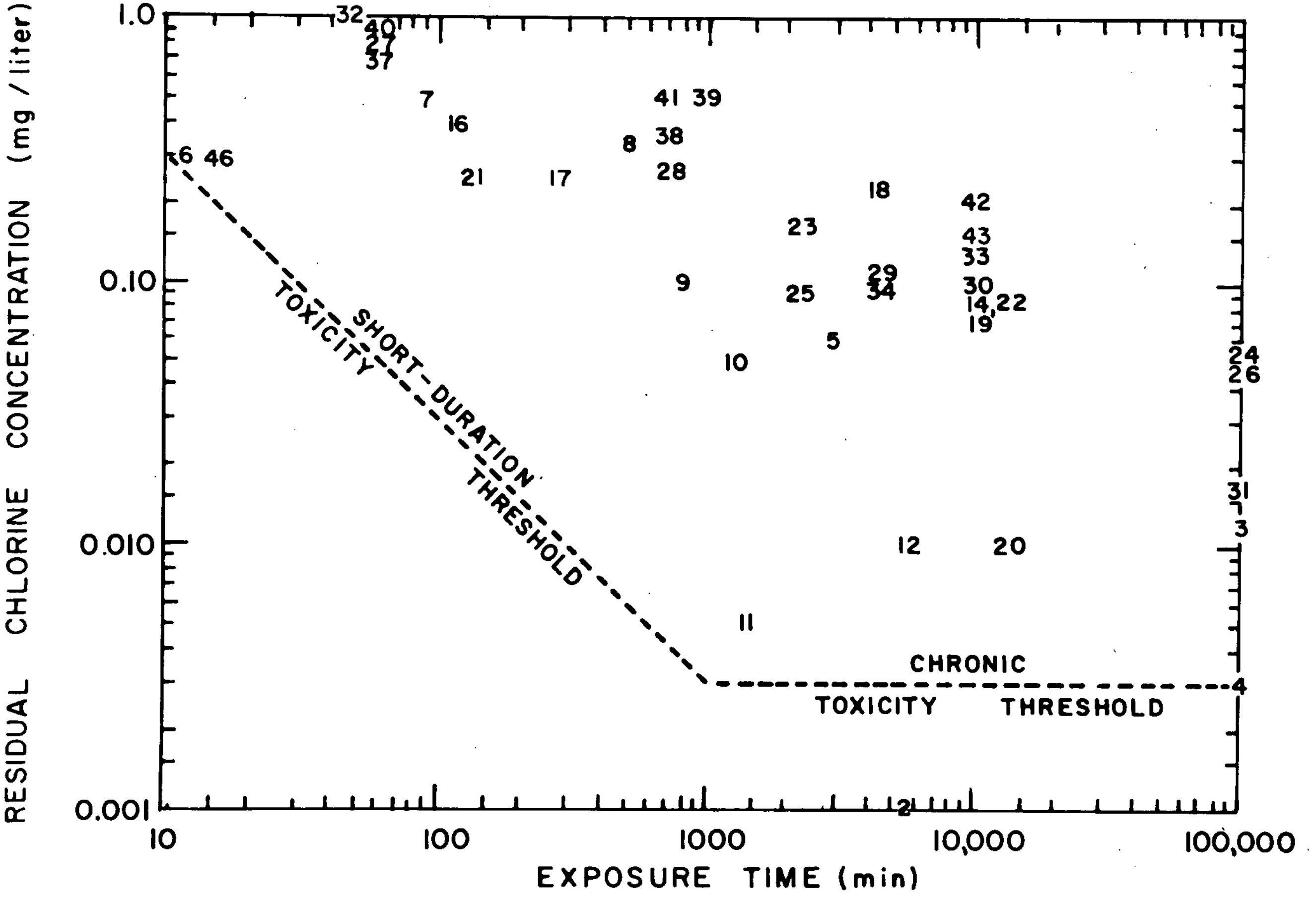

Fig. V-1 Summary of Residual Chlorine Toxicity Data

Table V-4. Key to Fig. V-1. Exposures of aquatic organisms to total residual chlorine. All concentrations were measured.

Species	No.	Effect endpoint[a]	Reference
Protozoa	1	Lethal	19
Cladoceran	2	Lethal (4 days)	20
Scud	3	Safe concentration	21
	4	Safe concentration	22
Trout fry	5	Lethal (2 days)	23
	6	Lethal (instantly)	23
Brook trout	7	Median mortality (90 min)	24
	8	Mean survival time (8.7 hr)	25
	9	Mean survival time (14.1 hr)	25
	10	Mean survival time (20.9 hr)	25
	11	Mean survival time (24 hr)	25
	12	67% lethability (4 days)	25
	13	Depressed activity	25
	14	7-day TL50[a]	21
	44	Not found in streams	26
Brown trout	45	Not found in streams	26
Fingerling rainbow trout	17	Lethal (4 to 5 hr)	27
Rainbow trout	15	Slight avoidance (10 min)	28
	16	Lethal (2 hr)	27
	18	96-hr TL50	29
	19	7-day TL50	30
	20	Lethal (12 days)	28
Chinook salmon	21	First death (2.2 hr)	31
Coho salmon	22	7-day TL50	21
	23	100% kill (1-2 days)	31
	24	Maximum non-lethal	31
Pink salmon	25	100% kill (1-2 days)	31
	26	Maximum non-lethal	31
Fathead minnow	27	TL50 (1 hr)	32
	28	TL50 (12 hr)	32
	29	96-hr TL50	33–35
	30	7-day TL50	21
	31	Safe concentration	22
White sucker	32	Lethal (30-60 min)	36
	33	7-day TL50	21
Black bullhead	34	96-hr TL50	21
Largemouth bass	35	7-day TL50	21
	37	TL50 (1 hr)	32
	38	TL50 (12 hr)	32
Smallmouth bass	36	Not found in streams	26
	39	Median mortality (15 hr)	24
Yellow perch	40	TL50 (1 hr)	32
	41	TL50 (12 hr)	32
	42	7-day TL50	21
Walleye	43	7-day TL50	21
Miscellaneous	46	Initial kill (15 min)	37
	47	Erratic swimming (6 min)	37

[a] TL50 = median tolerance limit.

during Unit No. 1 operation for approximately 40 minutes as compared to 10 minutes with Unit No. 2 in operation. The discharge concentrations of residual chlorine will be correspondingly higher from Unit No. 2. Thus, concentrations above the short-duration toxicity threshold (Fig. V-1) appear probable, particularly for larval organisms which are generally too fragile to test.

The probability of causing serious impacts to the aquatic community would be lessened by chlorination schedules that coincide with peak tidal flows during daylight hours. This procedure would reduce the exposure of the many species of planktonic crustaceans and larval fish which tend to concentrate near the bottom during daylight hours because most of the toxic chlorine compounds will be in the thermal plume, which will be spread out on the surface. Even with these precautions, a large portion of the biota will still be exposed to deleterious levels of residual chlorine. Because neither the concentration nor the duration of exposure can be established with certainty, the staff cannot estimate the level of impact which may be caused by releases of discharged chlorine. Thus, the applicant shall be required to determine the effects of the residual chlorine, including chloramines, on biota, taking into account the above-mentioned points on chlorination and chlorine toxicity.

d. Thermal Discharges

As described in Section III.E.1, large amounts of heat will be discharged to the Hudson River during Plant operation. Some published upper critical temperatures[38-41] for species found at Indian Point are given in Table V-5. During periods when ambient water temperatures are about 80°F, (26.7°C) many of these organisms will be living near their upper limits and probably above their thermal range of metabolic insensitivity (see Appendix V-1). Additions of large quantities of heat to the Hudson at these times could conceivably result in changes in the biotic community as described in Appendix V-1, Section A changes such as in the distribution of a single species or the species composition might not be readily apparent, especially if they involve planktonic microcrustaceans or algae. Secondary effects from such changes could also occur.

The most probable location for organisms to be affected by thermal discharges is in the plume. If the intake water temperature is 81°F and the discharge water is 96°F (temperature rise of 15F° in the condensers), with a flow rate of 2,650 cfs, the organisms in

TABLE V-5. UPPER TEMPERATURE LIMITS OF AQUATIC SPECIES FOUND IN THE HUDSON AT INDIAN POINT BASED ON LABORATORY STUDIES AND FIELD OBSERVATIONS[38-41]

Species	Acclimation Temperature		Upper Critical Temperature*		Criterion
	(°C)	(°F)	(°C)	(°F)	
Alosa pseudoharengus	15	59	23	73.4	T[a]
Alosa pseudoharengus			31.4	88	T
Alosa pseudoharengus			26.7-32.2	80-90	T
Osmerus mordax			21.5-28.5	71-83	T
Pseudopleuronectes americanus	7-28	45-82	22-29	72-84	48 hr TL_m
Pseudopleuronectes americanus			27.9-30.6	82-87	T
Pseudopleuronectes americanus (adult)			27	81	T
Pseudopleuronectes americanus (juvenile)			22-29	72-84	T
Microgadus tomcod			29	84	T
Microgadus tomcod (2 cm)			19-20.9	66-70	T
Microgadus tomcod (14-15 cm)			23.5-26.1	74-79	T
Microgadus tomcod (22-29 cm)			25.8-26.1	78.5-79	T
Menidia menidia	7-28	45-82	22.5-32.5	72-90	48 hr TL_m
Morone saxatilis (adult)			32	90	T
Morone saxatilis			25-27	77-81	Field observation
Morone saxatilis	4.4	40	23.9	75	8 hr LD_{50}
Morone saxatilis (juveniles)			35	95	T
Morone americanus	4.4	40	27.8	82	8 hr LD_{50}
Fundulus heteroclitus	7.2	45	37	99	8 hr LD_{50}
Fundulus heteroclitus			40	104	T
Fundulus heteroclitus	28	82	37	99	T

[a] T = maximum tolerated temperature.

TABLE V-5 (Cont'd)

Species	Acclimation Temperature (°C)	Acclimation Temperature (°F)	Upper Critical Temperature* (°C)	Upper Critical Temperature* (°F)	Criterion
Neomysis mercedes	15	59	25	77	24 hr LD_{50}
Neomysis mercedes	6-20	43-68	22-23.6	72-74	48 hr LD_{50}
Neomysis mercedes	15	59	27	81	5 hr LD_{50}
Neomysis americana	1-25	34077	15-28	59-82	24 hr LD_{50}
Crangon septemspinosa	15	59	27.5	59-82	24 hr LD_{50}
Monoculoides sp.	15	59	29	84	24 hr LD_{50}
Gammarus fasciatus	15	59	31.5	89	24 hr LD_{50}
Acartia tonsa			33	91	Lethal in 4 days
Acartia tonsa	5-25	41-77	31	88	100% lethal in 2 hr

about 10,000 cfs of water will be exposed to temperatures in excess of 85°F, about 5.6% of the water on each pass or about 20% per day (see Appendix V-2). By the time the temperature is reduced to 83°F, organisms in more than 10% of the bypass water have been exposed to temperatures of 83°F or more, or about 40% per day. Since planktonic organisms may pass the area many times, their chance of exposure to temperatures in excess of 83 to 85°F is very high but will vary with the dilution flow as indicated in Table V-6 (see Appendix V-2 for method of computation).

The duration of such exposure is very important in determining possible effects on the organisms so affected. Once the thermal plume reaches the surface, the rate of mixing will rapidly decrease. The duration of exposure to the increased temperature can be roughly estimated from the configuration of the thermal plume and the flow rates of the Hudson. Preliminary calculations indicate that elevated temperatures could last several hours. In view of the low tolerance of many of the species to increases in temperature and the high probability of exposure to elevated temperatures, thermal effects on different aquatic biota as described in Appendix V-1, Section A are anticipated.

e. Entrainment

One of the most important biological consequences of power plant operation with once-through cooling is associated with mortality of organisms entrained with the cooling water. In this way a power plant is similar to a large predator. The importance of such predation is related to the rate at which the organisms are "consumed," and for passive and nearly passive organisms, consumption rates are similar in magnitude to the rate at which the water is used. At Indian Point, since the average cross sectional area is about 160,000 ft^2, the volume contained within a linear mile of river at Indian Point is about 8.5×10^8 ft^3. The combined flow of 2,650 cfs through the once-through condensers of both Units will equal this volume in about 3.8 days.

It is apparent that populations of organisms susceptible to entrainment and maintained by local reproduction may be reduced by Plant operation and that a considerably larger proportion of the biota will be withdrawn with the addition of Unit No. 2 (Fig. V-2). These organisms will include bacteria, planktonic algae, many invertebrate species, fish eggs, and larvae. Table V-7 lists the fish species in the area whose eggs or larvae are

Table V-6. Probability of exposure of randomly distributed passive organisms in the Hudson at Indian Point to various levels of temperature increases resulting from plant operations

Values were derived using computations based on principles outlined in Appendix V-2 assuming a condenser ΔT of 15F°, average tidal flow of 180,000 cfs, and 2,6[illegible]0 cfs discharge of heated water to the Hudson

Dilution flow (cfs)	Number of chances	Probability of exposure at least once				
		ΔT = +15°	ΔT = +9°	ΔT = +7°	ΔT = +5°	ΔT = +3°
2,000	90.00	0.740	0.895	0.945	0.983	0.995
3,000	60.00	0.592	0.777	0.856	0.935	0.974
4,000	45.00	0.490	0.676	0.766	0.871	0.936
5,000	36.00	0.416	0.594	0.688	0.806	0.889
6,000	30.00	0.361	0.528	0.621	0.745	0.840
7,000	25.71	0.319	0.475	0.564	0.690	0.793
8,000	22.50	0.286	0.431	0.517	0.641	0.748
9,000	20.00	0.258	0.394	0.476	0.598	0.706
10,000	18.00	0.236	0.363	0.441	0.559	0.668
11,000	16.36	0.217	0.336	0.411	0.525	0.633
12,000	15.00	0.201	0.313	0.384	0.495	0.601
13,000	13.84	0.187	0.293	0.361	0.468	0.571
14,000	12.85	0.175	0.275	0.340	0.443	0.545
15,000	12.00	0.164	0.259	0.321	0.421	0.520
16,000	11.25	0.155	0.245	0.305	0.401	0.498
17,000	10.58	0.146	0.233	0.290	0.383	0.477
18,000	10.00	0.139	0.221	0.276	0.366	0.458
19,000	9.47	0.132	0.211	0.264	0.350	0.440
20,000	9.00	0.126	0.202	0.252	0.336	0.423
21,000	8.57	0.120	0.193	0.242	0.323	0.408
22,000	8.18	0.115	0.185	0.232	0.311	0.394
23,000	7.82	0.110	0.178	0.223	0.300	0.380
24,000	7.50	0.106	0.171	0.215	0.289	0.368
25,000	7.20	0.102	0.165	0.207	0.279	0.356
26,000	6.92	0.098	0.159	0.200	0.270	0.345
27,000	6.66	0.094	0.153	0.194	0.262	0.335
28,000	6.42	0.091	0.148	0.187	0.254	0.325
29,000	6.20	0.088	0.144	0.181	0.246	0.316
30,000	6.00	0.085	0.139	0.176	0.239	0.307
31,000	5.80	0.083	0.135	0.171	0.232	0.299
32,000	5.62	0.080	0.131	0.166	0.226	0.291
33,000	5.45	0.078	0.127	0.161	0.220	0.284
34,000	5.29	0.076	0.124	0.157	0.214	0.277
35,000	5.14	0.074	0.121	0.153	0.209	0.270
36,000	5.00	0.072	0.117	0.149	0.203	0.263
37,000	4.86	0.070	0.114	0.145	0.198	0.257
38,000	4.73	0.068	0.112	0.142	0.194	0.251
39,000	4.61	0.066	0.109	0.138	0.189	0.246
40,000	4.50	0.065	0.106	0.135	0.185	0.241

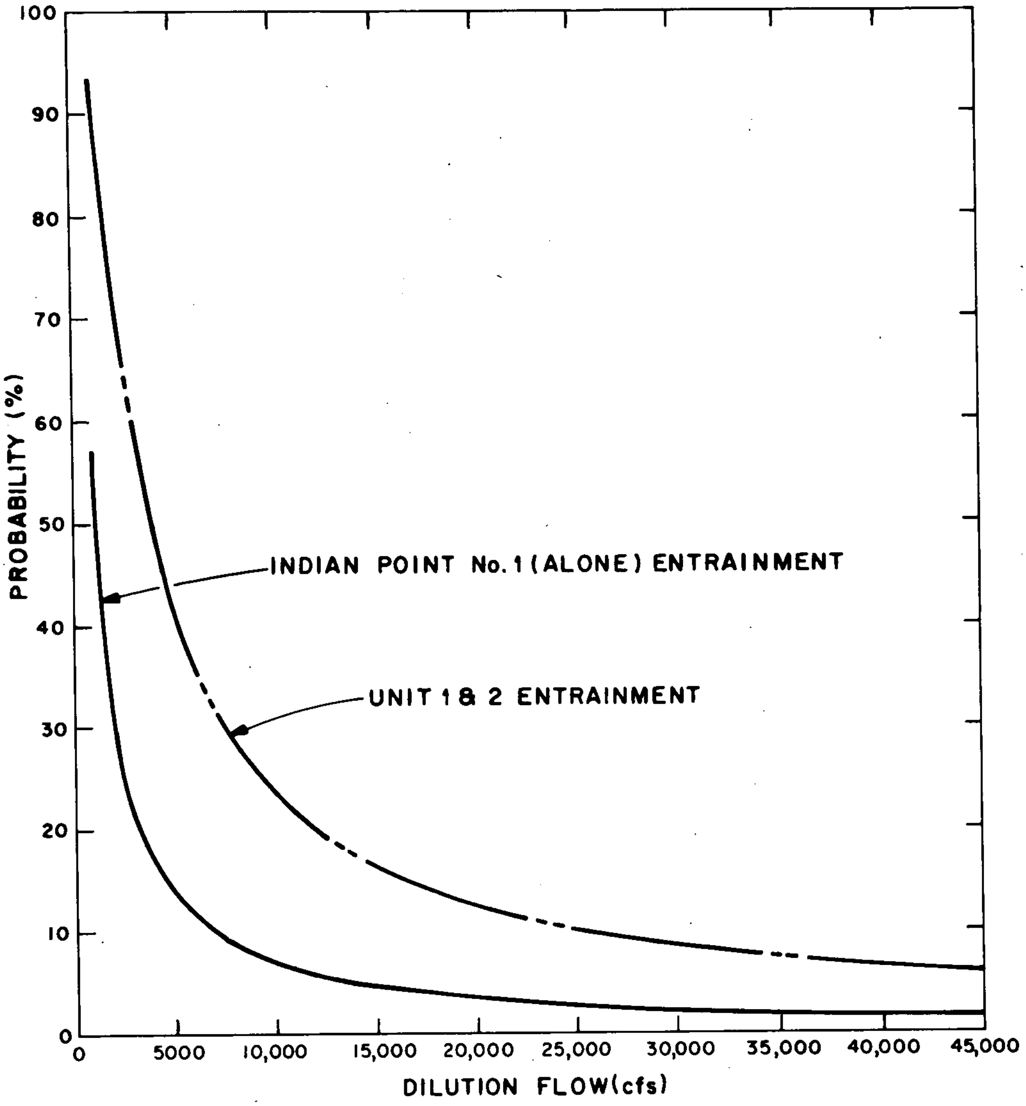

Fig. V-2
Comparison of Entrainment Probability of Indian Point Unit I and Units I and 2. Zero Recirculation is Assumed.

TABLE V-7. LIST OF ESTUARINE FISHES WITH VARIOUS LIFE STAGES WHICH ARE SUSCEPTIBLE TO ENTRAINMENT AND IMPINGEMENT AND WHICH HAVE BEEN COLLECTED DURING SAMPLING PROGRAM AT INDIAN POINT.

Species	Entrainment			Impingement
	Eggs	Larvae	Post-larval	
Striped bass	**	**	**	**
White perch		**	**	**
Tomcod	*	**	**	**
Bay anchovy	*	**	**	**
American eel			**	*
Smelt		**	**	**
Blueback herring		**	**	?
Alewife		**	**	*
Atlantic silverside		**	**	*
American shad		*	*	*

*Life stage present and susceptible to entrainment or impingement.
**Important fraction of local population may be subject to entrainment or impingement.

known to be vulnerable to entrainment. During their passage through the Plant, these organisms will be exposed to mechanical, thermal, and chemical damage. High mortality may result, especially for fragile species, during periods of chlorination. The terms "transport flow" and "dilution flow," and the methods used to determine the fraction of organisms entrained are presented in Appendix V-2. Based on the staff's calculations described in Appendix V-2, the monthly average probability of randomly distributed passive plankton moving downstream to be withdrawn varies from a low of about 6% in April to a high of 31% in August, although during drought conditions withdrawal may exceed 45%. Plankton that migrate via transport flows to maintain their position in the river will be the most susceptible to entrainment, since they may remain in the area for several weeks.

f. Impingement

A major problem encountered during the operation of Indian Point Unit No. 1 has been that of fish mortality resulting from impingement on the fine mesh screens used to filter out debris that could cause damage to the circulating water system. The available information concerning these fish kills has been compiled by the applicant,[42] and an analysis of the information has been reported and summarized by the Commission's Division of Compliance.[11] The following discussion is based on the information contained in these documents.

In March, 1963, fish were entering the open intake forebays of Unit No. 1 and subsequently killed and collected on the traveling screens. Striped bass, tomcod, and white perch comprised most of the fish that were killed. Apparently these kills included both juvenile and adult fish, including large striped bass. Efforts to reduce kills using air bubble screens, pneumatic sound sources, and smaller mesh mechanical barriers in front of the forebays were not effective in solving the problem. Subsequent efforts, including alterations of the physical structures surrounding the intakes and alterations of the intensity of the light, were not effective either.

In June, 1965, a correlation between additions of sodium hypochlorite and kills of large fish was noted. The point of addition of the sodium hypochlorite was moved behind the traveling screens. Following this change, large fish were no longer collected on the screens. Apparently, the sodium hypochlorite was either killing the larger fish directly or, more likely, was reducing the fishes' ability to avoid the intake.

The actual effectiveness of the fish protection efforts from 1963 to 1966 as described above cannot be ascertained because adequate data were not collected during this period. The only effort that produced desirable results was the change in procedure associated with adding sodium hypochlorite to the circulating water.

During the spring and summer of 1967, fine mesh (0.375 in. square wire mesh) screens were designed to eliminate the possibility of fish entering the forebays. This modification was the result of testing during January and March 1967 which showed a significant reduction in fish counted on the traveling screen of one forebay fitted with a fixed screen at its mouth. According to the applicant, this modification appeared effective until the winter of 1969, although fish count data to support this contention were not included.

Substantial fish kills at Unit No. 1 were observed during January 1970 and were thought to be the result of openings under the fixed screens. This conclusion is supported by the fact that a significant reduction of the number of fish counted on the traveling screens occurred after the openings were eliminated. This point was graphically illustrated in Fig. 6, page A-45 of Appendix S , of the applicant's Supplement No. 1 to the Environmental Report concerning the fish kills at Indian Point.[42] These data indicate that the magnitude of the fish kill was reduced from highs in excess of 16,000 to 18,000 fish per screen washing on February 1-3, to sustained counts of less than 50 fish per washing after February 6, 1970. However, collections of fish on the traveling screens when the fixed screens are in place do not adequately represent the extent of the fish kill, especially during periods when dead fish were netted from in front of the fixed screens and consequently could not have had a chance to be included in the counts of fish on the traveling screens. For instance, when the traveling screen count was reported to total 388 for March 6 and 7, 1970, there were approximately 120,000 fish netted in front of the fixed screens (Table 3, Reference 42). In essence, the impingement problem was simply shifted from the traveling screens to the fixed fine mesh screens. However, this process did reduce the average size of the fish which were captured.

These kills have included some 23 species, white perch being by far the predominant species and accounting for over 90% of winter fish kills. However, because of the large number of fish involved, substantial numbers of other species are also killed. For instance, from data obtained by the Raytheon Corporation, the total of fish killed from November 6, 1969 to January 11, 1970 at Unit No. 1 was 1,310,345 fish, 137,649 of which were striped bass.[11]

The fish that have been collected on the intake screens, identified, and measured are generally larger than 45 to 50 mm in length.[42] Since smaller fish are known to exist in the area, it is assumed that the minimum screenable size (at least for striped bass) is in the neighborhood of 40 to 45 mm. Smaller fish would be expected to go through the Plant.

The precise cause of the impingement problem is not completely understood. All the fish kills at Indian Point Unit No. 1 appear to have been associated with the Plant's condenser cooling water system. Fish appear to be caught against the screens by the force of the river water drawn into the Plant. Once caught against the screens, they are unable to escape and eventually succumb to exhaustion, although the precise cause of death is unknown. A number of possible factors contributing to the problem have been examined. The wharf and related structures located over the intakes may contribute by appearing to provide refuge for fish. Another factor may be related to the existence in wintertime of warmer river water in the vicinity of the Plant caused by discharge of heated river water from the Plant.

There is a definite seasonal variation in the magnitude of the kill, the highest mortalities occurring in the winter months and the lowest mortalities in the summer. Apparently, this is due to reduced swimming ability of many fishes at the very low (34°F) winter temperatures.

The most important contributing factor is the capturing capacity of the large volume of water withdrawn from the river.. The only action that really seems to reduce the level of mortality is a reduction in the intake velocity. Present evidence indicates that a reduction in the water velocity may greatly reduce the fish kill problem (Fig. V-3).

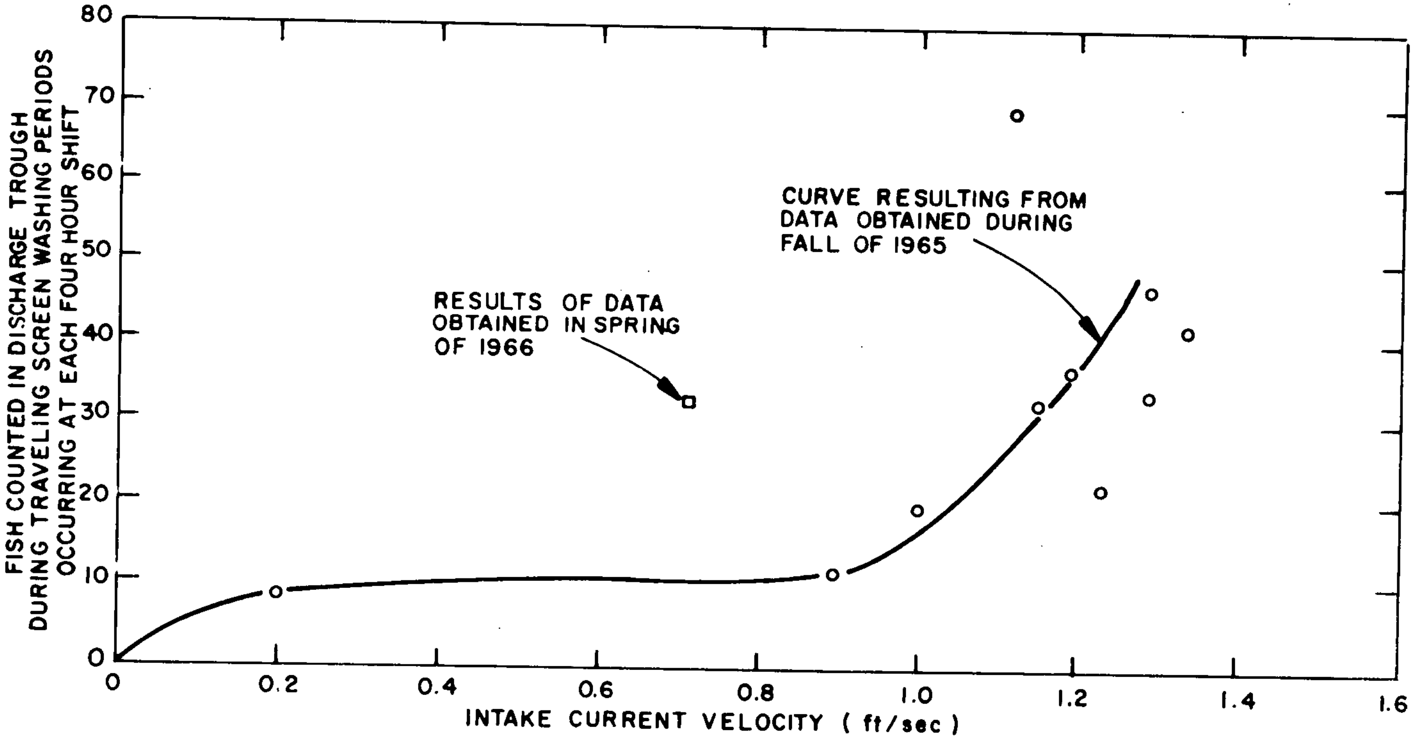

Fig. V-3
Fish Count Per Screen vs Average Current Velocity.

On October 19, 1971, the applicant presented testimony for support of its motion for testing Indian Point Unit No. 2 up to 50% of rated power and estimated the quantities of fish to be collected daily at the intake structure of Unit No. 2. These predictions depended on the abundance of fish in the area of the intake, the volume of water being withdrawn, and the intake velocities approaching the screens. The intake velocity would depend on (1) whether the de-icing loops were operating and (2) whether the recirculation loops were operating. Based on these different conditions of operation and the time of year, the applicant predicted that fish kills would be higher during the winter months. Based on these variables, during winter operation, about 593 lb/day of fish will be collected during a six-pump ull flow operation, and about 437 lb/day during six-pump reduced-flow operation at Indian Point Unit No. 2. At an average weight of 0.25 oz per fish, this value for reduced flow corresponds to about 30,000 per day or 5.5 million over a six month period. The fish kills would consist primarily of white perch (80%). During the winter, more than 90% of the catch was predicted to be white perch. Striped bass are collected throughout the whole year but amount to about 4% of the total fish collected. Many factors, including the daily movements of fish in the vicinity of the intake, influence the actual collection of fish each day.

The applicant has been continuing to conduct ecological and engineering studies on the topic of fish protection. During pump operations of Indian Point Unit No. 2, any fish impingement problem must be evaluated and designs developed to minimize it. The applicant has consulted the Indian Point Fish Advisory Board and a number of Federal, State, and local organizations on the overall program to provide for fish protection in connection with operation of the Indian Point Plants. Besides reduction of the intake velocity, other techniques that can be used include developing bypasses for fish which the applicant is in the process of building in preparation for this coming winter.

In the applicant's Environmental Report of August 6, 1970, its Supplement No. 1 to the Environmental Report letter to the Commission dated October 19, 1971, the Commission's Final Environmental Statement of November 20, 1970, and the February 1972 fish kill from testing two pumps of Unit No. 2, there is a discussion of the problem of fish kills occurring on the Hudson River from operation of Indian Point Unit No. 1 and the action being taken to reduce the fish kills prior to full power operation of Unit No. 2. At Indian Point Unit No. 2, protective screens have been installed at the outer face of the intake structure in guides already provided in the walls; however, preliminary calculations (see Appendix III-1) indicate that the water velocity through the outer fixed screens (1.32 fps) with normal pump operation will exceed that of Unit No. 1 (1.17 fps). If Unit No. 2 is placed in operation before some acceptable method of reducing the intake velocities is installed, the fish kills will probably exceed those experienced at Unit No. 1. The species and size composition of the fish will probably be about the same as for Unit No. 1, but the numbers of fish killed will be larger.

During the latter part of February 1972, the applicant tested two circulating water pumps, both at full flow (140,000 gpm) the first day and one pump at full flow for another four days. The fish kill was estimated by the New York State Department of Environmental Conservation (NYSDEC) to amount to about 175,000 white perch, striped bass, and other fish which had been impinged and killed on the Plant's water intake screens.

As a result, on February 29, 1972, the NYS Department of Environmental Conservation[65] sent an order to the applicant to halt the testing of two of the six circulating pumps. A hearing on March 10, 1972 was held before the NYS Department of Environmental Conservation to investigate the causes of the extensive fish kills. On April 28, 1972 this order was vacated by the NYS Department of Environmental Conservation to permit the testing of the circulating pumps after the applicant agreed to carry out a number of conditions outlined below:

(1) Reduction of the velocity of water intake to 60% capacity during the winter months when the temperature is less than 40°F. This can be accomplished by installation by the winter of 1972-73 of a bypass circulating cooling system to reduce flow from 140,000 gpm to 84,000 gpm for each of the six pumps.

(2) Installation of double air-bubble screens in front of all water intake at both Units before December 1, 1972.

(3) Development of plans for screened lagoons which would keep all fish away from intakes. Hydraulic model studies have to be completed by March 1, 1973.

Furthermore, if results of the air bubble screens prove to be unsatisfactory to protect fish during winter time and the lagoon studies indicate greater protection, the applicant shall build the lagoon to protect the fish.

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 No. 2, because the proportions of the various populations which will be present and susceptible to the intake are unknown.

2. Probable Biological Effects

The operation of Indian Point Unit No. 2 as presently designed should have little effect on the terrestrial biota on and off the site. On site, no serious detrimental impacts are expected, as the terrestrial biota of the area consist of forms tolerant of human intrusion. After construction is completed, the re-establishment of wildlife on the site should occur, particularly with the forested park available for a natural habitat.

The primary impact of the operation of the station will be associated with the aquatic environment. Several significant problems have been perceived, and some plausible consequences of operation are described in this section. Background material for the conclusions in this section may be found in Appendices II-2, V-1, V-2, and V-3 and Section II.F of this Statement.

a. Direct Effects of Plant and Station Operation on Biota

(1) Decomposers

The staff believes that no important changes will occur in bacterial populations as a result of Plant operations.

This conclusion is supported by the thermal tolerance studies conducted for the applicant which showed no important effects within the range of temperature which will result from Plant operation.[43]

(2) Producers

The staff's analysis indicates that significant changes in species population and composition could occur in the phytoplankton community as a result of Plant operation. However, the staff cannot at this time quantitatively assess the magnitude of the possible changes or the probability of their occurrence.

Information related to the operation of other power plants indicates that the assimilative capacity of entrained phytoplankton may be reduced or eliminated. Species so affected would be effectively removed from the reproductive population but for a time could contribute to other trophic levels. During periods of low flow, the equilibrium concentration of organisms so removed from the population can be a large proportion of the total population at Indian Point. Two possible consequences from this source of damage to the producer populations could occur: a decrease in production and a change in species composition.

Reduced production would reduce the food input to other tropic levels. Based on monthly average freshwater flows for the years 1918-1964, the staff has estimated in Appendix V-2 that the maximum possible consequence, which would result from a complete "reproductive kill" of the entrained organisms, would be a yearly reduction of about 17% of phytoplankton productivity at Indian Point, with much higher reductions during the low flow periods of the summer. The magnitude of these figures would be altered by changes in productivity in the thermal plume. When ambient river temperatures are below optimum for algal growth, productivity would be significantly increased in the plume. This effect would be amplified because the increase in temperature would be greater in the upper layer, which is the photosynthetically active zone. Thus, a much greater increase in productivity could result from thermal discharges than would occur if either photosynthesis or elevated temperatures were randomly distributed in the volume of water. When ambient temperatures are at their highest levels, considerable inhibition of production may also occur in the plume, which again would be more significant than if photosynthesis were evenly distributed in the water column. The net result could be a greater variation in algal populations than now occurs; greater production in winter and spring would be followed by a reduction in the summer and fall, which would reduce the import of food (algae) to the rest of the community during late summer as a result of both "reproductive death" and inhibition in the plume.

A different type of change in the algal populations resulting from the "reproductive death" and plume inhibition during late summer would be more likely. Strong selection would occur and would favor algae with higher thermal optima and tolerance. The net result could be significant increases in the populations of blue-green algae and concurrent reductions in diatoms; populations of green algae may also be altered.

Data from the laboratory and field studies conducted for the applicant support this position.[43] The staff's conclusion concerning changes in species composition is based on differential responses of the various species to the thermal discharges. When ambient temperatures are below optima for all species, most would respond to increased temperatures with increased production. However, when ambient temperatures are above the optima for some species and below optima for others, an increase in temperature would increase production in some species while it decreased production in others. With this situation, the resultant production of the mixture would be less responsive to temperature changes than before and could show either slight increases or decreases in productivity. The effect that this would have on populations would be to inhibit production in those near or above their thermal optima and enhance production in those below their thermal optima.

The staff believes that significant changes may occur in the algal populations during summer conditions. Present data[44] indicate that the fluctuations predicted in the preceding discussion may already be occurring as the result of natural cycles which perhaps are augmented by the operation of Indian Point Unit No. 1 and the Lovett Plant (Fig. V-4). Complete interpretation of these data is not possible because the effects of temperature and salinity cannot be separated and because some of the algae, namely, the blue-greens, may have originated elsewhere. However, if these fluctuations are temperature dependent, the additional operation of Indian Point Unit No. 2 may greatly magnify the changes. These changes could be easily detected by the proper biological sampling program.

(3) Consumers

(a) Benthic Fauna

The direct effects will be the result of the interaction of four factors: entrainment of larvae, thermal discharges, sodium hypochlorite releases, and intake scouring. The operation of the Indian Point complex will have a detrimental effect on the resident benthic organisms over a small portion of the estuary. The velocity of the intake water is expected to cause scouring over a small area of the bottom adjacent to these structures and may eliminate these areas as suitable habitats for some benthic species. Many of these organisms have planktonic larvae which would be subjected to entrainment. Although sufficient data are not available to quantify the magnitude of this aspect of the problem, some mortality of entrained larvae can be expected.

High mortality of entrained plankton could have two effects on the benthic biota. There would be an incremental reduction of larvae, which could affect recruitment rates, and, at the same time, there would be an increase in food availability as damaged or killed plankton settle to the bottom. Consequently, a high mortality rate of entrained organisms could direct more production through the benthic community and thereby slightly increase the density of benthic fauna. The combined effects of entrainment mortality of larvae and increased productivity in the benthic community, if of sufficient magnitude, would have the capability of causing changes in the species composition of the attached benthos.

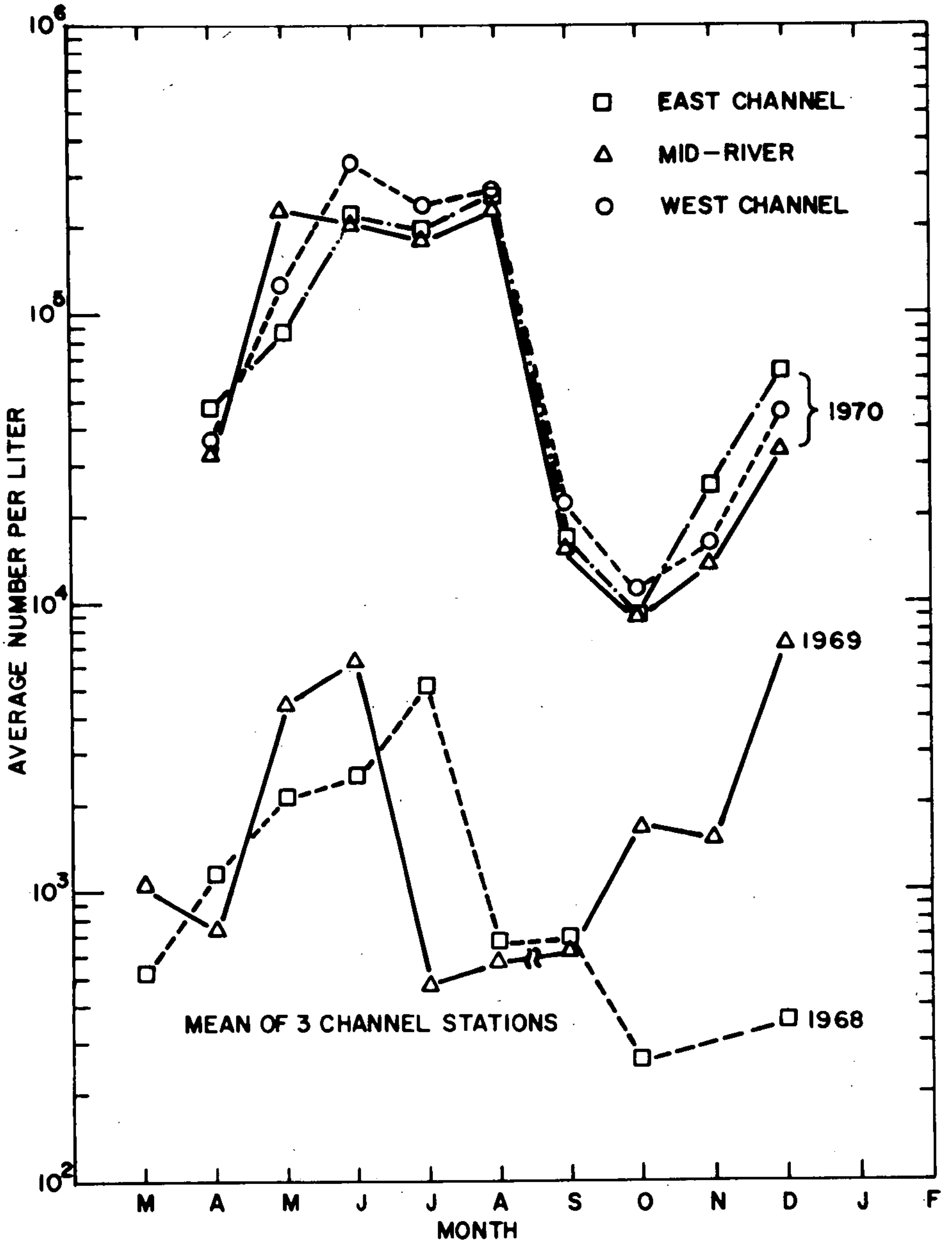

Fig. V-4
Phytoplankton Abundance at
Indian Point

From the above evidence, some changes can be expected to occur in the species composition and density of the benthic community, but these changes will probably not be important.

(b) Zooplankton

The combined influences resulting from Plant operations may affect the zooplankton community. These effects will result from additions of residual chlorine, entrainment, and exposure to the thermal plume. If high entrainment mortality is encountered, selection for heat-tolerant microcrustaceans with short population turnover rates will result. However, the situation will be complicated by the residual chlorine releases, which will be at concentrations greater than those known to reduce reproductive capability in *Daphnia*. Thus, there could be a significant reduction in the concentrations of some species of microcrustaceans during late summer as a result of Plant operation.

Larger epibenthic crustacean components (amphipods and mysids) of the zooplankton will be similarly affected. Most of these species undergo diurnal vertical migrations when they leave their substrate and move up into the water column at night and back to their substrate during the day. Thus, their susceptibility to the intake will be increased at night. The possible consequences to the populations of these species are related to the fractions of the populations being affected and the length of the generation time. Although some data are available on the spatial and temporal distribution of these species at Indian Point, they have little predictive utility as related to the populations as a whole. The reasons are that the available data include only the densities of the free-swimming organisms and do not provide adequate estimates of the total population, which is composed of both free-swimming individuals and those dwelling on the substrate. The species most likely to be adversely affected is the opossum shrimp, *Neomysis americana*, since it has a long (annual) generation time and is temperature sensitive. These organisms move in and out of the Indian Point area with the salt front. During periods of high fresh water runoff the *Neomysis* are concentrated downstream from the Indian Point site. However, as the salt front moves north of the Plant these animals move upstream into the Plant vicinity. Thus, the population which is present at Indian Point is composed of the same individuals which were previously located downstream. Data compiled by Raytheon Company demonstrate the seasonal and salinity effects which influence the distribution of *Neomysis* at Indian Point.[18]

> "Maximum concentrations occurred during June, July, and August, resulting primarily from the presence of free swimming juveniles. The seasonal and north-south distribution among transects clearly indicated a close relationship to salinity concentrations until early June. During the later part of June and early July, *Neomysis* was more concentrated upstream where salinity values are lower. Since this period coincided with the presence of maximum numbers of juveniles, these data may indicate that sensitivity to salinity is not as important a factor as it appeared to be for adults. *Neomysis* was more abundant in bottom collections." (pp. 6-7)

The concentration of *Neomysis* juveniles upstream from the Station indicates the potential for an impact on the Hudson population of these organisms. It appears from these data that the zone which will be influenced by Station operation is an important nursery area for the Hudson aquatic population. As a consequence, deleterious effects of Station operation in this locality may be felt throughout the region of the Hudson which depends on this nursery area for recruitment.

An important consideration is that the *Neomysis* migrate vertically in the water column on a diurnal cycle and are more numerous on the surface at night but at mid-depth or the bottom during the day.[18] Such migrations enable these organisms to passively migrate upstream or downstream using the density flows and thereby to remain within a zone of preferred salinity. However, this life style also causes these animals to be susceptible to being entrained with the condenser cooling water. The fraction of the population which will pass through the Plant is uncertain. However, organisms within the volume of water which passes the Plant will be exposed about four times a day. Since they remain in this zone for several weeks, they will probably be exposed a large number of times, resulting in a significant proportion of these animals passing **through the Plant (Table V-7)**.

Destruction of large numbers of *Neomysis* may occur but might not affect the yearly recruitment rate. However, large reductions in the standing crop of *Neomysis* would preclude their availability as food for other organisms at Indian Point. Again, the possibility of reproductive inhibition via residual chlorine toxicity could inhibit the development of compensatory increases in reproductive potential at the same time that the populations are decreasing from destruction by Plant operation. The net result would be that recruitment to the *Neomysis* population at Indian Point would depend on immigration from other locations.

A further complication in determining the effects of destruction of *Neomysis* by the Indian Point Station is that this region may be an important nursery area for the Hudson population, with high net annual emigration to Haverstraw Bay and the Tappan Zee, where they serve as food organisms for young fish. Obviously, if net emigration has a much greater effect than mortality in maintaining a stable population of *Neomysis* near the salt water front, additional reduction of the population at Indian Point could cause serious reductions in the populations elsewhere as well.

Operation of Unit No. 2 will decrease the reproductive potential of the Hudson for *Neomysis* to some extent. High entrainment mortality will reduce the standing crop of *Neomysis* but may be compensated for by increased immigration from other areas.

Similar arguments apply to *Gammarus fasciatus* and other species with long generation times. However, the data supplied by the applicant[43] indicate that *Gammarus* populations are less likely to be affected than are populations of *Neomysis* because of higher thermal tolerances.

(c) Fish

Because of the location of the Station in the low salinity zone of the Hudson Estuary, operation of Indian Point Units Nos. 1 and 2 with the present once-through cooling system will adversely influence the fish populations that use the area for spawning and initial periods of growth and development. Recruitment rates and standing crops of several species may be appreciably lowered in response to the increased mortality caused by entrainment of eggs and larvae and of impingement of young-of-the-year.

Those species most likely to be affected include the tomcod, bay anchovy, blueback herring, alewife, American eel, smelt, American shad, white perch, and striped bass. Direct effects on the freshwater species such as the two sturgeons that commonly occur in the vicinity of Indian Point are not expected to be severe.

Because the striped bass is economically important for both sport and commercial fisheries, the staff has analyzed in greatest detail the probable impact of Plant operations on the populations of this species that are maintained by recruitment from nursery areas in the Hudson River. The entrainment analysis (Appendix V-3) and the following summery of the staff's assessment of the probable response of Hudson-dependent populations of striped bass to the operation of Indian Point Units Nos. 1 and 2 with once-through cooling are the basis for the conclusions just given.

Each spring, adult striped bass migrate upstream and enter the freshwater portion of the river where spawning occurs as temperatures increase from about 50° to 70°F (Table V-8). However, over 90% of the annual egg production occurs during the period of time when temperature increases from about 58° to 63°F. During years of below normal temperature rises, spawning is delayed and the adults migrate further upstream. Thus, the longitudinal distribution of the egg production in the estuary is partly controlled by temperature. Because of this relationship between temperature and spawning location, the discharge of heated water by the Indian Point Units can be expected to result in a greater proportion of the annual production of fertilized eggs occurring in the vicinity of the Plant, although the extent of this effect would vary from year to year depending on the salinity of the water at Indian Point.

The eggs and larvae drift with the currents in a net downstream direction and concentrate in the region of low salinity, generally in the vicinity of the Plant (Fig. A-V-12). The juvenile bass grow slowly at first and remain planktonic for about 6 to 8 weeks (Fig. V-5). During this period, they are susceptible to entrainment by the Plant (Fig. V-6 and Table V-9). At the end of their planktonic stage, the young bass begin to move into shallow water, either along shore or on shoals. The importance of such shoals is apparent from the high concentrations of young bass in the shallow trawl stations sampled by Raytheon Company (Table V-10). These areas serve as nursery grounds where the juvenile bass grow rapidly. The major such nursery in the Hudson River occurs below Indian Point in Haverstraw Bay and the Tappan Zee (Fig. V-7). In 1968, trawl sampling of shoals for the length of the river showed that 70 to 90% of the surviving portion of the total annual production of young bass had migrated past Indian Point by late July or early August (Table V-11).

Table V-8. Effect of temperature on spawning of striped bass in the Hudson River during the Hudson River Fisheries Investigation (1966–1968)

Week	Temp (°F)	Incubation time, I (hr)	Weekly average	Total weekly egg production	Weekly % of total spawn
1966			× 10^6	× 10^6	
4/24–4/30	50.1	100	0.36	0.6	0.3
5/1–5/7	50.0	100	12.48	21.0	1.1
5/8–5/14	50.3	99	11.71	19.9	1.0
5/15–5/21	53.4	88	15.68	29.9	1.5
5/22–5/28	58.9	70	274.04	657.7	33.3
5/29–6/4	62.6	58	250.37	725.2	36.7
6/5–6/11	66.2	45	102.80	383.8	19.5
6/12–6/18	69.1	36	16.74	78.1	3.6
6/19–6/25	73.7	21	7.15	57.2	2.3
				1973.4	
1967					
5/7–5/13	50.7	98	9.00	15.43	4.3
5/14–5/20	52.5	92	4.15	7.58	2.1
5/21–5/27	55.4	82	26.46	54.21	15.0
5/28–6/3	57.6	77	66.51	145.11	40.2
6/4–6/10	64.4	52	42.03	135.8	37.7
6/11–6/17	68.5	38	0.17	0.75	0.2
6/18–6/24	69.5	35	0.29	1.39	0.4
				360.27	
1968					
4/21–4/27	53.1	90	0.29	4.0	0.2
4/28–5/4	56.0	81	10.25	96.0	4.7
5/5–5/11	58.3	73	24.18	413.0	20.4
5/12–5/18	60.4	66	42.41	796.0	39.3
5/19–5/25	61.5	63	14.87	295.0	14.6
5/26–6/1	62.7	58	11.32	243.0	12.0
6/2–6/8	65.2	50	3.07	74.0	3.7
6/9–6/15	66.6	44	3.55	96.0	4.7
6/16–6/22	68.4	39	0.096	4.0	0.2
6/23–6/29	70.7	31	0.096	4.0	0.2
6/30–7/6	73.2	23	0.096	0.6	0
				2025.6	

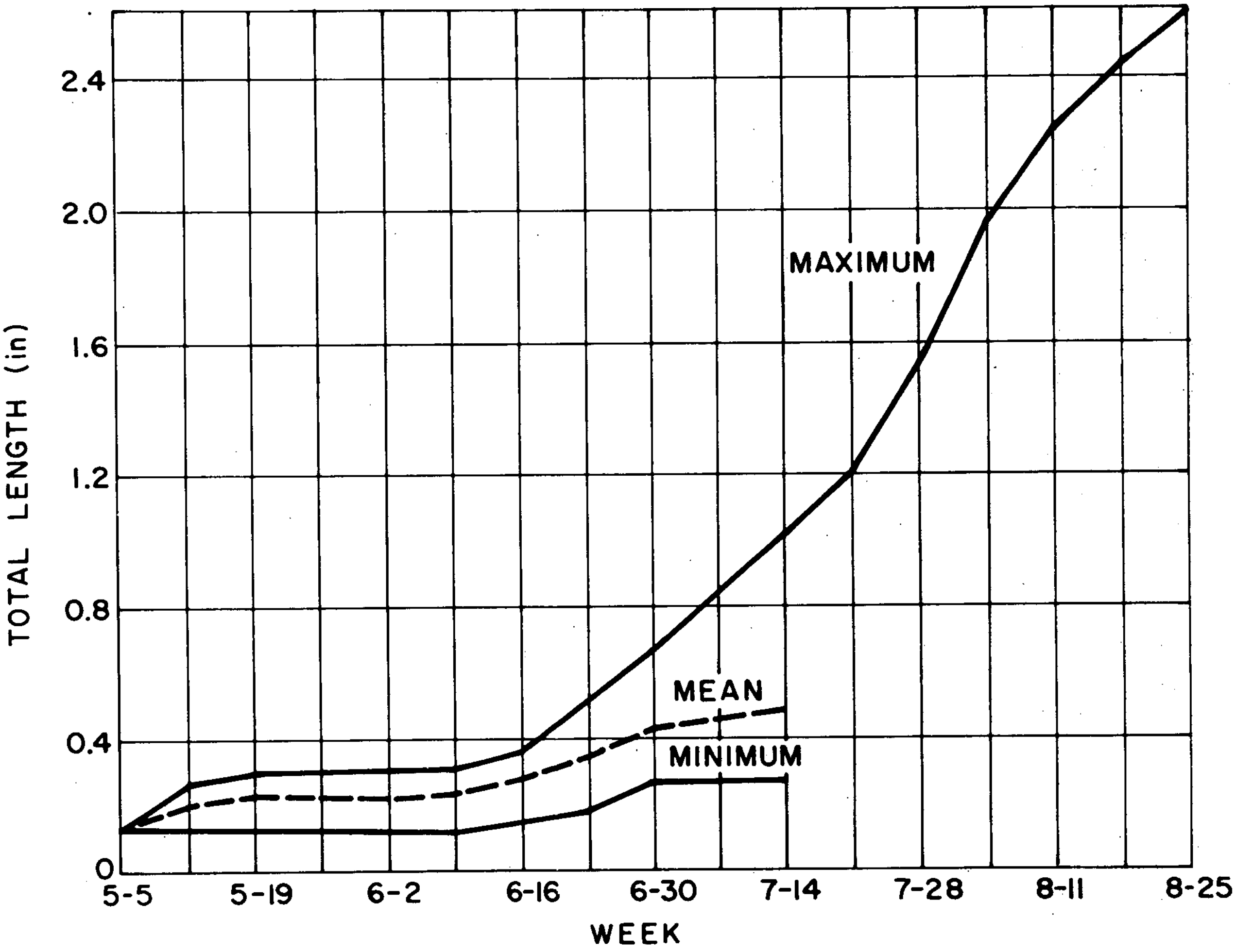

Fig. V-5. Growth of striped bass in Hudson River.

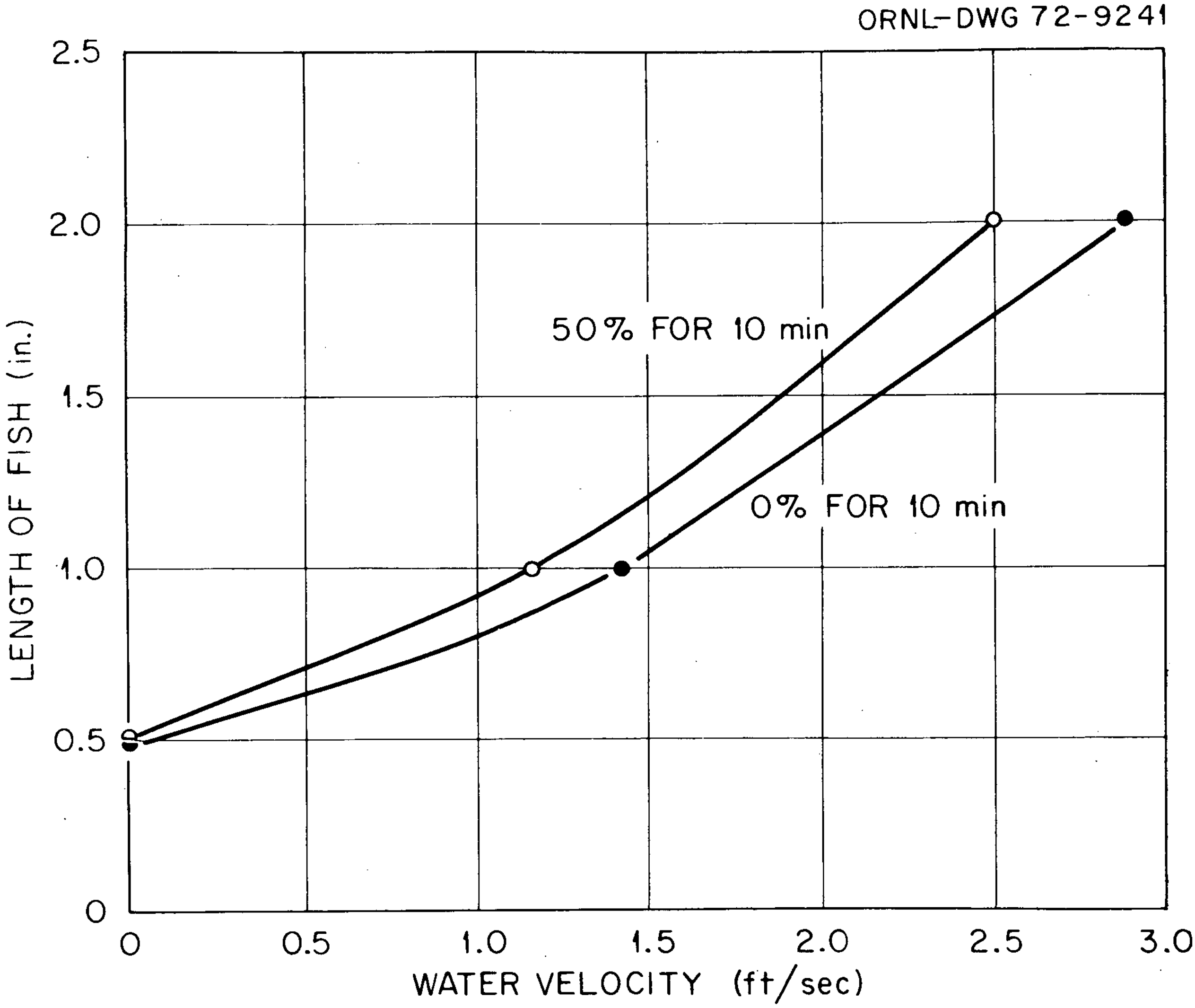

Fig. V-6. Water velocity (ft/sec).

Table V-9. Estimated velocities of water entering plankton nets during 1966 sampling period of Cornwall study that indicate susceptibility of larvae to entrainment at these velocities

Station	Total tows	Volume strained (ft^3)	Average velocity[a] (fps)
Coxsackie	85	126,000	0.93
Saugerties	86	153,000	1.11
Kingston	94	151,000	1.01
Hyde Park	76	121,000	1.00
Malboro	141	211,000	0.94
Cornwall	509	884,000	1.09
Peekskill	95	150,000	0.99
Croton	81	129,000	1.00

[a] $$\text{Velocity} = \frac{\text{Volume strained}}{\text{No. of tows} \times 900 \text{ sec/tow} \times \pi(0.75 \text{ ft})^2}$$

Table V-10. Catch of striped bass in bottom trawls in the Lower Hudson estuary in 1969 and 1970, showing importance of shallow shoals as nursery grounds (number per 7-min trawl haul)

Depth level	Station	Mile point	Depth (ft)	1969						1970									
				July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Shallow	1	29	10	77	58	98	231												
	5	36	12	291	126	108	354	88	21						12	196	555	308	0
	3	35	10	355	61	28	14	4	5						41	14	112	252	39
	7	38	11	115	217	168	168	31	1				1	18	9	84	100	56	196
	8	39	12	485	64	39	69	61	20			6			19	22	84	145	145
	9	40	12	149	119	335	146	29	3			0	1	0	2	78	112	112	140
	12	44	12	100	144	87	19	83	21	39		0	0	10	3				
Intermediate	2	29	26	4	51	0	21												
	4	35	34	10	19	1	120	3	3						0	0	0	0	0
	6	38	30	62	312	4	122	0	1				1	<1	9	0	0	0	0
Deep	15	40	45			0	7	1	3			1	0		0	0	0	0	0
	16	41	45			1		0	4			16			0	0	0	0	0
	11	42	50	1	1	1	1	<1	4	22	1	3	0	2	2	0	0	0	0
	10	42	45	0	4	8	16	1	0	61	4	2	0	<1	<1	0	0	0	0
	13	45	50	1	3	3	1		0				0	1	1	0	0	0	0
	14	47	47	0	1	3	1	2	1						0	0	0	0	0

[a] Raytheon Company stations.

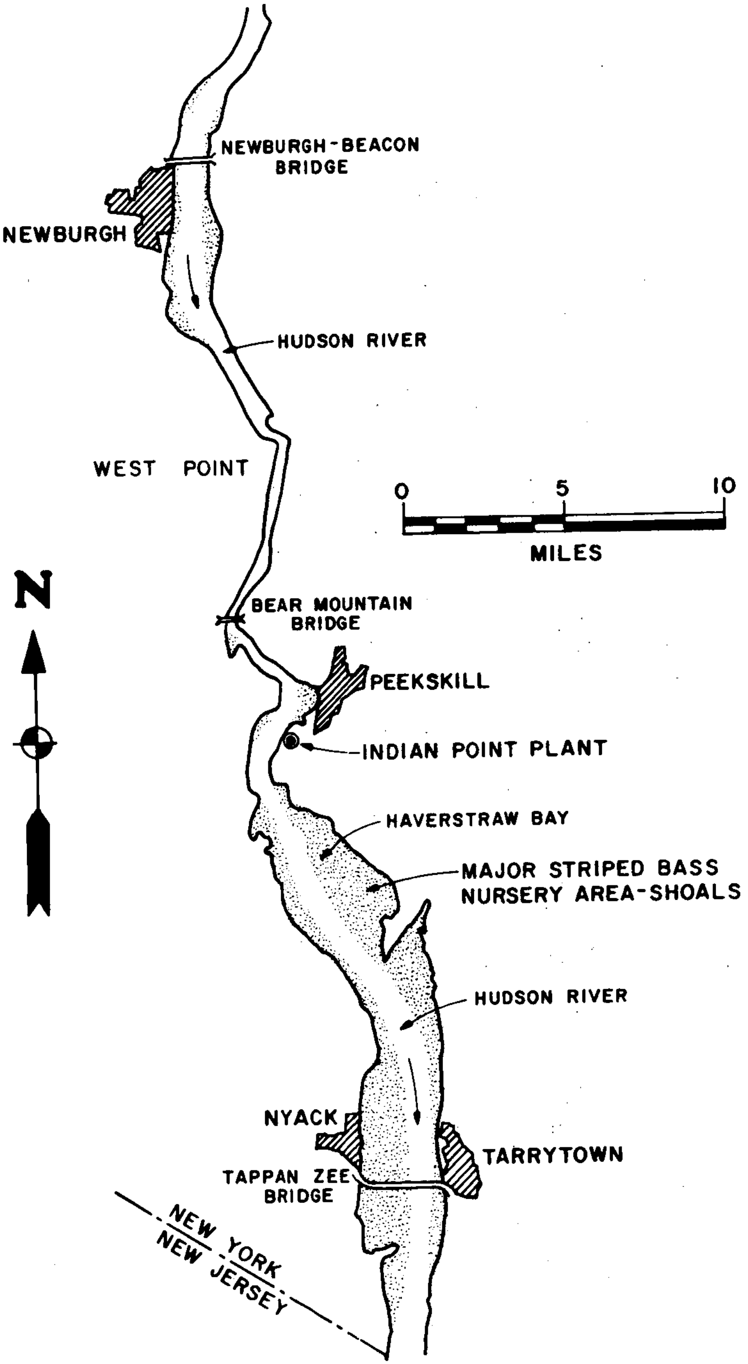

Fig. V-7. Major striped bass nursery and spawning areas in the Hudson River.

Table V-11. Data on distribution of young-of-the-year striped bass taken by shoal trawls in July – August 1968

Reach	Index of shoal area	Period						Mean of means	
		July 28–Aug. 3		Aug. 11–Aug. 17		Aug. 25–Aug. 31			
		No.	Index	No.	Index	No.	Index	No.	Index
Coxsackie	17.3	0	0	0	0	0	0	0	0
Saugerties	16.5	0.2	3.3	0	0	0	0	0.1	1.1
Kingston	10.0	1.7	16.7	0	0	0.3	3	0.7	6.6
Hyde Park	2.1								
Marlboro	4.8	0.3	1.4		2.4	1	4.8	0.60	2.9
Cornwall	7.6	22.9	173.4	0	0	104	787.3	42.3	320
			194.8		2.4		795.1		330.8
Peekskill	4.8								
Haverstraw Bay	24.1	102	2458.2	12	289	29.7	715.8	48	1156.8
Tappan Zee	38.5	9.6	369.6	36	1386	29.7	1074	25.1	962.5
			2827.8		1675.2		1789.8		2119.3
TOTAL			3022.6		1677.6		2584.9		2449.9
% above Indian Point			6.4		0.1		30.8		13.5
% below Indian Point			93.6		99.9		69.2		86.5[b]

[a] The period index is the product of the shoal area index and the number of fish caught per trawl haul.

[b] From the published mean of samples, this value is 85.4% (Ref. 1).

The applicant's suggestion that the downstream migration is composed of older fish that are not susceptible to entrainment is not supported by the available data. The peak abundance of young-of-the-year striped bass below Indian Point generally occurs in late July and early August (Figs V-8 and V-9). Furthermore, the peak abundance in the smaller upstream nursery areas does not precede the peak downstream; instead, the two coincide (Fig V-9). In addition, the disappearance of larvae from plankton nets and surface trawls coincides with their appearance in shoals and the shallow areas which can be sampled with seines (Fig. V-10).

These factors necessitate the conclusion that the greatest proportion of young-of-the-year bass which annually populate the Haverstraw nursery area move past Indian Point as larval or early post-larval fish and are susceptible to entrainment.

The staff analysis indicates that during June and July of most years from 30 to 50% of the striped bass larvae which migrate past Indian Point from upstream spawning areas are likely to be killed by entrainment (See Appendix V-2). In addition, large numbers of older striped bass will be killed by impingement. The combined effect of these two sources of mortality will decrease recruitment to the adult population of striped bass which depend upon the Hudson River for spawning. As a result, there is high probability that there will be an initial 30 to 50% reduction in the striped bass fishery which depends upon the Hudson for recruitment.

This conclusion is opposite that which has been expressed by the applicant's consultants in presenting their development of a conceptual analysis and their corresponding mathematical model which was used to predict the effects of entrainment of the eggs, larvae, and early juvenile stages on the adult striped bass population. They concluded that operation of the two Indian Point Units for 1 year would have a very minor impact on the population of striped bass and predicted that this reduction would be no greater than 2.6 to 3.7% of the adult population.[66]

Two important differences exist between the modeling techniques used to develop the entrainment predictions presented by the applicant's consultants and developed by the staff. The first of these is related to the downstream transport of larvae and their tendencey to concentrate as they drift into the saline portion of the estuary. Specifically, the applicant's model assumes uniform distribution and does not reflect the increased abundance of larvae

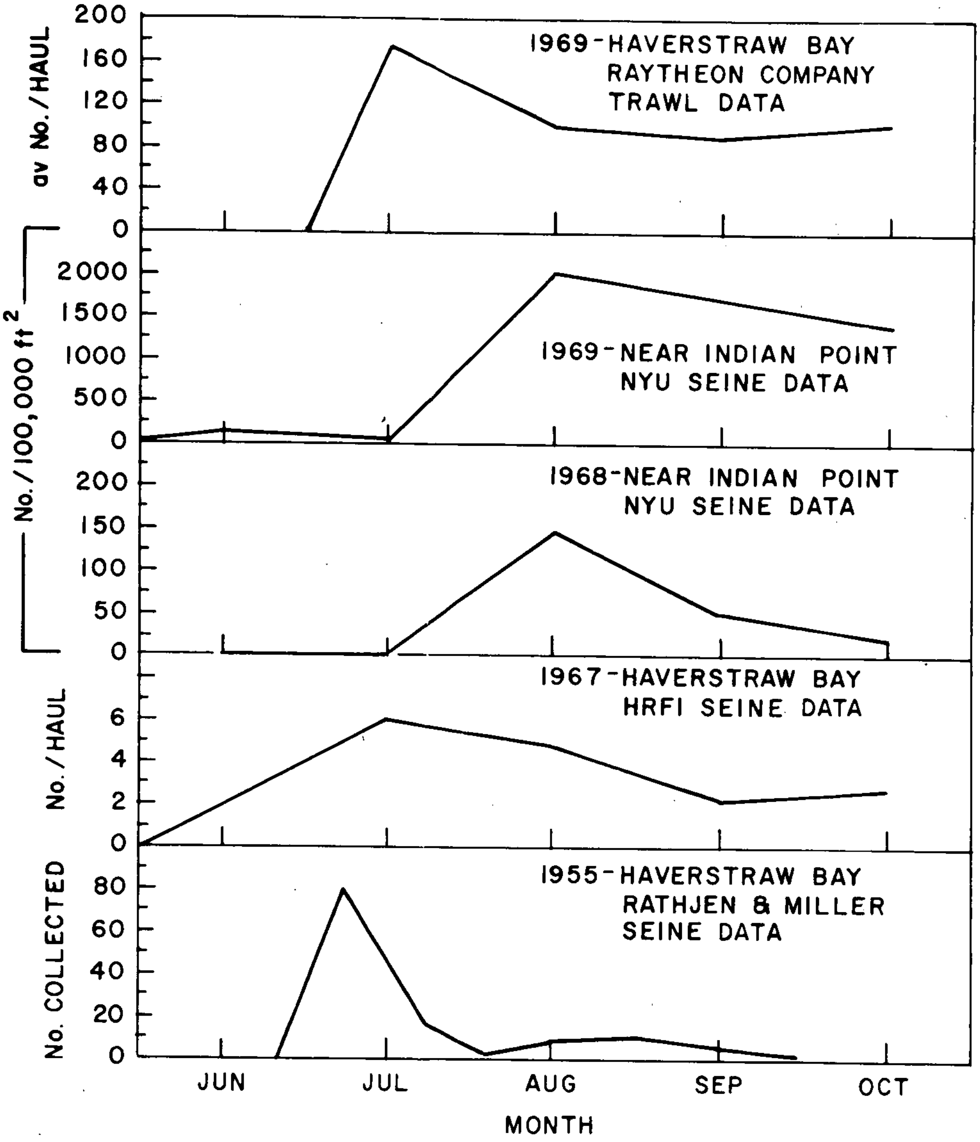

Fig. V-8. Season of peak abundance of young striped bass in the Hudson estuary below Peekskill.

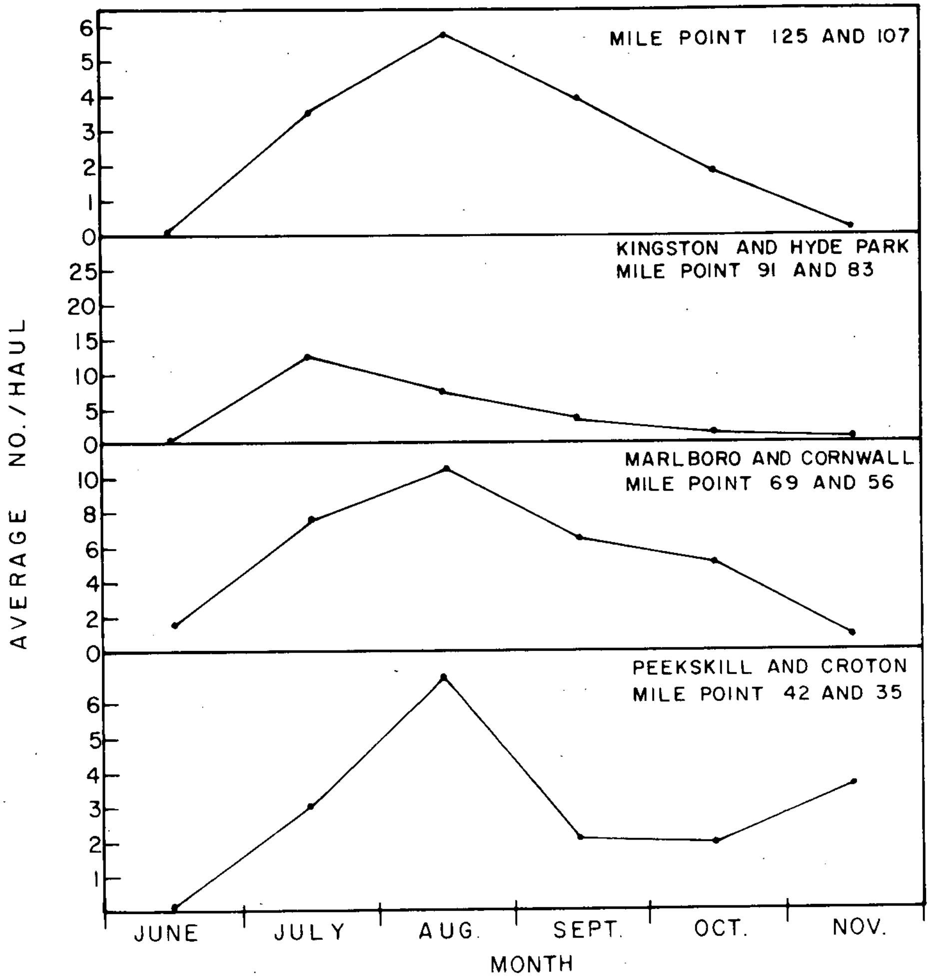

Fig. V-9. Seasonal abundance of young-of-the-year striped bass as determined from the 1967 seine haul data of the Hudson River Fisheries Investigation.

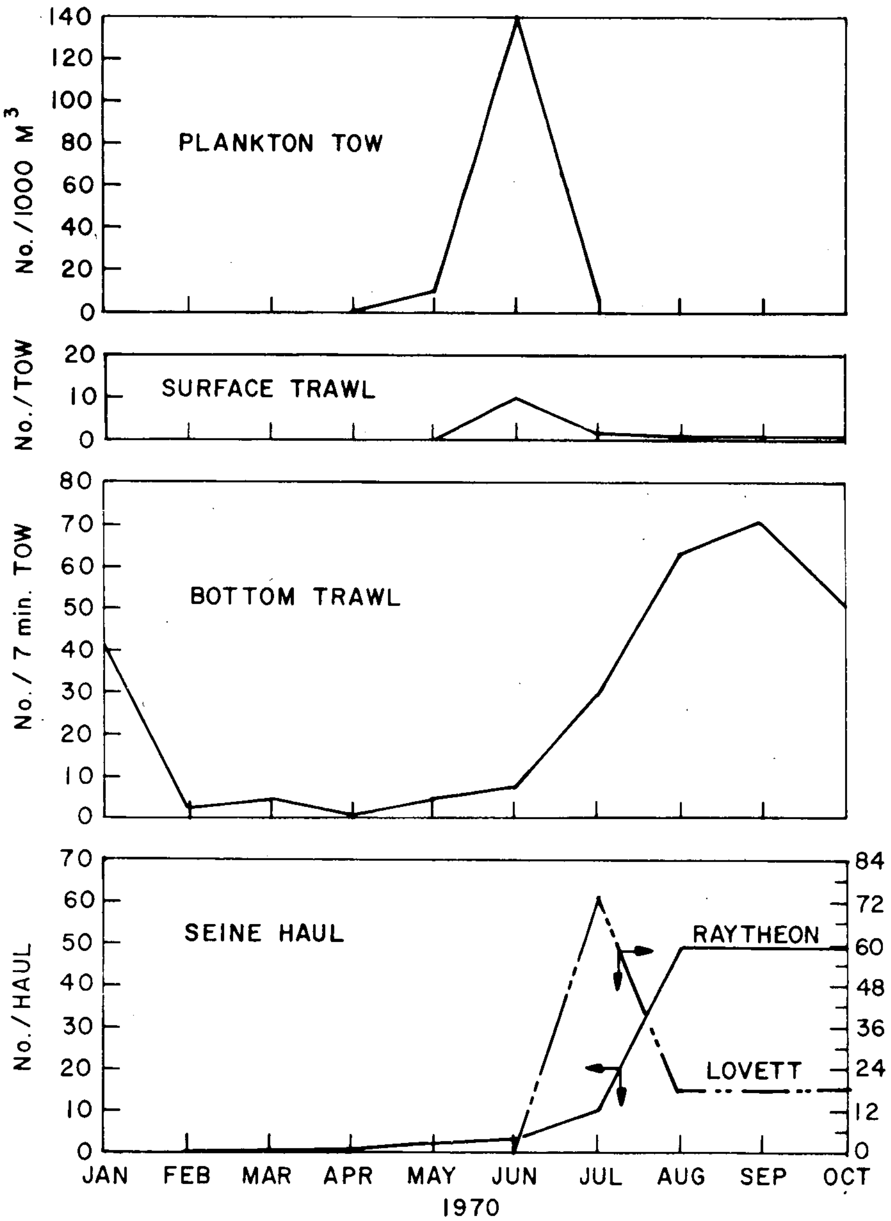

Fig. V-10. Seasonal catch of striped bass in various types of sampling gear in the Hudson near Indian Point during 1970.

near Indian Point. In contrast, the staff estimate of entrainment is based on a transport model described in Appendix V-3 that predicts both abundance and distribution of larvae within the estuary, including the concentrations that occur in the nursery areas below the Plant site. A comparison of the observed post-spawning larval distribution and that predicted by the staff's transport model is made in Fig. V-11. The transport model predicts entrainment values which are 1.2 to 2 times greater than the corresponding estimates given by the completely mixed model used by the applicant, depending upon the location of spawning and the flow condition being modeled.

The second difference, which is the most important factor that contributes to the apparently large differences between the numerical values affixed to entrainment by the applicant and by the staff, results from the method of presentation. The applicant's analysis was designed to estimate the impact which would result from a single year of operation, and the results were expressed not in terms of recruitment loss but rather in terms of the percentage reduction in the entire population. As a consequence, direct comparison between the two estimates is not possible. However, because of the way the applicant formulated mortality rates in its model [66] the mortality caused by entrainment can be separated from natural mortality. For the completely mixed system, the fractional reduction (F_e) to recruitment can be computed from the relationship between the total volume (V_T) used in the model and the volume of water used by the Plant (V_P = flow x time) during the period of vulnerability (T), i.e.,

$$F_e = \frac{V_P}{V_T + 0.5\ V_P}$$

Substitution of the applicant's value of 57.35 billion ft^3 for the total volume and 11.8 billion ft^3 for the Plant volume used during the period of vulnerability (52.5 days) yields an entrainment estimate of 18.6%.

Because of the applicant's limitation of operation to 1 year, the 18.6% value was compared with the applicant's estimate of 2.6 to 3.7% by reducing the number of 1 year old in the applicant's assumed age-frequency distribution by 18.6% (from 87,402 to 71,117). (See J. Lawler's testimony of April 5, 1972 on entrainment in Reference 66). This procedure resulted in reducing the applicant's total

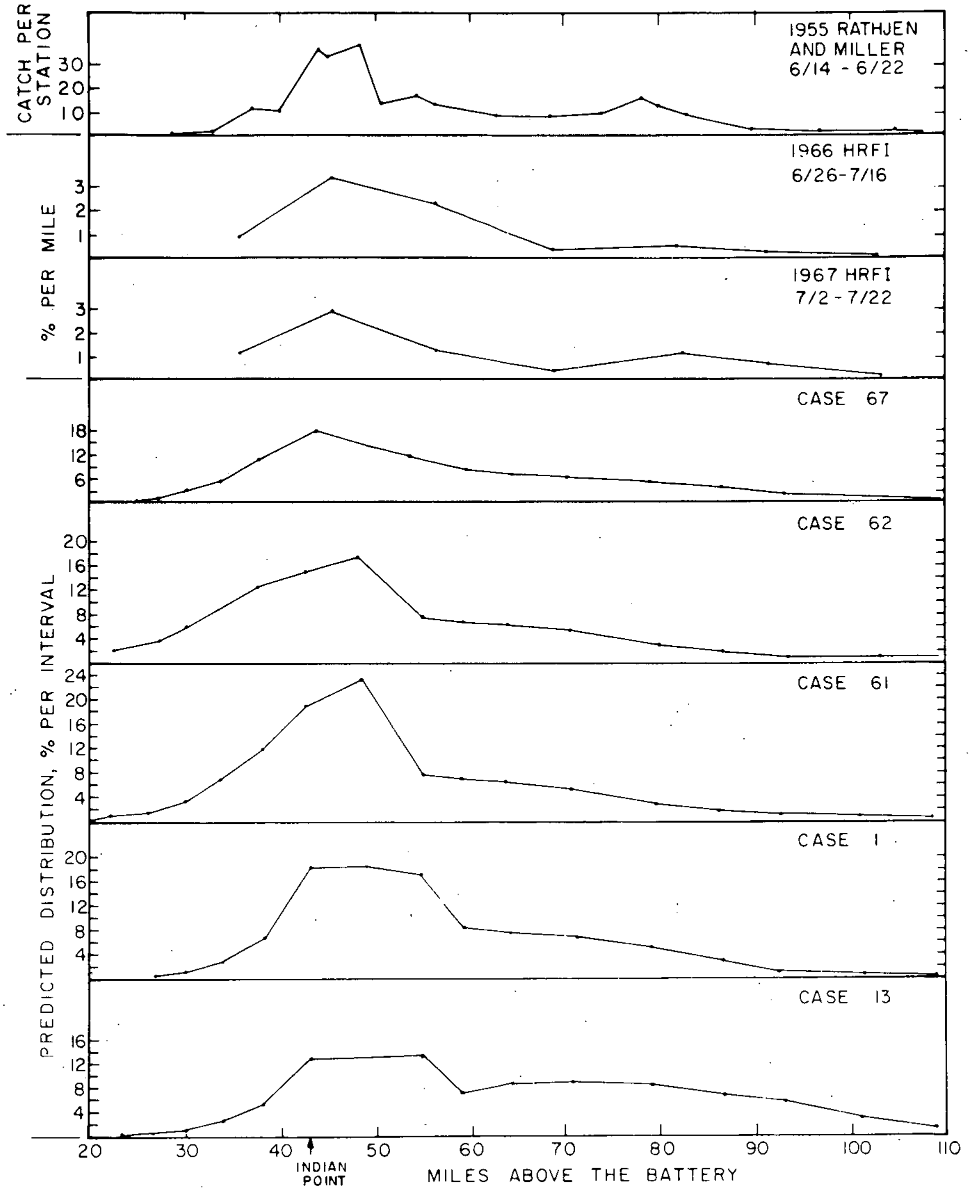

Fig. V-11. Distribution of larval striped bass in the Hudson; field observations and computer model estimates.

population level from 201,550 to 185,265 which is the value that was presented in Fig. 7.[66] Thus, the model used by the applicant estimates an annual recruitment loss of about 19%.

The principle assumption in both of these techniques which could effectively reduce the rate of recruitment loss is that the mortality rate of each life stage is independent of the density of the species. This assumption is probably valid or nearly so after the first year but may not be for the first year of life. In simplified terms, the reproductive strategy of the species is to supersaturate the nursery areas with young striped bass and let density-dependent mortality reduce the population to a level near the maximum production capability of the estuary. Thus, the number of recruits leaving the estuary each year is relatively stable and is somewhat independent of the number of eggs spawned, provided sufficient spawn is produced to saturate the nursery areas. Thus, relatively stable recruitment is maintained over a wide range in the standing crop of adults. Therefore, changes in the standing crop of adults caused by commercial or sport fisheries would not affect recruitment so long as sufficient breeding stock is maintained to saturate the nursery areas. However, the reduction of the number of breeding individuals caused by exploitation by the fisheries would reduce the margin of saturation by which recruitment might remain constant.

The response of a population to abnormal mortality reflects in part the manner in which the density of the population is controlled. The degree of crowding (density) and the pattern of dispersion of individuals (whether random, uniform, or clumped together in a limited area) are especially important in determing the degree of interaction between individuals of the same and of other species. Some populations tend to be self-limiting in that the rate of growth decreases as the density increases. Such populations tend to level off in density before saturation, thus assuring that adequate resources are maintained. Other populations are not self-limiting but tend to grow in geometric sequence unless checked by forces outside the population. Such populations are generally limited by habitat resources or predation. For species such as striped bass, which support a large fishing industry, the major predator is man.

The generation time is another important factor in determining the response of populations to mortality. Species with very fast generation times (hours or days) whose populations are regulated by density-dependent factors, such as resource limitations, would be able to maintain population levels in spite of increased mortality. Population maintenance in species such as striped bass with longer generation times (6 years) would require increased reproductive capability in the survivors to maintain the population level.

On the other hand, a species whose population is regulated by factors other than its own density, e.g., predation or competition with other species, could not compensate for changes in survivorship of the other individuals in the population. Consequently, a sustained removal of a significant portion of such species would ultimately eliminate the population in the area, provided, of course, that there was no additional source of reproductive stock moving into the area from elsewhere and that the level of predation remained constant.

The existence of a reproductive compensatory reserve in a population enables it to compensate for additional mortality and thereby maintain a relatively stable population density. The maximum number of young fish produced in a season is determined by the size and food resources within their nursery areas. As long as sufficient eggs are produced to provide enough offspring to saturate the nursery area, the recruitment of young fish to the fishery and adult population will remain relatively constant. However, if the adult population is reduced sufficiently so that it is unable to produce sufficient offspring to saturate the nursery, the recruitment of young to the adult population will decline, thereby reducing the adult population size. If the average fecundity per indivudual adult does not increase, then a positive feedback would be instigated, which would cause the population decline to accelerate as long as mortality rates remain constant.

This discussion of density-dependent mortality is limited to compensatory mechanisms within the population which tend to cause higher mortality rates when the population is dense and lower mortality rates at low population levels. However, in applying the concepts outlined, it is recognized that predation plays a large role in determining survival. If adequate substitution foods are not available to the predators involved, then mortality rates could well be higher at low population levels even if the density-dependent mechanisms are favoring increased survival. Thus, the following cases are strictly applicable to situations where density feedback mechanisms are primarily responsible for maintaining a stable population size.

Two factors are important for a population to produce sufficient offspring to saturate the available habitat: the absolute number of viable eggs produced and the fraction of the eggs, larvae, and juveniles that dies from factors which are independent of the population density. Thus, any increase in the density-independent mortality in the population will cause a corresponding change in the minimum level of fecundity that must be maintained to keep recruitment constant. If the population remains within its compensatory density, then such an increase in density-independent mortality may have any of several possible effects. For instance, if the population is resource limited, an increased fecundity per individual might cause a change in the age structure of the population but little change in biomass. That striped bass are not limited in this manner can be seen from the fact that no important change in growth pattern has been observed, although population densities have increased by an order of magnitude on the Atlantic coast.

The staff analysis indicates that the predatory influence of the fishery controls the striped bass population. Figure V-12 shows increases in striped bass commercial landings in the mid-Atlantic region are associated with declines in Hudson River landings. Furthermore, catches in the Hudson can be used to predict landings in the Atlantic five years later (Fig. V-13). This relationship is not surprising because the 16-in. size limit restricts catches to large individuals and thus would reflect fluctuations in abundance of mature fish returning to the river to spawn. Because of the linearity of the relationship and the fact that 93% of the variability in recruitment to the Atlantic population can be attributed to the abundance of mature fish in the Hudson, increased mortality of larvae and juveniles is very likely to cause proportionally reduced recruitment.

Furthermore, an inverse correlation exists between the Hudson landings and both effort and catch by the Atlantic fishery; thus, it must be concluded that the population is highly sensitive to changes in mortality rates and that the fishery itself is fluctuating because of overexploitation during periods of high fishing intensity (Figs. V-14 and V-15).

The 4- to 6-year lag between spawn and recruitment to the fishery masks the effect of any increased mortality for the same length of time. Plant operation during a period of overexploitation would have an additive effect such that recruitment to the fishery would

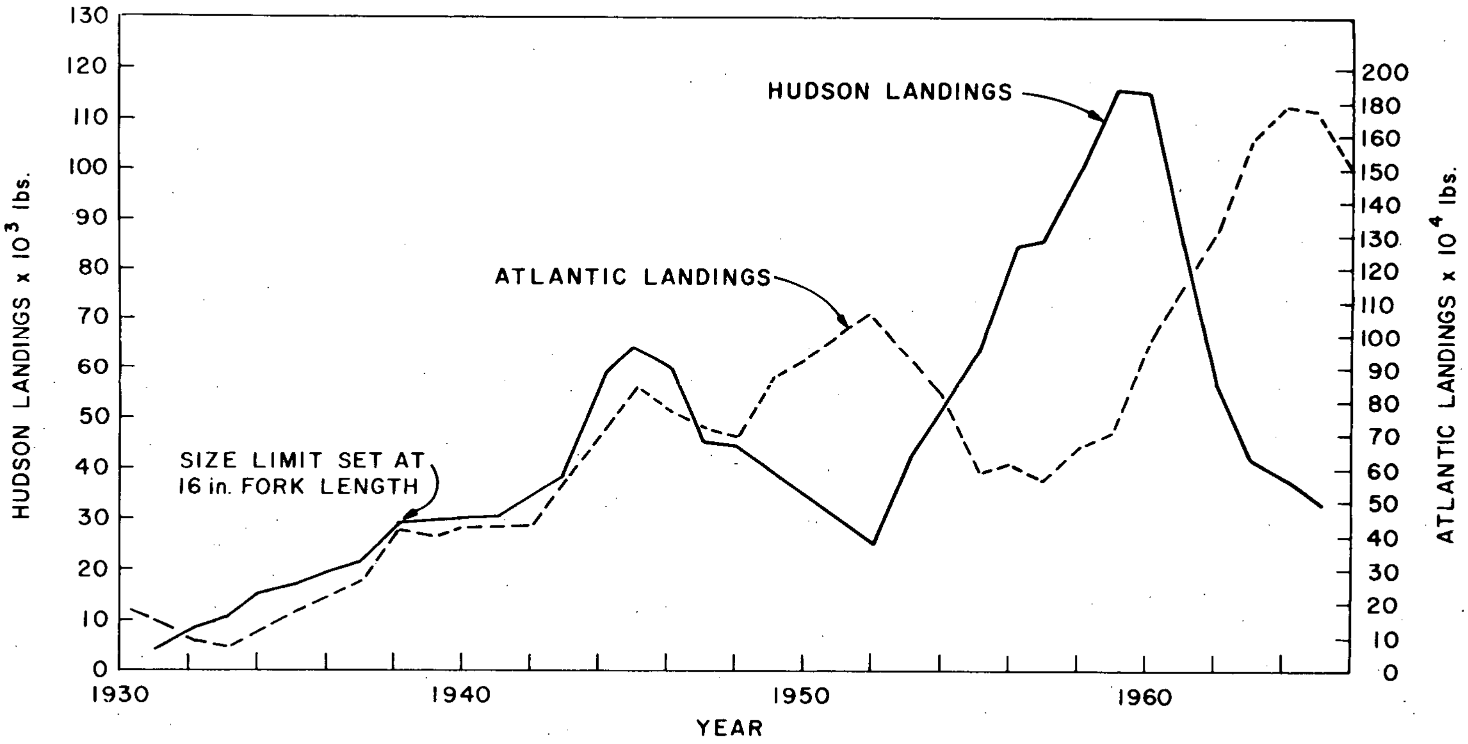

Fig. V-12. Striped bass landings by commercial fisheries in the Hudson River and the mid-Atlantic region.

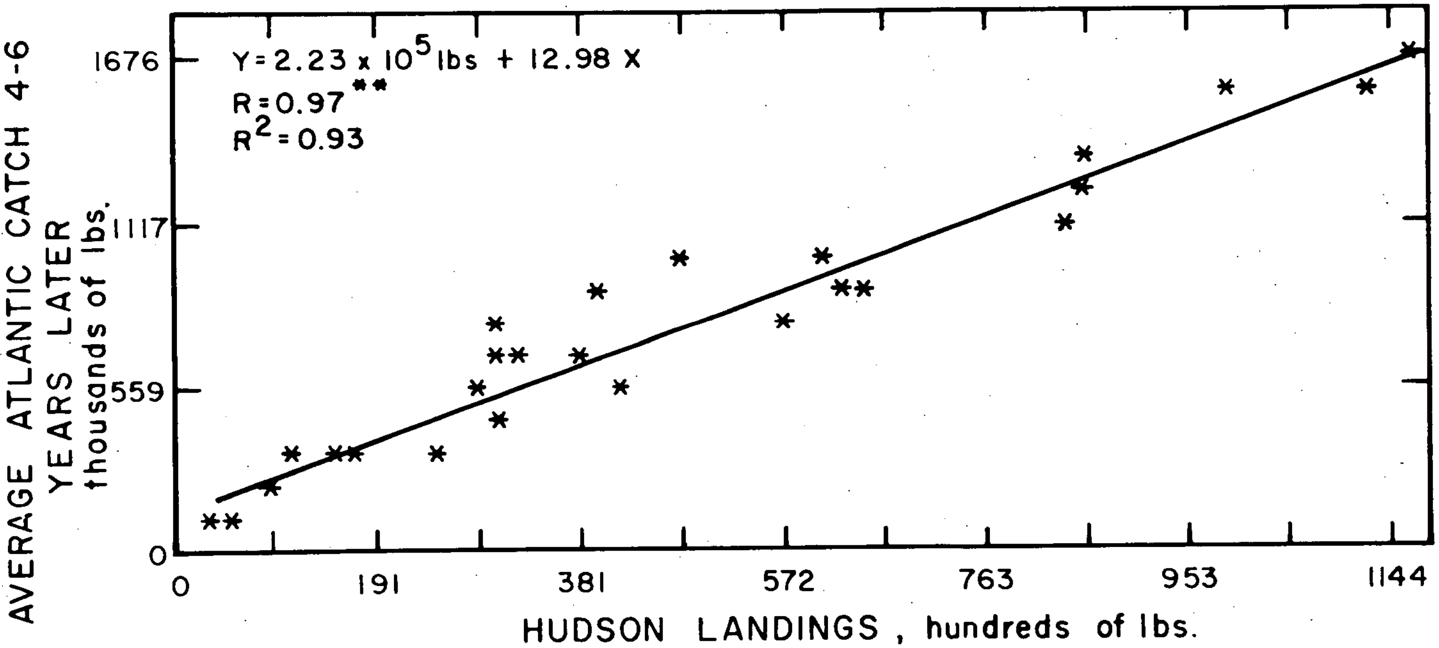

Fig. V-13. Effect of reproductive stock in the Hudson on recruitment to the mid-Atlantic striped bass fishery.

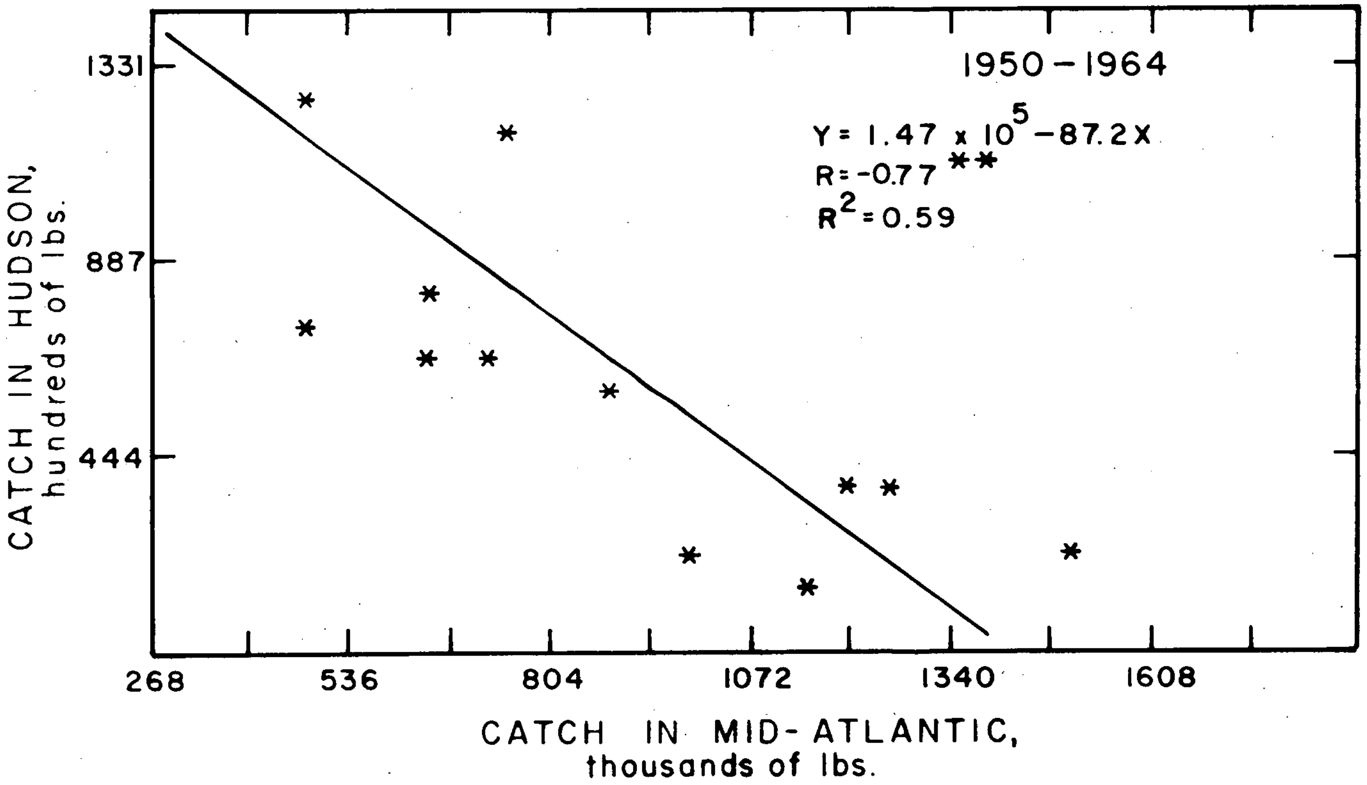

Fig. V-14. Effect of mid-Atlantic striped bass landings on landings of striped bass in the Hudson.

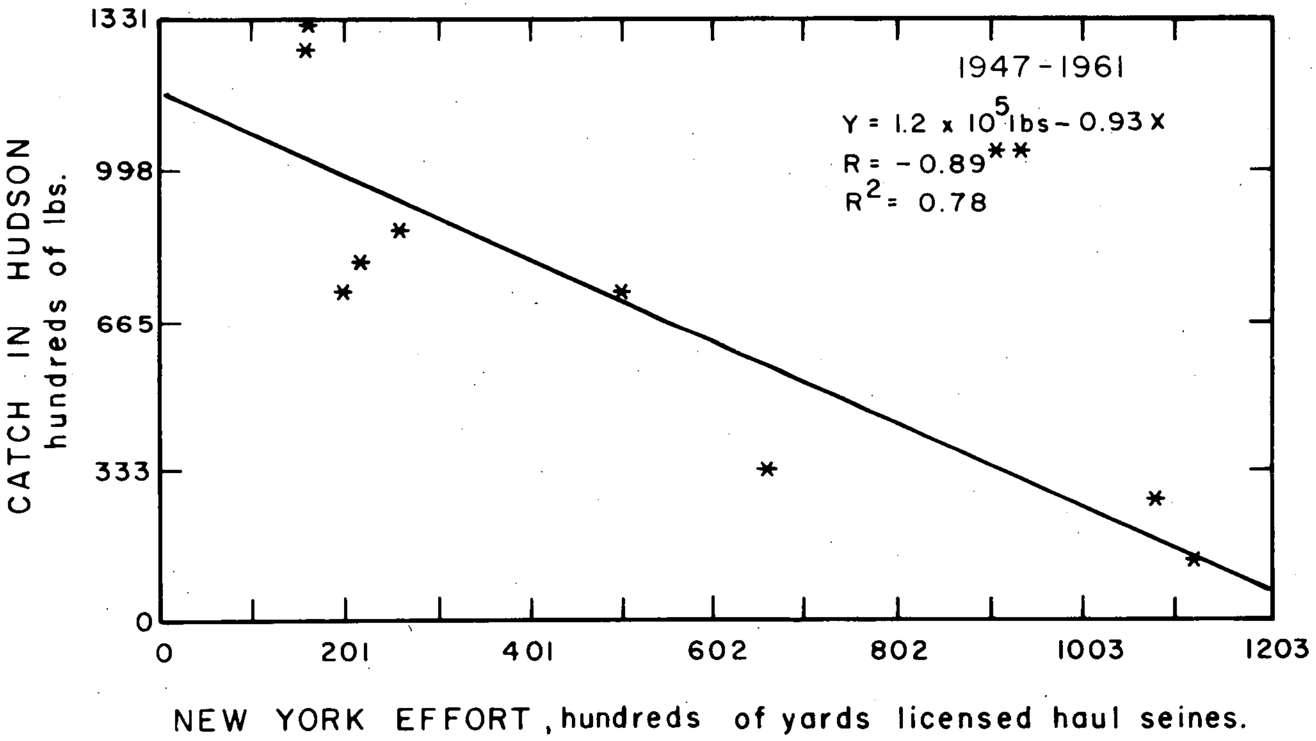

Fig. V-15. Effect of fishing intensity on reproductive stock of striped bass in the Hudson be further reduced, resulting in a dramatic decline in the mid-Atlantic landings. The effect of Plant operation for even a short period is therefore expected to reduce future landings in the neighborhood of 35 to 50%, beginning about the fifth year after operation begins.

Many of the Hudson River fish populations may have the ability to compensate for Plant-caused increases in mortality. However, available information on shad and on striped bass along the Atlantic coast shows fairly conclusively that compensatory capabilities in these species are not the factors which presently determine the population level. Furthermore, the 1965-1969 NYU 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.

(2) Indirect Effects

Less obvious effects might accompany chronic exposure to increases in temperature (or radiation and chemical stresses from Plant releases). These effects could alter food conversion, growth rate, or reproductive potential and might alter the interspecific relationships. For example, changes within the plankton populations have a potential for causing changes in populations of other trophic levels. The extent and importance of such changes would be correlated with the ecological function of the organisms involved and the relative densities of their populations.

The importance of this type of consideration can be seen in the following hypothetical example. Phytoplankton species A is the principal food of zooplankton species B, which is the principal food for early larval stages of a dominant fish species. A power plant in the area begins to operate and increase the surface temperature several degrees over ambient. Because of poor light penetration in the slightly turbid water, the principal zone of phytoplankton growth is in the upper, thermally altered layer. Phytoplankton species X is better fitted to grow and reproduce in the warmer water and replaces species A. However, X is a poor-quality food for zooplankton B. As a consequence, the population of zooplankton B decreases and the food supply for the larval fish is diminished, causing significant reduction in their yearly production. As the numbers of these fish decline

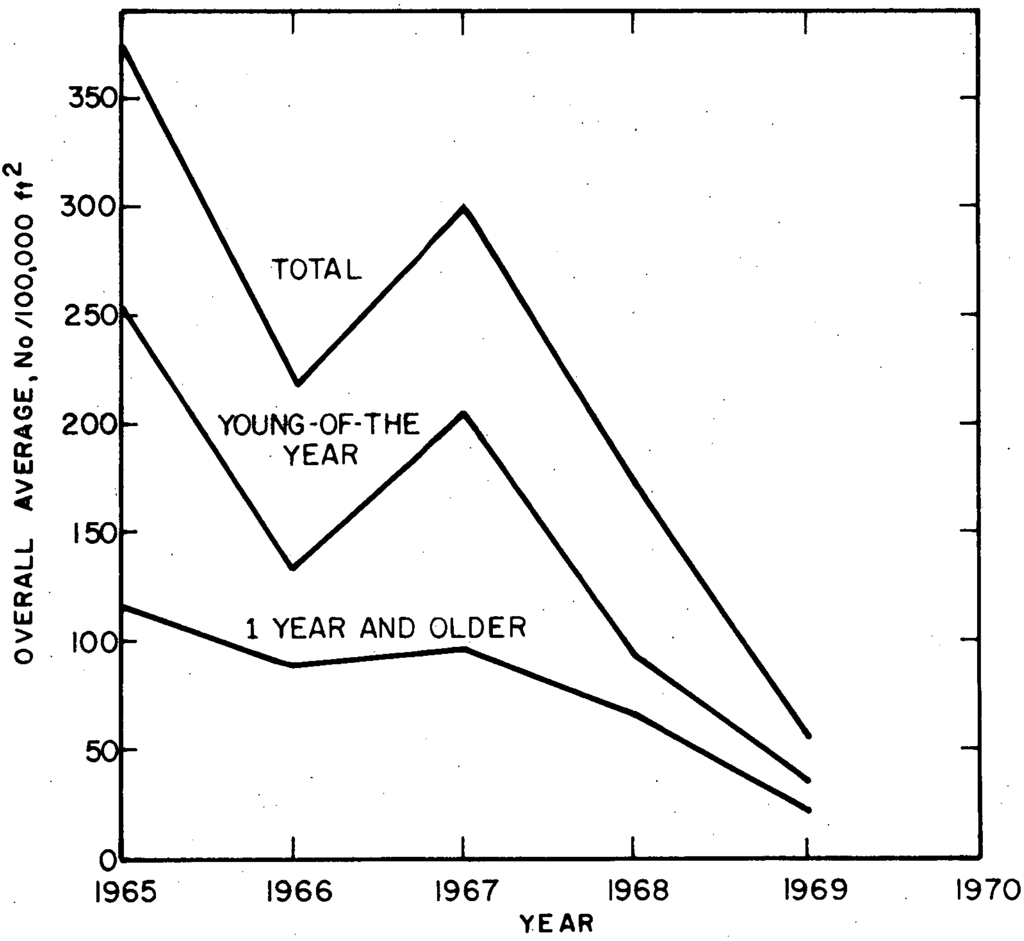

Fig. V-16. Average annual abundance of white perch in the Hudson as estimated by seine haul data.

through several seasons, the reproductive capacity of the population declines, and they exert less and less of an influence in the area. If this species were a top carnivore, changes in its population could result in changes in the populations of other fish species as well. Changes in these populations would also have their effects.

The above hypothetical example is presented to demonstrate one manner in which indirect effects of pollutants may result in extensive changes in the biological composition of a body of water. The extent of these effects depends on several factors, which must be known to make accurate predictions of the consequences of operation of any power plant:

(a) The species composition of the affected area must be known and the relationships between various species understood.

(b) The spatial and temporal distribution of the species in the area must be known.

(c) The relationships between each species and its physical environment must be understood.

(d) The sensitivity of the various species to alterations in their chemical and physical habitat must be known.

All this information would be needed to produce reliable predictions of the consequences of Plant operations on the biota. Many reasons, including lack of time, resources, and adequate sampling techniques, preclude the acquisition of the necessary information. At Indian Point, the complexity of the interactions of the biota with each other and through natural cycles of salinity and temperature is very difficult. Unfortunately, even if all of the relationships were known, reliable biological predictions of the indirect effects of the operation of the Station could not be developed with the present state of the art. As a result, staff assessment of these aspects of environmental effects of Plant operation will be necessarily qualitative. However, it is important to understand that over an extended period of time these effects may have far greater consequences than the direct effects on the biota.

Many indirect effects of Plant operation can be foreseen. However, because of the complexity of the interactions of the biota and the uncertainty of the magnitude of the direct effects of Plant operations on the various species that occur at Indian Point, any definitive statements concerning indirect effects are not possible. The only plausible change in the biota that would have considerable immediate importance to the system as a whole is the probability of inducing greater seasonal fluctuations of algal populations and of increasing the proportion of blue-green algae in the population. These changes would alter the seasonal and directional components governing the transfer of matter and energy through the food web. These changes could result in changes in productivity at all levels of the system and thereby would favor changes in species composition of consumer organisms. The importance of changes in primary productivity at Indian Point cannot be evaluated without additional data on the origin and magnitude of organic detritus in the Hudson.

The staff believes adequate evidence is not available to properly evaluate the qualitative or quantitative aspects of the indirect effects of the operation of the Indian Point Station but that a high potential for important changes do exist.

3. Biological Monitoring Program

a. Data Analyses

The staff does not agree with many of the conclusions expressed by the applicant in Supplement No. 1 to Environmental Report for Unit No. 2.[1] It is apparent that many of the applicant's conclusions are not consistent with the data acquired by its consultants. On page 2.3.6-5 of this Supplement, for example:

> "The Hudson River, upstream and downstream from Indian Point, is used by migrating and resident fish species for spawning and as a nursery area. Based on the data which have been collected, Con Edison believes that the operation of Unit No. 2 will not have an adverse effect on the Hudson River Fishery. Of the six key fish species chosen by the Hudson River Policy Committee to be investigated and be used as ecological indicators, four (alewife, blueback herring, striped bass, and American shad) spawn upriver from

> Indian Point. Therefore, their eggs and larvae are not vulnerable to the intake and thermal plume at Indian Point." (page 2.3.6-5)

Extensive data gathered by the Raytheon Company[18,45,46] and by Northeastern Biologists,[47] both of which are consultants for the applicant, clearly show that larvae of the striped bass, alewife, and blueback herring are susceptible to the intake and thermal plume.

In other cases the applicant presented conclusions concerning the impact of its proposed operations without providing any discussion of an analysis upon which its conclusions are based. For example:

> "As discussed in Section 2.3.3.4, these thermal discharges will result in a temperature distribution in the Hudson River within the surface temperature limits established by the New York State Criteria Governing Heated Discharges. Moreover, the actual temperature distribution with Units 1 and 2 in operation will be below these limits most of the time. Therefore, it can be stated that thermal discharges will not adversely effect the aquatic environment. It may also be added that the sphere of influence of this thermal discharge is small as compared to the extent of the river in the vicinity of Indian Point and therefore, effects on biota, if any, will be local." (page 2.3.6-6)

In view of the staff analysis, it is difficult to understand how these conclusions were reached. The "sphere of influence" of the thermal discharge is certainly not small but will in fact extend in both upstream and downstream directions for distances proportional to the fraction of water that has been present at Indian Point (see Appendix V-2). In addition, the applicant apparently assumes that no adverse effects will occur within the legal discharge limits but provides no explanation of its assumption.

In view of the staff's assessment of the magnitude of the possible biological impact of Plant operations and its view that the simple gathering of data is not sufficient for environmental protection, the staff feels that rigorous examination of available data together with new data from the postoperational monitoring program should be done by the applicant and its consultants, under the review and with advice from the Fish Advisory Board and the Hudson River Fish Technical Committees in the light of present knowledge concerning the environment in the Hudson River and elsewhere. This statement applies equally well to the analyses of data gathered in ongoing and future studies. From such information a plan of action should be developed by the applicant in cooperation with State and Federal officials of the Fish and Wildlife Service to minimize the potential ecological damage to the biota. As discussed in Chapter XII.G and in response to the Department of Commerce comments in Appendix XII-4, these committees are primarily advisory in nature rather than provide direct control over ecological studies.

b. Study Design

The ecological studies conducted for the applicant[1] are reviewed and coordinated by two types of committees:

> "In order to assure the adequacy of all ecological studies conducted by Con Edison, the studies are directed by the Hudson River Policy and Technical Committees. Each of these committees consists of representatives from New York State Department of Environmental Conservation, New Jersey Division of Fish and Game, National Marine Fisheries Service (formerly the U.S. Bureau of Commercial Fisheries) and the U.S. Bureau of Sport Fisheries and Wildlife. In addition, representatives from the Connecticut State Board of Fisheries and Game participate as advisors in all Policy Committee meetings. The committees outline and supervise the studies and ensure that they are performed in a professional manner. The committees present their conclusions and recommendations to Con Edison.
>
> "In addition to the Hudson River Policy and Technical Committees, Con Edison has organized a Fish Advisory Board consisting of expert biologists and engineers from the United States and Great Britain." (page 2.3.6-9)

See Chapter XII for further discussion of the role of these committees in providing advice to the applicant. Both the Department of Commerce and the applicant commented on the functions and authority the committees have.

c. Present Studies

The ongoing research at Indian Point was outlined in the applicant's Supplement No. 1 to Environmental Report[1] as follows:

> "In November 1970, New York University Institute of Environmental Medicine was contracted by Con Edison to perform studies on the effect on passing aquatic organisms through the condenser. These studies are being done at Unit No. 1 located at Indian Point.... .... Two consecutive years of such investigation are envisioned. Studies will also be conducted on non-screenable organisms passing through the condenser of Unit No. 2, which is scheduled to go into operation in 1972.
>
> "Scope of this work includes studies on survival, extent of mechanical damage, thermal shock tolerance and effects on reproductive potential of entrained organisms. Effect on the productivity of the entrained phytoplankton is also under investigation. Consideration is being given to such aspects as recycling of already exposed organisms to the condenser passage, time required for passage through the condensers, exposure in the discharge canal and reproduction rates of organisms in the ambient water." (page 2.3.6-7)
>
> "Monitoring programs have been utilized at the Indian Point site as early as 1958. These programs are of three general types. The first of these, which utilizes the Automated Environmental System (AES), concentrates primarily on the thermal, chemical and hydrological aspects of the environment. The second program deals exclusively with environmental monitoring related to radiological aspects of plant operation. In addition, many biological, hydrological and mechanical aspects of the environment are monitored in

connection with studies being done for Con Edison by various consultants." (page 2.3.6-12)

"The Automated Environmental System (AES) has been used since 1969 and continuously monitors temperature, dissolved oxygen and pH in water pumped directly from in front of the intake canal from a depth of 13-3/4 feet below mean low water. In addition, temperature, dissolved oxygen, pH, salinity and cupric ion are monitored in water pumped directly from the effluent canal from a depth of 5-1/2 feet below mean low water ....The AES unit also maintains a tide and temperature record of the Hudson River immediately surrounding the Indian Point site." (page 2.3.6-12)

"Con Edison's radiological environmental monitoring program includes measurements of radioactivity in fresh water, river water, river sediments, fish, aquatic vegetation, vegetation, soil and air in the vicinity of the Indian Point station. This program began with a survey instituted in 1958 (four years prior to operation of Unit No. 1) to determine the radioactivity in the environment in the vicinity of the Indian Point station. The purpose of this survey was to determine the natural background radioactivity and to show the variations in the activities that may be expected from natural sources, fallout from bomb tests, and other sources in the vicinity. The program has been continued to the present so that changes in the environment resulting from operation of Unit No. 1 could be accounted for, and will be continued throughout the operating lifetime of all three units.

"Aquatic vegetation from the lake on site and other nearby lakes is sampled during the growing season and analyzed for gross beta activity, and a gamma spectrum is also run. Aquatic vegetation is collected from the Hudson River at points at the discharge canal, one-half, one and two miles downstream from the plant. This vegetation is analyzed in the same manner as the lake aquatic vegetation. Bottom sediment is taken from the Hudson River in the vicinity of the plant and at points one-half, one and two

> miles downstream. This sediment is measured for gross beta activity and is also analyzed for gamma activity.
>
> "River fish caught in the vicinity of the plant are measured for gross beta and a gamma spectrum analysis is made. Land vegetation is sampled primarily in the downwind direction from the plant at points one-quarter, one-half, one and two miles south of the plant." (page 2.3.6-18)

d. Planned Studies

The applicant has stated its intentions concerning the implementation of future studies. The scope of these studies was described in Supplement No. 1[1] to the Environmental Report for Unit 2 as follows:

> "Plans are in progress for a continuation of the study performed by the Raytheon Company during 1969-70 as a long term ecological study in the vicinity of Indian Point to assess any effects with respect to the operation of the station. These studies will be directed by the Hudson River Policy and Technical Committees and financed by Con Edison. This ecological work will investigate the interaction of plant operation with the environment of the river.
>
> "The survey will include sampling macro and microplankton, fishes, benthic organisms and water chemistry, as a continuation of the work performed during 1969 and 1970. Con Edison proposes to continue the collection of such data until December 1975, with decreasing sampling intensity from year to year. A discussion of some particular aspects follows.
>
> "Thermal plumes were mapped by infrared aerial photography in conjunction with bathythermograph readings from boats during 1969 and 1970. Mapping will be done when Unit No. 2 goes on-line with tide stages, discharge gate configurations and seasons as variables. Mapping will also be done in 1974 when Unit No. 3 is expected to go on-line.
>
> "Entrainment studies will be continued at Unit No. 1

for two years and at Unit No. 2 for one year. It is expected that a two year study will provide the data needed to determine the effect of passing non-screenable organisms through the plant.

"Con Edison has been monitoring the traveling screen washings for impinged fishes since 1970. These data are necessary to determine the species composition being collected. This monitoring will be extended to Unit No. 2 when the unit begins commercial operation.

"Con Edison proposes that the food habits of five major fish species from the Indian Point area be investigated. These studies will enable a further evaluation of the position of white perch in the food web and its relationship, if any, to striped bass. Con Edison proposes to also investigate the food habits of the different size groups of each species.

"A study will be undertaken to determine the age and growth of white perch and striped bass. This data will be used to further evaluate the population dynamics of these species in the Hudson River.

"This study will also supply pertinent data needed to estimate the natural mortality of each species. It is felt that such data would be of value in any meaningful assessment of the effect on the fish population of such other factors such as entrainment in the plant intake, as well as commercial and sport exploitation.

"Con Edison is also proposing that a tagging study be performed on white perch and striped bass at the Indian Point site. Population estimates and movement patterns of these fish need to be studied by tagging and recapturing before an evaluation can be made on the effect of exploiting them at the intakes.

"The data from such a study will be useful in making population estimates and the recaptures will also

> supply data useful in determining movement patterns. This movement data, in turn, may be utilized to determine whether the plants are effecting a local population, a migrating population, or populations that aggregate in the area only during winter.
>
> "It is thought that fish kills at Indian Point during winter months are partly attributable to the lethargic condition of fish. A scientific evaluation of such a lethargic state and the extent to which it contributes to fish kills is proposed. No work has been done on response of white perch and other Hudson River fish species to near freezing temperatures. It is not unlikely that considerable mortality may be occurring under natural conditions and these dead fish may be collecting on the intake screens. It is therefore proposed that tests be conducted at near freezing temperatures (33 ± 2 F.) to determine survival, swim speed and the scope of activity of white perch." (page 2.3.6-12)

The Department of the Interior in its comments in Appendix XII-1 believes "that the sampling intensity should not be decreased until the effects of Units Nos. 1, 2, and 3 have been determined." Entrainment studies should also be continued until such time as definitive information has been gathered. Interior also recommended that the applicant consult with the Bureau of Sport Fisheries and Wildlife on the development of the detailed plan to minimize environmental harm and have the plan reviewed when completed.

e. Needed Information

In order to properly evaluate the biological impact of the operation of Indian Point Units Nos. 1 and 2, several questions must be answered and several aspects of the biota must be monitored:

1. The flow characteristics of the Hudson within the zone bounded by the length of the tidal excursion from low to high tide in the upstream direction and throughout Haverstraw Bay in the seaward direction shall be detailed in both vertical and horizontal cross sections through complete tidal cycles under a variety of lunar phases and a variety of fresh water inflows. These

studies should include not only steady-state conditions but also conditions of net-upstream and net-downstream movement of salt water.

2. The magnitude of entrainment mortality shall be determined by the applicant. For these studies, samples should be taken from both ends of the canal, i.e., as close to the condenser as possible and just before the water is discharged into the river. In addition, several locations in the plume should be sampled. These samples should be compared with those taken at the intake and from various stations in the river and held several days to determine any latent mortality. Organisms that survive should be cultured to determine any loss of reproductive capabilities. The species composition must be determined and compared to the river as a whole and should include both producer and consumer species.

3. The sensitivity to residual chlorine shall be determined for all life stages of common or otherwise important species which are present at Indian Point. The tolerance limits must be compared to levels in the thermal plume and the river.

4. The thermal plume will be mapped, and the duration of exposure of organisms to the various temperature increments should be determined. The species composition of the plume must be measured and compared to the adjacent segments of the river. The amount of inhibition and augmentation of photosynthetic activity in the plume would have to be established. In addition, the composition of the phytoplankton community must be carefully monitored.

5. The reproductive status and food requirements of the more abundant consumer species must be determined. The species of crustaceans included need to be those which appear to be most susceptible to entrainment or thermal damage. The fish species involved would have to include those species which have eggs or larval stages susceptible to withdrawal. Among these would be the bay anchovy, white perch, tomcod, blueback herring, alewife, smelt, and striped bass.

6. Data gathered concerning thermal effects and entrainment mortality shall include times when the ambient temperature is at its yearly maximum.

7. Radiological monitoring shall continue and be applied to dose calculations for terrestrial and aquatic organisms.

8. The monitoring of impingement of fish on the screens shall include counts of those impinging on the outer fixed screens as well as the traveling screens.

The data collected would have to be analyzed in view of the present knowledge and applied to the populations of organisms in the Hudson at Indian Point.

E. RADIOLOGICAL IMPACT OF ROUTINE PLANT OPERATION ON MAN

1. Introduction

Radioactive nuclides will be released during operation under normal conditions as liquids and gases from both Indian Point Unit No. 1 and Unit No. 2. The release of these effluents will be conducted in accordance with the limitations set forth in 10 CFR 20[48] and the guidance of 10 CFR 50[49] to keep the levels of radioactive material in effluents to unrestricted areas "as low as practicable." Operating experience with similar power plants licensed for operation by the Commission has shown that actual releases of radionuclides from these plants have generally been small fractions of the limits set forth in 10 CFR 20, consistent with the Commission's policy of limiting radioactive releases to the lowest practicable level. Information on radioactive releases from operating experience of pressurized power reactors is shown in Appendix III-3.

The limitations set forth in 10 CFR 20 are based upon recommendations of national and international radiation protection groups which represent the consensus of informed and responsible scientific judgment on the radiation exposure limits for occupational workers and the general public. No detectable radiological effects on man are expected to result from releases of radionuclides meeting 10 CFR 20 limitations.

2. General Considerations For Determination of Dose Estimates

Pathways for external (radiation source outside the body) and internal (radiation source inside the body) exposures are schematically illustrated in Fig. V-17. Immersion in the gaseous effluent as it is diluted and dispersed could lead to external exposure, while the dispostion of radioactive particulates on the land surface could lead to direct external exposure and to internal exposure by the ingestion of food products through various food chains. Similarly, swimming in waters in which radionuclides have been discharged could lead to external exposure, while the utilization of these waters for fishing, drinking, irrigation, or food preparation could lead to internal exposures. The doses calculated for the internal exposures are estimates of the total dose an individual will accrue within his lifetime from each pathway.

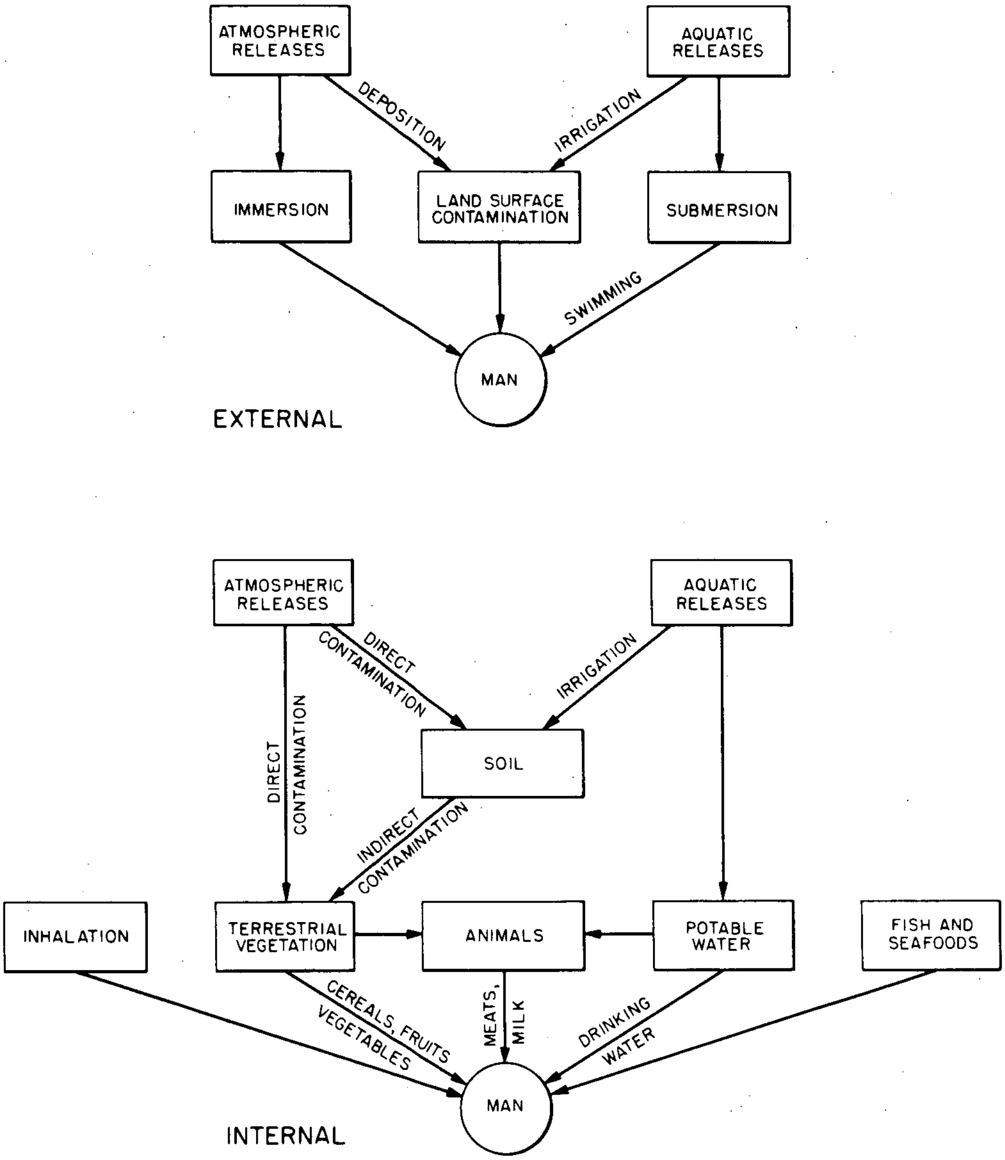

Fig. V-17. Pathways for radiation exposure of man.

Annual radiation doses, both to individuals [in millirem (mrem), where 1 millirem is 1/1000 rem] and the population (in man-rem) near the reactor are estimated. The man-rem or population dose is the sum of the total body doses to all individuals in the population considered. The dose estimates are based on an all adult population. For radioactive iodine in milk, the dose estimated for a 1-year-old child is about 10 times as large as for an average adult.[50,51] Where they are significant, the estimates of dose to organs other than total body are discussed.

Factors for converting internal radiation exposures to dose were obtained with models and data published by the International Commission on Radiation Protection[10] and other recognized authorities.[52] These models and data have been incorporated in computer programs[53] to facilitate estimation of dose. Factors for converting external radiation exposures to dose were obtained with a computer code containing models adapted from standard texts.[54,55]

a. Dispersion of Gaseous Effluents

Average annual concentrations of radionuclides contained in the air and deposited on the ground at distances up to 50 miles from the Plant site were obtained from an atmospheric transport model[56,57] for which a computer program was developed.[58] The deposition velocities used in the calculations for the noble gases (krypton and xenon), methyl iodide (CH_3I), and molecular iodine (I_2), and particulates were 10^{-6}, 10^{-3}, and 1 cm/sec, respectively. In this model, the reductions of radionuclide concentrations in the air at ground level by radioactive decay and deposition on the ground are taken into account.

b. Dispersion of Liquid Effluents

The concentration of radionuclides in a body of water receiving liquid effluents depends on the half-lives of the radionuclides and the effective volume of water as well as mixing characteristics. The complex nature of the estuary leads to large variations in the estimates of radionuclide concentrations in the water, on the bottom sediment, and in the biota.

3. Estimates of Dose

Estimates of doses to individuals and the population within 50 miles which result from radionuclide effluents discharged during normal operation of Indian Point Units Nos. 1 and 2 are treated below. Estimated doses to an individual for several exposure pathways are given in Table V-12 for radionuclide releases through both the initial and modified radioactive waste systems (see Tables III-6, 7, 8, 10, 12 and 13). The cumulative population dose from immersion in gaseous effluents is given as a function of distance in Table V-13 for both the initial and modified radioactive waste system. The estimates of dose due to gaseous effluents are based on the anticipated radionuclide releases given in Section III.E.2 of this Statement and the meteorological data specific to the site of Indian Point as given in the applicant's Supplement No. 1 to the Environmental Report. The anticipated radionuclide releases in liquid effluent as described in Section III.E.2 will be diluted at the point of discharge by a varying factor which depends upon the net fresh water flow and tidal mixing of the Hudson River.

a. Gaseous Effluents

The average concentrations of radionuclides at ground level were estimated in each of sixteen 22.5° sections at various distances from the site. The concentration of gaseous effluent released from Indian Point Unit No. 1 except for the iodines is calculated for release from the 88-meter stack ($X/Q = 1.9 \times 10^{-8}$ sec/m^3, 1000m south). The gaseous effluent from Unit No. 2 and the iodines from Unit No. 1 are released from their respective exhaust vents on top of the containment buildings. No credit is taken for the height of the buildings and the ground level concentrations are calculated for a surface release ($X/Q = 2.6 \times 10^{-6}$ sec/m^3, 1000m south). Because of the irregular shape of the property line defining the Indian Point site, estimates of dose are made for several locations.

(1) Dose Estimates for Immersion and Ground Contamination

The highest estimate of total body dose [3.1 and 3.3 millirem per year (mrem/yr.) of release respectively for the initial and modified radioactive waste systems] occurs for an individual continuously located at the proposed visitors' center. However, only a small part of this dose would be received by a person present at the visitors' center during the time of an average visit. If the center has 100,000 visitors per year and each visitor stays for two hours, then an estimate of the annual visitor-population dose is 0.75 man-rem.

TABLE V-12. ESTIMATED DOSES TO INDIVIDUALS PER YEAR OF NORMAL RADIONUCLIDE RELEASE FROM BOTH INDIAN POINT UNITS NOS. 1 AND 2

Pathway	Location or amount	Total-body dose (millirem)		Thyroid dose (millirem)	
		Initial radioactive waste system	Modified radioactive waste system	Initial radioactive waste system	Modified radioactive waste system
Air immersion and surface contamination. Locations measured from Indian Point Unit No. 2 to:					
Proposed visitor center	107 m E	3.1	3.3	3.1	3.3
Property line	630 m ESE	0.14	0.15	0.14	0.15
Property line	970 m S	0.14	0.15	0.14	0.15
Property line	520 m SW	0.23	0.24	0.23	0.24
Inhalation of contaminated air. Locations measured from Indian Point Unit No. 2 to:					
Proposed visitor center	107 m E	0.02	0.02	14	13
Property line	630 m ESE	<0.01	<0.01	0.57	0.55
Property line	970 m S	<0.01	<0.01	0.52	0.51
Property line	520 m SW	<0.01	<0.01	0.88	0.85
Terrestrial food chain	970 m S	<0.01	<0.01	<1.0[a]	<1.0[a]
Aquatic food chain	16 lb of fish per year	0.31	0.054	1.2	0.61
Swimming (Hudson River)	1% of year	<0.01	<0.01	<0.01	<0.01

[a] Based on an upper estimate of the above ground vegetable crops consumed immediately after harvest.

TABLE V-13. SUMMARY OF THE ANNUAL TOTAL-BODY DOSES ESTIMATED FOR IMMERSION IN THE GASEOUS EFFLUENTS FROM BOTH INDIAN POINT UNITS NOS. 1 AND 2

Distance (miles)	Cumulative population (1970)	Initial radioactive waste system		Modified radioactive waste system	
		Cumulative population dose (man-rem)	Individual average dose (millirem)	Cumulative population dose (man-rem)	Individual average dose (millirem)
0-1	2,213	0.16	7.2×10^{-2}	0.17	7.7×10^{-2}
0-2	18,552	0.53	2.9×10^{-2}	0.58	3.1×10^{-2}
0-3	30,175	0.63	2.1×10^{-2}	0.70	2.3×10^{-2}
0-4	39,465	0.69	1.7×10^{-2}	0.75	1.9×10^{-2}
0-5	65,830	0.79	1.2×10^{-2}	0.86	1.2×10^{-2}
0-10	211,373	1.2	5.7×10^{-3}	1.2	5.7×10^{-3}
0-20	916,379	2.0	2.2×10^{-3}	2.1	2.3×10^{-3}
0-30	4,302,799	4.7	1.1×10^{-3}	4.7	1.1×10^{-3}
0-40	10,710,185	8.2	7.7×10^{-4}	7.9	7.4×10^{-4}
0-50	16,507,168	10	6.1×10^{-4}	9.9	6.0×10^{-4}

Estimates of total body dose are given in Table V-12 for three locations on the property line surrounding the site. A commercial building is located near the intersection of Bleakley and Broadway (630 meters ESE). The nearest sizeable residential areas lie to the south of the site. For the portion of this site not bounded by water, the highest estimate of total body dose is found at 520 meters SW. The adjoining property at this location is owned by Georgia Pacific and is not currently used as a residential area. It is therefore estimated that an annual dose of <0.1 mrem would be received by a person spending 8 hours per day at this location. The estimates of total body and thyroid doses for both the initial and modified radioactive waste systems are given in Table V-12 for all of these locations. About 5 to 10% of these dose estimates are attributable to ground contamination.

The population dose (see Table V-13) from immersion for persons living within 50 miles (1970 census) of the Station is 10 man-rem for the initial radioactive waste system and 9.9 man-rem for the modified system.

(2) Dose Estimates for Inhalation

The estimates of internal dose for inhalation are based on an inhalation rate of 2 x 10^7 cc/day.[10] The estimates of the total body and thyroid doses are given in Table V-12 for both the initial and modified waste systems at the same locations for which external doses were estimated. The total dose to the thyroid from external exposure and internal inhalation exposure to the gaseous effluent is the sum of the two separate dose estimates. (For example the estimated annual dose to the thyroid of a person at the visitors' center 8 hours per day would be 5.7 mrem.)

(3) Dose from Radioparticulates and Iodine by Food-Chain Pathways

Deposition of radioparticulates and iodine occurs from the gaseous effluent to crops and soil. Direct ingestion by man of radionuclides deposited on truck crops is possible. Indirect ingestion of radionuclides via meat produced by animals pastured on exposed areas is also possible, and an additional pathway which utilizes all of these mechanisms exists for nuclides carried into the soil by rainfall and subsequently into food plants through their roots. A general purpose environmental model[59] was used to estimate the resulting dose to an individual. The total-body estimate of less than 0.01 mrem/yr of release at 970 meters in the southern direction is based on the assumption that all of the individual's above ground vegetables are produced at this location. The corresponding annual thyroid dose is estimated to be <1.0 mrem.

An estimate of dose from ^{131}I and ^{133}I was made for the pasture-cow-milk-man pathway. The same general environmental model used above[59] converted the deposition rate to a radioiodine concentration in milk. The estimate of dose to the thyroid of an individual drinking 0.6 liters of milk per day was made for milk produced at the dairy approximately 9 miles south of Indian Point. The estimated thyroid dose to an adult drinking this milk is 0.36 mrem/yr of radionuclide release.

b. Liquid Effluents

The anticipated quantities of radionuclides in the liquid effluents discharged from the initial and modified radioactive waste systems of Units Nos. 1 and 2 are listed in Tables III-6, 7, and 8. These effluents will be mixed with an average cooling water flow of 2.0×10^{15} cc/yr (2,230 cfs) and then further diluted by a factor ranging from 2 to 20 after this water is discharged into the Hudson River. Radioactive decay for 1 day and an average river dilution of 10 were used in calculating the concentration of each radionuclide.

(1) Dose Estimates for Ingestion of Fish

The highest total-body dose to an individual from fish consumption is estimated to be 0.31 mrem/yr of release. The daily consumption rate for fish was assumed to be 20 gm (16 lb per year is the per capita figure for the United States)[60] all of which came from the Hudson River downstream from the site where the average river dilution of the discharged effluent is assumed to be 10. Radionuclide concentrations in the fish were assumed to be in equilibrium with those in the river and were determined by multiplying the radioactivity levels in water by the respective bioaccumulation factors (radionuclide concentration in fish flesh divided by radionuclide concentration in water). The complexities of estuaries make it difficult to postulate average conditions which will simply take into account the variations of fresh water flow, salt water intrusion, biota populations, etc. The freshwater bioaccumulation factors shown in Table V-2 were used to obtain the estimates of dose to man from fish consumption.

A population dose from ingestion of fish is difficult to estimate due to the lack of fish harvest data for the Hudson River. If it is assumed that 1% of the approximately 16 million people living within 50 miles of the site obtain 10% of their fish from the Hudson River (a total of 260,000 lb/yr), an annual population dose of 5 man-rem is estimated for the initial radioactive waste system. The estimated population dose reduces to 0.87 man-rem for the modified waste system.

(2) Dose Estimates for Ingestion of Hudson River Water

No estimate of the dose was made for this exposure pathway, since at no place downstream from Indian Point is the river used as a source of municipal drinking water. Table II-2 of Chapter II lists the municipals using water from the Hudson River. All of these cities are north of the Indian Point site. Poughkeepsie which uses the greatest amount of Hudson River for drinking water is 30 miles upstream from Indian Point.

(3) Dose Estimates for Swimming in the Hudson River

Swimming in the river was considered a potential source of external exposure. The estimate of less than 0.01 mrem/yr of radionuclide release for the radiation dose to an individual was calculated under the assumption that he would swim in the river 1% (1 hour per day for three months each year) of the year. The estimated annual population doses of 0.12 and 0.08 man-rem were obtained, respectively, for the initial and modified radioactive waste systems by assuming that 1% of the population living within 50 miles of the site spends 1% of the year swimming in the river.

c. Direct Radiation

The refueling water storage tank, approximately 15 meters NE of the containment of Indian Point Unit No. 2, is a source of direct radiation due to the storage of excess water received from the primary cooling system upon startup after a refueling cycle. A preliminary estimate of the total body dose rate by the applicant at the visitors' center (approximately 107 meter E) is <0.03 mrem/hr. The corresponding estimated dose rate at the intersection of Bleakley and Broadway would be <0.001 mrem/hr. A radioactive decay period of 6 weeks (normal refueling time) is assumed before the excess refueling water is put into the storage tank without any treatment. These estimates of dose are maximum since shielding and further radionuclide decay in the storage tank would reduce the dose rate.

4. Assessment of Annual Dose Estimates

A summary of estimated annual doses which might be expected by individuals at points of maximum exposure to the gaseous effluents is given in Table V-12. These doses are not reduced by shielding factors or occupancy factors. The sum of the annual total body dose estimates for offsite individuals from immersion, inhalation, and ground surface contamination is less than 1% of natural background dose and less than 0.2% of the exposure limits of 10 CFR 20.

The annual doses expected to result from the liquid releases are summarized in Table V-12. These doses are only very small fractions of natural background for releases from either the initial or modified radioactive waste system.

The estimated population dose from immersion in the gaseous effluents is shown in Table V-13. The average dose within 50 miles of the Station is less than 0.001% of the natural background dose.

Those individuals of the present population distribution who spend all of their time within 2 miles of the Plant would receive on the average less than 0.04% of the typical background dose of 0.1 rem/yr. This is far below the normal variation in background dose and represents no measurable radiological impact on the population from the operation of Indian Point Units Nos. 1 and 2. Similar considerations for the liquid effluents indicate that no discernible radiological impacts are expected. A summary of the annual radiological impact in terms of man-rem from all pathways and the affected population is presented in Table V-14.

5. Radiation Monitoring

The applicant began a preoperational radiological environmental monitoring program in 1958 to determine the levels of radioactivity prior to Plant operations (operation of Indian Point Unit No. 1 began in 1962) and to show the variations in the levels that could be expected from natural sources, fallout from weapons testing, and other sources in the vicinity of Indian Point.[61] The program included measurements of radioactivity in samples of fresh water, river water, rainwater, river bottom sediments, fish, aquatic vegetation, soil, terrestrial vegetation, and air in the environs of the Indian Point Station. In addition, the New York State Department of Environmental Conservation has conducted extensive radiological surveys in the vicinity of the Indian Point Station since 1958, and the New York University Institute

TABLE V-14. INTEGRATED ANNUAL DOSE TO THE GENERAL POPULATION FROM THE OPERATION OF THE INDIAN POINT STATION[a]

Pathway	People	Initial radioactive waste system (man-rem)	Modified radioactive waste system (man-rem)
Cloud (immersion)	16,000,000	10	9.9
Fish	160,000	5.0	0.87
Swimming	160,000	0.12	0.08
Visitors' center (direct radiation + immersion)	100,000	<7	<7
Transportation of irradiated fuel	300,000[b]	1.8[c]	1.8[c]
Transportation of radioactive waste	180,000	0.9	0.9
Total		<25	<21

[a] Annual exposure dose from natural background is 0.1 rem to the individual and 1,600,000 man-rem to the general population of 16,000,000 (based on 1970 census).

[b] Dose from shipment by rail. Shipment may be made by truck, in which case the dose will be 3.4 man-rem.

[c] This includes ten people close by and two drivers as well as 300,000 people along the route.

of Environmental Medicine has conducted a research program on the ecology of the Hudson River since 1964, which includes radio-ecological studies. Both of these programs are continuing. Although the New York University Institute of Environmental Medicine research program is not characterized as a monitoring program, the results of the study are germane since they provide information about the distribution of radionuclides in the river system.

The radiological environmental monitoring survey program for Indian Point Unit No. 2 will be a continuation of the preoperational studies and Indian Point Unit No. 1 post-operational environmental monitoring surveys.[61] The survey program is designed to be conducted at three different program levels, with the program level in use at any particular time being dictated by the Plant releases for the preceding month. A detailed tabulation of the program levels, criteria which govern the program level to be used, and a map which shows sampling and measurement locations are given in Section 2.3.6.3 of the applicant's Supplement No. 1 to the Environmental Report. Both the applicant's and New York State's radiological environmental monitoring programs are geared to provide more intensive surveillance in the event of a significant increase in radioactive discharge from the Plant.

The applicant's radiological environmental monitoring program is well designed to evaluate the radiation levels in the environment resulting from Plant operations.

F. TRANSPORTATION OF NON-RADIOACTIVE AND RADIOACTIVE MATERIAL FROM AND TO INDIAN POINT STATION

1. Transportation of Nuclear Fuel and Solid Radioactive Waste

The nuclear fuel for the Indian Point reactors is slightly enriched uranium in the form of sintered uranium oxide pellets encapsulated in stainless steel or zircaloy fuel rods. Each fuel element is made up of 204 fuel rods about 12 feet long. Each year in normal operation, about 40 fuel elements are replaced in Unit No. 1 and 65 fuel elements will be replaced in Unit No. 2.

The applicant has indicated that cold fuel for the reactor will be transported by truck either from Cheswick, Pennsylvania, a distance of 450 miles, or Columbia, South Carolina, a distance of about 800 miles. The applicant has indicated the irradiated fuel will be transported by truck or rail to Morris, Illinois, a distance of about 1,000 miles. The present plans are to transport the irradiated fuel by truck from the site to the nearest railhead (about 1.5 miles from the site boundary) and by rail the remainder of the 1,000 miles to the Midwest Fuel Recovery Plant in Morris, Illinois. Future shipments of irradiated fuel may be by truck only. The solid wastes will be transported by truck to Morehead, Kentucky, for disposal, a distance of about 600 miles. Transport of radioactive material will be conducted under the Commission's regulations 10 CFR 71, and the Department of Transportation's (DOT) regulation's 49 CFR 173.[63] The DOT in its comments in Appendix XII-9 upon the Draft Statement stated that the impact of this project upon transportation is minimal and that it has no objection to the project.

a. Transport of Cold Fuel

The applicant has indicated that cold fuel will be shipped in AEC-DOT approved containers which hold two fuel elements per container. About eight truckloads of seven containers each will be required each year to meet the needs of both reactors.

b. Transport of Irradiated Fuel

Fuel elements removed from the reactor will be unchanged in appearance and will contain about 30 to 50% of the original U-235 (which is recoverable). As a result of the irradiation and fissioning of the uranium, the fuel element will contain large amounts of radioactivity, mostly fission products. As the radioactivity decays, it produces radiation and "decay heat." The amount of radioactivity remaining in the fuel decreases according to the length of time after removal from the reactor. After removal from a reactor, the fuel elements are placed under water in a storage pool for cooling prior to being loaded into a cask for transport.

Although the specific cask design has not been identified, the applicant states that the irradiated fuel elements will be shipped after at least a 90-day cooling period in Federally-approved casks designed for transport by either truck or rail. The cask will weigh perhaps 30 tons for truck or 100 tons for rail. To transport the irradiated fuel from Unit No. 2, the applicant estimates 22 truckload shipments per year with two fuel elements per cask and one cask per truckload; or 10 rail carload shipments per year with seven fuel elements per cask and one cask per carload. With the addition of 13 truckloads or six carloads for transporting the irradiated fuel from Unit No. 1, that would be a total of 35 truckloads or 16 carloads per year from both Units. An equal number of shipments will be required to return the empty casks.

c. Transport of Solid Radioactive Wastes

The applicant estimates that from 100 to 150 drums of solid radioactive wastes will be produced in operating Unit No. 2 each year with the initial radwaste system. Spent resins and waste evaporator bottoms will be solidified in a mixture of vermiculite and cement and soft, solid wastes such as paper, rags, etc., compacted in DOT-approved containers for shipment and disposal. The applicant estimates from five to 10 truckloads of drums of wastes will be shipped out for disposal from Unit No. 2 each year. The staff estimates an equal number of truckloads from Unit No. 1, to average 15 truckloads per year from both Units.

d. Principles of Safety in Transport

Protection of the public and transport workers from radiation during the shipment of nuclear fuel and waste, described above, is achieved by a combination of limitations on the contents (according to the quantities and types of radioactivity), the package design, and the external radiation levels. Shipments move in routine commerce and on conventional transportation equipment. Shipments are therefore subject to normal accident environments, just like other non-radioactive hazardous cargo. The shipper has essentially no control over the likelihood of an accident involving his shipment. Safety in transportation does not depend on special routing.

Packaging and transport of radioactive materials are regulated at the Federal-level by both the AEC and DOT. In addition, certain aspects such as limitations on gross weight of trucks, are regulated by the States.

The probability of accidental releases of low level contaminated material is sufficiently small that, considering the form of the waste, the likelihood of significant exposure is extremely small. Packaging for these materials is designed to remain leakproof under normal transport conditions of temperature, pressure, vibration, rough handling, exposure to rain, etc. The packaging may release its contents in an accident.

For larger quantities of radioactive materials, the packaging design (Type-B packaging) must be capable of withstanding, without loss of contents or shielding, the damage which might result from a severe accident. Test conditions for packaging are specified in the regulations and include tests for high-speed impact, puncture, fire, and immersion in water.

In addition, the packaging must provide adequate radiation shielding to limit the exposure of transport workers and the general public. For irradiated fuel, the package must have heat-dissipation characteristics to protect against overheating from radioactive decay heat. For fresh and irradiated fuel, the shipper must also provide under both normal design basis damage conditions a specified margin of criticality safety.

Each package in transport is identified on two sides by a distinctive radiation label; there are also warning signs on the transport vehicle.

Based on the truck accident statistics for 1969,[63] a shipment of fuel or waste from a reactor may be expected to be involved in an accident about once every six years. In case of an accident, procedures which carriers are required[64] to follow will reduce the consequences of an accident in many cases. The procedures include segregation of damaged and leaking packages from people, and notification of the shipper and DOT. Radiological assistance teams are available through an inter-Governmental program to provide equipped and trained personnel These teams, dispatched in response to calls for emergency assistance, can mitigate the consequences of an accident.

2. Radiological Impact - Transportation Exposures During Normal (No Accident) Conditions

a. Cold Fuel

The transport of cold fuel has been described in Section V.F.1.a. Since the nuclear radiations and heat emitted by cold fuel are small, there will be essentially no effect on the environment during transport under normal conditions. Exposure of individual transport workers is estimated to be less than 1 millirem (mrem) per shipment. For the eight shipments, with two drivers for each vehicle, the total dose would be about 0.02 man-rem*/yr. The radiation level associated with each truckload of cold fuel will be less than 0.1 mrem/hr at 6 feet from the truck. A member of the general public who spends 3 minutes at an average distance of 3 feet from the truck might receive a dose of about 0.005 mrem per shipment. The dose to other persons along the shipping route would be extremely small.

b. Irradiated Fuel[4]

Irradiated fuel will be transported either by truck or by a combination of truck and rail. Based on actual radiation levels associated with shipments of irradiated fuel elements, the staff estimates the radiation level at 3 feet from the truck or rail car will be about 25 mrem/hr. The individual truck driver would be unlikely to receive more than about 30 millirem in the 1,000 mile shipment. For the 35 shipments by truck during the year with two drivers on each vehicle, the total dose would be about 2 man-rem/yr.

For the combination truck-rail shipment, the individual truck driver would be unlikely to receive more than 15 mrem in the short trip to the railhead. The staff estimates that during the transfer of the cask from the truck to the rail car, four men might work for an hour at an average distance of 6 feet from the cask and might receive individual doses of about 10 mrem/hr.

Train breakmen might spend a few minutes in the vicinity of the car at an average distance of 3 feet, for an average exposure of about 0.5 rem per shipment. With 10 different brakemen involved along the route, the total dose for 16 shipments during the year is estimated to be about 0.08 man-rem.

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*Man-rem is an expression for the summation of whole body doses to individuals in a group. In some cases, the dose may be fairly uniform and received by only a few persons (e.g., drivers and brakemen) or, in other cases, the dose may vary and be received by a large number of people (e.g., 10^5 persons along the shipping route.

The total dose to transport workers for the 16 shipments by truck and rail, assuming two drivers on each truckload, would be about 1.2 man-rem.

A member of the general public who spends 3 minutes at an average distance of 3 feet from the truck or rail car might receive a dose of as much as 1.3 mrem. If 10 persons were so exposed per shipment, the total annual dose for the 35 shipments by truck would be about 0.5 man-rem and for the 16 shipments by rail, about 0.2 man-rem. Approximately 300,000 persons who reside along the 1,000-mile route over which the irradiated fuel is transported might receive an annual dose of about 0.9 man-rem if transported by truck, and 0.4 man-rem if transported by rail. The regulatory radiation level limit of 10 mrem/hr at a distance of 6 feet from the vehicle was used to calculate the integrated dose to persons in an area between 100 feet and 1/2 mile on both sides of the shipping route. It was assumed that the shipment would travel 200 miles per day and the population density would average 330 persons per square mile along the route.

The amount of heat released to the air from each cask will vary from about 30,000 Btu/hr for truck casks to about 250,000 Btu/hr for rail casks. For comparison, 35,000 Btu/hr is about equal to the heat released from an air conditioner in an average size home. Although the temperature of the air which contacts the loaded cask may be increased a few degrees, because the amount of heat is small and is being released over the entire transportation route, no appreciable thermal effects on the environment will result.

c. Solid Radioactive Wastes

As noted in Section V.F.1.c, about 15 truckloads per year of solid radioactive wastes will be shipped to a disposal site. Under normal conditions, the individual truck driver might receive as much as 15 mrem per shipment. If the same driver were to drive the 15 truckloads in a year, he could receive an estimated annual dose of about 225 mrem during the year. A total dose to all drivers for the year, assuming 2 drivers per vehicle, might be about 0.5 man-rem.

A member of the general public who spends 3 minutes at an average distance of 3 feet from the truck might receive a dose of as much as 1.3 mrem. If 10 persons were so exposed per shipment, the total annual dose for the 15 shipments by truck would be about 0.2 man-rem. Approximately 180,000 persons who reside along the 600-mile route over which the solid radioactive waste is transported might receive an annual dose of about 0.2 man-rem. These doses were calculated for persons in an area between 100 feet and 1/2 mile on either side of the shipping route, assuming 330 persons per square mile, 10 mrem/hr at 6 feet from the vehicle, and the shipment traveling 200 miles per day.

G. PLANT DISMANTLING AND DECOMMISSIONING

Under the Commission's regulations in 10 CFR 50, an application must contain information sufficient to demonstrate that the applicant possesses or has reasonable assurance of obtaining the funds necessary to cover the estimated costs of permanently shutting the Plant down and maintaining it in a safe condition. It is expected that the applicant will supply detailed dismantling information to the Commission at such time that an application for an amendment to the operating license for dismantling of the facility is filed. The staff will at that time conduct a Safety and Environmental Evaluation of the decommissioning procedures proposed by the applicant.

1. Impacts on the Environment

Dismantling the Plant will have many of the same impacts on the environment as the original site preparation and Plant construction. There will be temporary disturbances due to the dismantling activities and the permanent restoration of most of the site to ecological productivity.

It is expected that the dismantling of the Plant will cost several millions of dollars and take more than a year to complete. During that time, workmen will be on the site, quantities of debris, salvageable material, and radioactive material will be transported under controlled conditions from the site by truck, barge, or rail. Concrete and other construction materials will be used to entomb the reactor and associated radioactive components. In response to comments from the Department of the Interior in Appendix XII-8: the level of any radioactive material left after decontamination will be required to meet the Commission's regulations. The applicant will be required to assure that no hazard to groundwater or to the surrounding area will occur. This will be accomplished by removing those materials whose radioactivity level could cause any problems and by shipping them to a Federally-approved site for burial. At no time will the applicant be allowed to leave any highly radioactive material buried along the banks of the Hudson River. A considerable amount of earth-moving will be required to restore the parking lots and other areas to usable grade levels, and finally, a security fence will be erected on the ground above the entombed reactor site.

To the extent that any structures of components are not completely demolished and their foundations removed, that small amount of land will be committed to nonproductive use. If the soil under any structure which has been demolished is not replaced or cleared of chemical contamination, that land will be nonproductive until natural processes leach the chemicals away.

2. Radiological Impacts on Environment

The dismantling of the Plant will have radiological impacts characteristic of those of transporting irradiated fuel and radioactive wastes from the site. (See Section V.F.)

The radioactive materials not transported offsite most likely will be entombed with the reactor and associated components. The entombment will be designed to maintain its integrity for sufficient time for radioactive decay of activated and fission products. In addition, the entombment will be permanently placarded to identify it as a radioactive area.

After dismantling is completed and the site is maintained in a safe condition, it is anticipated that the proposed action will have no significant radiological impact on the environment.

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VI. ENVIRONMENTAL IMPACT OF POSTULATED ACCIDENTS

A. PLANT ACCIDENTS

A high degree of protection against the occurrence of postulated accidents at Indian Point Unit No. 2 is provided through correct design, manufacture, and operation, and the quality assurance program used to establish the necessary high integrity of the reactor system, as considered in the Commission's Safety Evaluation dated November 16, 1970 and the Supplements to the Safety Evaluation. Deviations that may occur are handled by protective systems to place and hold the Plant in a safe condition. Notwithstanding this, the conservative postulate is made that serious accidents might occur, in spite of the fact that they are extremely unlikely; and engineered safety features are installed to mitigate the consequences of these postulated events. The probability of occurrence of accidents and the spectrum of their consequences to be considered from an environmental effects standpoint have been analyzed using best estimates of probabilities and realistic fission product release and transport assumptions. For site evaluation in the staff's safety review, extremely conservative assumptions were used for the purpose of comparing calculated doses resulting from a hypothetical release of fission products from the fuel against the 10 CFR 100 siting guidelines. The calculated doses that would be received by the population and environment from actual accidents would be significantly less than those presented in the staff's Safety Evaluation. The Commission issued guidance to applicants on September 1, 1971, requiring the consideration of a spectrum of accidents with assumptions as realistic as the state of knowledge permits. The applicant's response was contained in the Supplement No. 2 to the Environmental Report, dated October 15, 1971.[1]

The applicant's report has been evaluated, using the standard accident assumptions and guidance issued as a proposed amendment[2] to Appendix D of 10 CFR 50 by the Commission on December 1, 1971. Nine classes of postulated accidents and occurrences ranging in severity from trivial to very serious were identified by the Commission. In general, accidents in the high potential consequence end of the spectrum have a low occurrence rate, and those on the low potential consequence end have a higher occurrence rate. The examples selected by the applicant for these classes are shown in Table VI-1. The examples selected are reasonably homogeneous in terms of probability within each class, although the staff considers the release of the waste gas decay tank contents as more appropriately in Class 3, and the steam generator tube rupture as more appropriately in Class 5. Certain assumptions made by the applicant do not exactly agree with those in the proposed

TABLE VI-1

CLASSIFICATION OF POSTULATED ACCIDENTS AND OCCURRENCES

Class	AEC Description	Applicant's Example(s)
1.0	Trivial incidents	Not considered
2.0	Small releases outside containment	Small valve or pipe leak in the auxiliary building
3.0	Radwaste system failures	Waste gas decay tank valve leak; inadvertent discharge of the contents of a waste liquid tank or waste gas decay tank
4.0	Fission products to primary system (BWR)	Not applicable
5.0	Fission products to primary and secondary systems (PWR)	Normal operation with fuel failures and steam generator leaks
6.0	Refueling accidents	Dropped fuel assembly inside containment
7.0	Spent fuel handling accident	Dropped fuel assembly outside containment
		Onsite transportation accident
8.0	Accident initiation events considered in design basis evaluation in the SAR	Loss of coolant, rupture of waste gas decay tank, control rod assembly ejection, steam line break, steam generator tube rupture
9.0	Hypothetical sequence of failures more severe than Class 8	Not considered

Annex to Appendix D, but the use of alternative assumptions does not significantly affect overall environmental risks. Table VI-2 reflects the types of accidents described in the proposed amendment to Appendix D, 10 CFR Part 50, published in the Federal Register on December 1, 1971, for comment and interim guidance.

The staff's estimates of the dose which might be received by an assumed individual standing at the site boundary in the downwind direction, using the assumptions in the proposed Annex to Appendix D, are presented in Table VI-2. The staff's estimates of the integrated exposure that might be delivered to the population within 50 miles of the site are also presented in Table VI-2. The man-rem estimate was based on the projected population around the site for the year 1980.

To rigorously establish a realistic annual risk, the calculated doses in Table VI-2 would have to be multiplied by estimated probabilities. The events in Classes 1 and 2 represent occurrences which are anticipated during Plant operation and their consequences, which are very small, are considered within the framework of routine effluents from the Plant. Except for a limited amount of fuel failure and some steam generator leakage, the events in Classes 3 through 5 are not anticipated during Plant operation; but events of this type could occur sometime during the 40-year Plant lifetime. Accidents in Classes 6 and 7 and small accidents in Class 8 are of similar or lower probability than accidents in Classes 3 through 5 but are still possible. The probability of occurrence of large Class 8 accidents is very small. Therefore, when the consequences indicated in Table VI-2 are weighted by probabilities, the environmental risk is very low. The postulated occurrences in Class 9 involve sequences of successive failures more severe than those required to be considered in the design basis of protection systems and engineered safety features. Their consequences could be severe. However, the probability of their occurrence is so small that their environmental risk is extremely low. Defense in depth (multiple physical barriers), quality assurance for design, manufacture and operation, continued surveillance and testing, and conservative design are all applied to provide and maintain the required high degree of assurance that potential accidents in this class are, and will remain, sufficiently small in probability that the environmental risk is extremely low.

Table VI-2 indicates that the realistically estimated radiological consequences of the postulated accidents would result in exposures of an assumed individual at the site boundary to concentrations of

TABLE VI-2

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS

Class	Event	Estimated Fraction of 10 CFR 20 Limit at Site Boundary[1]	Estimated Dose to Population in 50-Mile Radius, Man-rem
1.0	Trivial incidents	2/	2/
2.0	Small releases outside containment	2/	2/
3.0	Radwaste system failures		
3.1	Equipment leakage or malfunction	0.095	49
3.2	Release of waste gas storage tank contents	0.37	190
3.3	Release of liquid waste storage tank contents	0.004	2.3
4.0	Fission products to primary system (BWR)	N. A.*	N. A.*
5.0	Fission products to primary and secondary systems (PWR)		
5.1	Fuel cladding defects and steam generator leaks	2/	2/
5.2	Off-design transients that induce fuel failure above those expected and steam generator leak	0.002	1.1
5.3	Steam generator tube rupture	0.12	65
6.0	Refueling accidents		
6.1	Fuel bundle drop	0.02	10
6.2	Heavy object drop onto fuel in core	0.34	180
7.0	Spent fuel handling accident		
7.1	Fuel assembly drop in fuel rack	0.012	6.5

Class	Event	Estimated Fraction of 10 CFR 20 Limit at Site Boundary[1]	Estimated Dose to Population in 50-Mile Radius, Man-rem
7.2	Heavy object drop onto fuel rack	0.05	26
7.3	Fuel cask drop	N. A.*	N. A.*
8.0	Accident initiation events considered in design basis evaluation in the safety analysis report		
8.1	Loss-of-coolant accidents		
	Small Break	0.21	190
	Large Break	1.8	5,800
8.1(a)	Break in instrument line from primary system that penetrates the containment	N. A.*	N. A.*
8.2(a)	Rod ejection accident (PWR)	0.18	580
8.2(b)	Rod drop accident (BWR)	N. A.*	N. A.*
8.3(a)	Steamline breaks (PWR's outside containment)		
	Small Break	<0.001	0.34
	Large Break	0.001	0.65
8.3(b)	Steamline breaks (BWR)	N. A.*	N. A.*

1/ Represents the calculated fraction of a whole body dose of 500 mrem or the equivalent dose to an organ.

2/ These releases are expected to be in accord with proposed Appendix I to 10 CFR 50 for routine effluents (i.e., 5 mrem/yr to an individual from either gaseous or liquid effluents).

* N. A. means not applicable.

radioactive materials within or comparable to the Maximum Permissible Concentrations (MPC) of Table II, Appendix B of 10 CFR 20. Table VI-2 also shows that the estimated integrated exposure of the population of 21,000,000 (estimated 1980 population) within 50 miles of the Plant from each postulated accident would be orders of magnitude smaller than that from naturally occurring radioactivity, which corresponds to approximately 2,100,000 man-rem per year based on a natural background level of 100 millirem per year. When considered with the probability of occurrence, the annual potential radiation exposure of the population from all the postulated accidents is an even smaller fraction of the exposure from natural background radiation and, in fact, is well within naturally occurring variations in the natural background. It is concluded from the results of the realistic analysis that the environmental risks due to postulated radiological accidents are exceedingly small.

B. TRANSPORTATION ACCIDENTS

1. Cold Fuel

The cold fuel to be transported to Indian Point has been described in Section G.F.1.a. Under accident conditions other than accidental criticality, the pelletized form of the nuclear fuel, its encapsulation, and the low specific activity of the fuel, limit the radiological impact on the environment to negligible levels.

The packaging is designed with a specific safety margin to prevent criticality under normal and severe accident conditions. To release a number of fuel assemblies under conditions that could lead to accidental criticality would require severe damage or destruction of more than one package, which is unlikely to happen in other than an extremely severe accident.

The probability that an accident could occur under conditions that could result in accidental criticality is extremely remote and is considered to be impossible for all meaningful purposes. If criticality were to occur in transport, persons within a radius of about 100 feet from the accident might receive a serious exposure but beyond that distance, no detectable radiation effects would be likely. Persons within a few feet of the accident could receive fatal or near-fatal exposures unless shielded by intervening material. Although there would be no nuclear explosion, heat generated in the reaction would probably separate the fuel elements so that the reaction would stop. The reaction would not be expected to continue for more than a few seconds and normally would not occur. Residual radiation levels due to induced radioactivity in the fuel elements might reach a few roentgens per hour at 3 feet. There would be very little dispersion of radioactive material.

2. Irradiated Fuel

Effects on the environment from accidental releases of radioactive materials during shipment of irradiated fuel (see Section V.F.1.b) have been estimated for the situation where contaminated coolant is released and the situation where gases and coolant are released.

a. Leakage of contaminated coolant resulting from improper closing of the cask is possible as a result of human error, even though the shipper is required to follow specific procedures which include tests and examination of the closed container prior to each shipment. Such an accident is highly unlikely during the 40-year life of the Plant.

Leakage of liquid at a rate of 0.001 cc per second or about 80 drops/ hour is about the smallest amount of leakage that can be detected by visual observation of a large container. If undetected leakage of contaminated liquid coolant were to occur, the amount would be so small that the individual exposure would not exceed a few millirem and only a very few people would receive such exposures.

b. Release of gases and coolant is an extremely remote possibility. In the improbable event that a cask is involved in an extremely severe accident such that the cask containment is breached and the cladding of the fuel assemblies penetrated, some of the coolant and some of the noble gases might be released from the cask.

In such an accident, the amount of radioactive material released would be limited to the number of fuel rods which were ruptured or became perforated. This material consists of the noble gases in the void spaces in the fuel pins and some fraction of the low level contamination in the coolant. Persons would not be expected to remain near the accident due to the severe conditions which would be involved, including a major fire. If releases occurred, they would be expected to take place in a short period of time. Only a limited area would be affected. Persons in the downwind region and within 100 feet or so of the accident might receive doses as high as a few hundred million. Under average weather conditions, a few hundred square feet might be contaminated to the extent that it would require decontamination (that is, Range I contamination levels) according to the standards[3] of the Environmental Protection Agency.

3. Solid Radioactive Wastes

It is highly unlikely that a shipment of solid radioactive waste will be involved in a severe accident during the 40-year life of the Plant. If a shipment of low-level waste (in drums) becomes involved in a severe accident, some release of waste might occur but the specific activity of the waste will be so low that the exposure of personnel would not be expected to be significant. Other solid radioactive wastes will be shipped in Type-B packages. The probability of release from a Type-B package, in even a very severe accident, is sufficiently small that, considering the solid form of the waste and the very remote probability that a shipment of such waste would be involved in a very severe accident, the likelihood of significant exposure would be extremely small.

In either case, spread of the contamination beyond the immediate area is unlikely and, although local clean-up might be required, no significant exposure to the general public would be expected to result.

4. Severity of Postulated Transportation Accidents

The events postulated in this analysis are unlikely but possible. More severe accidents than those analyzed can be postulated and their consequences could be severe. Quality assurance for design, manufacture, and use of the packages, continued surveillance and testing of packages and transport conditions, and conservative design of packages ensure that the probability of accidents of this latter potential is sufficiently small that the environmental risk is extremely low. For those reasons, more severe accidents have not been included in the analysis.

5. Alternatives to Normal Transportation Procedures

Alternatives, such as special routing of shipments, providing escorts in separate vehicles, adding shielding to the containers, and constructing a fuel recovery and fabrication plant on the site rather than shipping fuel to and from the Station, have been examined. The impact on the environment of transportation under normal or postulated accident conditions is not considered to be sufficient to justify the additional effort required to implement any of the alternatives.

REFERENCES FOR CHAPTER VI

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VII. ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

A. FACTORS RESPONSIBLE FOR ADVERSE EFFECTS

Several factors associated with the operation of Indian Point Units Nos. 1 and 2 are capable of producing adverse effects. The more important of these factors in the order of their importance include:

1. Entrainment of large numbers of planktonic organisms in the once-through cooling system.

2. Impingement of large numbers of various fish species on the intake screens.

3. Discharges of heated water to the Hudson River.

4. Discharges of toxic amounts of residual chlorine or chloramines to the Hudson River.

5. Releases of radionuclides to the environment.

6. Reduction of dissolved oxygen concentrations in the effluent water.

Other adverse effects would include the consumptive use of non-replenishable natural resources and the long-term commitment of other resources. These aspects of the Plant are discussed in Chapters VIII and IX and are not included in this Chapter.

B. PROBABLE ADVERSE EFFECTS

1. Land Use

The Indian Point facilities for Units Nos. 1, 2, and 3 occupy 35 acres of the 239-acre site. The operation of Indian Point Unit No. 2 should not produce appreciable alterations in the public use of the general area beyond those caused by the operation of Unit No. 1. The site is to be developed for multiple public use, including a new visitors' center, a nature area, and increased parking facilities. A reactor simulator for training reactor operators is also on the site. The applicant's planned activities in landscaping and re-planting the remaining portion of the site and the development of an 80-acre forested park with a small freshwater lake should ultimately more than compensate for the loss of any wildlife habitat because of the land committed to the facility. Since the site was formerly an amusement park which was eventually abandoned, the change to a power plant site may have resulted in less damage to the terrestrial ecosystem of the area than, for example, if the amusement park had expanded or had been converted to some other business activity involving destruction of all the land area.

No additional land was required for transmission line corridors to carry the Plant's electrical output to the switchyard and eventually to the applicant's power system. No added right-of-way was required to convert a single 345-kV transmission line from Unit No. 2 to the Buchanan Substation located 200 feet from the Indian Point site boundary. The line from the Buchanan Substation is parallel to an existing 138-kV transmission line now in service. The applicant has selected the line design and construction of the needed transmission poles to conform to the guidelines for protection of aesthetic and other environmental values.

2. Air Use

The operation of Indian Point Unit No. 2 would not greatly increase the level of nonradioactive air pollutants in the area. Only minor amounts of combustion products as listed in Table III-16 will be released from the Station during testing operation of diesel-powered engines for emergency use. Air pollution at the site would be primarily from the combustion of sulfur-containing fuel oil used in the superheater of Unit No. 1. The applicant is converting from fuel oil containing 1% sulfur to one of 0.3% sulfur. In both cases the sulfur dioxide levels will be within Federal limits. Air pollution in the region of older oil-burning power plants, however, could be reduced by being able to change the status of some of these plants from one of base-load capacity to reserve capacity and eventually retiring these plants altogether.

3. Water Use

Plant operation has the potential for causing changes in the biological and physical aspects of the environment and for imposing some limitations on future industrial uses of the Hudson River. The principal adverse effect that could limit future industrial uses of the Hudson River is related to the discharged heat. The once-through condenser cooling system may preclude the nearby construction and operation of additional industrial facilities which would add to the thermal load of the Hudson River near Indian Point. However, Plant operations should not interfere with present industrial or community utilization of the resource. Ground water supplies will not be affected by Plant operation because any thermal, chemical, and radioactive releases would flow directly into the Hudson River.

The construction of the intake and discharge structure along the river banks disturbed a minor amount of benthos. Dredging and filling caused some silting of the river water. However, the resultant impact on aquatic communities has been minimal during any modification of the physical structure. Much of the impact from construction took place several years ago when the work on construction of Units Nos. 1 and 2 was just started.

As indicated in Table III-2, operation of Units Nos. 1 and 2 will require the withdrawal of large volumes of water from the Hudson River to dissipate the waste heat. The State of New York and the Federal Government require that this warm water, which will be returned to the Hudson, be dissipated in accordance with their regulations governing the discharge of thermal effluents into estuaries.

a. Flow Characteristics of the Hudson River Estuary

Predominantly, the flow at Indian Point is tidal in nature, with peak ebb and flood flows ranging from 200,000 to 300,000 cfs. Monthly average freshwater flow rates in the lower Hudson range from 6,500 cfs in August to 38,000 cfs in April. The weekly average drought freshwater flow which may be anticipated in one year out of ten is 3,000 cfs.

Salt water intrudes upriver to an extent determined by the existing rate of freshwater flow. At Indian Point, salt water will be present when the freshwater flow is less than approximately 20,800 cfs. The salinity of the water is an indication of the extent of the movement of the salt front unstream from Indian Point.

A large circulatory flow pattern exists throughout the salt intrusion zone which is superimposed on the oscillatory tidal flow and the downstream freshwater flow. On the average, over a full tidal cycle, there is a net upstream movement of more saline water along the bottom of the river and a net downstream movement of less saline water along the surface of the river - in effect, a two-layer flow. At any one instant, however, there is no distinct interface between the two "layers" because there is vertical mixing throughout the depth of the river. Further details of the characteristics of the river flow in relation to a description of the dispersal of the thermal plume and the transport of aquatic organisms are found in Section II.E.1, Section III. E.1, Appendix V-2, and Appendix V-3 of this Statement.

b. Water Withdrawal

The withdrawal rate of a maximum of 1,200,000 gpm or 2,650 cfs of river water for once-through cooling for Units Nos. 1 and 2 represents an appreciable fraction of the Hudson River volume. In springtime, when fresh water is abundant, the saltwater front is pushed downstream of Indian Point, and the river flow is entirely freshwater flow, then the volume withdrawn at the Plant is about 13% to 8.6% of the river flow, when it ranges between 20,000 cfs and 30,000 cfs. In the summer, when freshwater flow is low, the saltwater front has pushed its way upstream of Indian Point, and the river flow is saline water flow, then the volume of water withdrawn is about 12%, based on a seaward flow of 22,000 cfs. The withdrawal of fresh water by the once-through cooling system ranges from 13% at 20,000 cfs during late spring to about 35% at 7,300 cfs during the summer. The applicant proposes to decrease intake flow during the winter by partial recirculation of the discharge water.

c. Heat Dissipation

With pump flow reduction in the winter, the temperature rise of the thermal discharges will increase. Based on a maximum flow of 840,000 gpm plus 30,000 gpm service water, the thermal discharge is about 15F° above ambient river water temperature. The reduction of flow through the pumps to 504,000 gpm would increase the temperature rise from 15F° to 24F°. The applicant in its comments in Appendix XII-23 has provided a table to indicate the temperature rise for a number of pumping conditions. (See Table XII-1.)

The heated cooling water from Indian Point is discharged into the Hudson River through a submerged multiport structure. The heat dissipation models presented by the applicant as discussed in Section III.E.1 have a number of deficiencies that make their conclusions uncertain. The staff's analysis indicates that the New York State thermal regulation of a 90°F maximum river surface temperature will be met even under summer operating conditions when the ambient river temperature is at its maximum. However, the additional New York standards for surface area and cross-sectional area enclosed within the 4F° isotherm may not be met. The area occupied by the 4F° isotherm will be less than 50% of the vertical cross-sectional area of the river, but there is a reasonable probability that the increase in temperature at the surface of the river may be more than 4F° for more than two-thirds of the surface area of the river and may even extend across the whole width of the river." The applicant will have to demonstrate in actual practice that the thermal discharge regulations can be met through the entire year.

4. Biological Impact

No important changes in the terrestrial biota are expected to result from Plant operation. The principal adverse effects will occur in the aquatic environment of the Hudson River. The operation of the Indian Point facility will subject aquatic organisms to stress through toxic properties of residual chlorine, thermal stresses of the waste heat, and mortality resulting from the impingement of fishes and entrainment of phytoplankton, microcrustaceans, and larval stages of larger invertebrates and any of the estuarine fishes which use the area for spawning.

The use of sodium hypochlorite to prevent fouling of the circulating water system may result in toxic concentrations of chloramines in the Hudson River near Indian Point. The concentrations can be slightly lowered by limiting chlorination to periods of peak tidal flow. Also, the effects can be minimized by restricting chlorination to the daylight hours, when most of the larger zooplankton will be near the bottom, away from the highest concentrations which initially will occur in the thermal plume. Neither of these alternatives will eliminate the problem. The chlorine demand of the river water could result in producing some chloramines which are also toxic to fish and biota. Other chemicals listed in Table III-14 are expected not to result in further degradation of the water quality of the Hudson River.

Drops in dissolved oxygen concentrations were measured between the intake and discharge of cooling water for Unit No. 1. Although these measurements made by the applicant may be in error, it is possible that Unit No. 2 may produce the same effect. A significant drop in dissolved oxygen concentration during passage of water through the Plant could be deleterious at times. For example, at a time when the demand for oxygen by the biota is high and unfavorable environmental conditions cause low ambient oxygen levels, an additional artificial drop in dissolved oxygen could have significant effects on the aquatic community. Thus, the dissolved oxygen levels in the discharge canal and plume should be routinely examined during the initial operation of the Plant. If dissolved oxygen is significantly depressed in the canal or plume during periods of low dissolved oxygen in the summer, then steps such as use of aeration should be taken to alleviate this.

The relationship of Plant operations to entrainment of non-screenable organisms and to impingement of larger organisms on the screens which filter debris from the cooling water is a problem of considerable magnitude. If both Units operate as they are presently constructed, then a substantial increase can be expected in the numbers of fish killed by impingement. Based on a larger withdrawal of water through the three condensers of the once-through cooling system of Unit No. 2 compared with one of Unit No. 1, an increase in fish kills totaling 2.5 to 3 times the number killed by Unit No. 1 may result from operation of Unit No. 2.

The entrainment of planktonic organisms appears to be the most serious threat to the aquatic community. Entrained organisms will be exposed to mechanical, thermal, and chemical damage. Most species of the aquatic organisms in the area will be subject to entrainment at some life stage. These include phytoplankton, planktonic crustaceans, and larval stages of benthic invertebrates and of many of the estuarine fishes which use the area for spawning. The species of fish which appear most likely to be affected include the striped bass, alewife, blueback herring, tomcod, smelt, American shad, and white perch.

The staff's assessment of the ecological impact indicates over the long-term the operation of this Plant has a significant potential for causing extensive damage to the biological community within the Hudson River. Of real concern are the populations of the anadromous fishes listed above and the food web that supports them. Changes in species composition and seasonal density will probably occur in the phytoplankton community from their natural seasonal cycles by temperature changes due to thermal discharges. Important changes may occur in planktonic and epibenthic invertebrates, which are the principal food organisms for the fish populations, thereby affecting the availability of the food for other fish populations.

The results of increased mortality or decreased reproductive success in the various species will reduce their ability to reproductively compensate for additional mortality from other causes. If their compensatory reserve is already low, the operation of the Indian

Point complex may result in distinct reductions in the populations of these species. The area of the Hudson River estuary affected by such changes in local populations will extend throughout the area which depended on the affected population for recruitment.

Among the anadromous fishes, the alewife, blueback herring, smelt, American shad, tomcod, and striped bass may be significantly affected by Plant operation. For example, the striped bass populations which depend upon recruitment from the Hudson River include not only the Hudson itself, but much of Long Island Sound and the New York Bight as well. The staff's analysis indicates that Plant operations will kill 30-50% of the annual production of striped bass through impingement and entrainment. If their compensatory reserve were high, then no significant changes in recruitment to the various adult populations would occur. However, there is a direct linear correlation between landing of adults in the Hudson and subsequent catch in the Mid-Atlantic, and consequently there will be an initial drop in recruitment to the adult population and a subsequent decrease in the adult population. The operation of Units Nos. 1 and 2 with once-through cooling beyond 5 years could result in cumulative effects that would cause a substantial reduction in the striped bass populations in areas dependent on recruitment from the Hudson River.

The staff has responded in Chapters V, XII, and the Appendices V-1, V-2 and V-3 to comments from Federal and State agencies and the applicant, and interested persons, regarding biological impacts of Plant operation.

5. Radioactive Releases and Radiological Impact

The Plant, along with Unit No. 1, will release small quantities of radioactivity into the environment during normal operation; the concentrations will be low-level and well below the limits set in the Commission's regulations.

Based on normal operation of the Plant with 0.25% defective fuel, with a steam generator leak of 20 gallons per day, and over 60- to 45-days holdup of radioactive gases respectively, the estimated radioactive releases at Indian Point would result in total-body doses to an individual of <1.0 mrem/year near the site boundary which is one-fourth of the 5-mrem guide in proposed Appendix I of 10 CFR 50. Furthermore, individual doses would be less than 1% of the present limits set forth in 10 CFR 20. The man-rem dose to the population within 50 miles of the site will be about 2.2% for the initial and 2.18% for the modified radioactive waste system of the suggested guideline [400 man-rems/year for each 1000 MW(e)] that should be achievable by conformance with the numerical values in proposed Appendix I of 10 CFR 50. These dose estimates are small fractions (<0.005%) of the dose due to natural background. Individuals spending all of their time within 2 miles of the reactor would receive on the average only about 0.03% of the typical background dose of 100 mrem/year. This is far below the normal variation in background dose. No discernible radiological impact on the population therefore is expected due to the normal operation of Units Nos. 1 and 2. Similar considerations for the liquid radioactive wastes indicate that no discernible radiological impacts are expected.

The applicant in Supplement No. 1 discusses improvement of some of the components of the radioactive waste system. Improvements including polish demineralizers, improved waste evaporator and steam generator blowdown purification equipment for treating liquid wastes, and charcoal traps for gaseous wastes will reduce the radioactivity released by the Plant. Use of the modified radioactive waste system will assure that the radioactive releases to the environment will be as low as practicable, as defined in proposed Appendix I of 10 CFR 50. Radioactive releases from neither the present nor the modified radwaste systems will have a significant adverse impact on man. In-Plant monitoring and controls, as well as radiological monitoring of samples taken within and without the site boundaries, are designed to assure that all radioactive releases will be well within the Commission's regulations in 10 CFR 20 and 10 CFR 50.

Transportation to and from the Plant of non-irradiated and irradiated fuel and solid radioactive wastes which are packaged and shipped in Federally-approved containers and shielded casks will be subject to both the Commission's regulations in 10 CFR 70 and 71 and the Department of Transportation's (DOT) regulations in 49 CFR 170-179. The probability of accidental release of any radioactivity during transport is sufficiently small, considering the form of the transported material and its packaging, that the likelihood of significant radiation exposure is remote. With use of proper packages and containers, continued surveillance and testing of packages, and conservative design of packages, the environmental risk is small.

The potential exposures to the population from postulated accidents during operation of the Plant will depend on the type and magnitude of the accident that may result. In Chapter VI, different types of accidents and the probabilities of occurrence indicate that when multiplied by the probability of occurrence, the potential radiation exposure of the population from all the postulated accidents is an even smaller fraction of exposure than that from natural background radiation and is, in fact, well within naturally occurring variations in the natural background. It is concluded from the results of the realistic analysis that the environmental risks due to postulated accidents involving abnormal release of radioactivity during operation of the Indian Point Unit No. 2 at full power are exceedingly small.

Although the radionuclides released into the environment will not cause important dose increases to man, the radionuclide concentrations which aquatic organisms will be exposed to, or which are internally digested, could result in increased radiation exposures above that which the aquatic organisms normally are exposed to from natural radiation. These increased radiation doses, however, are less than the levels which are needed to produce observable effects on terrestrial and aquatic organisms and thus no damage is anticipated from Plant operation.

VIII. THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

This Chapter sets forth the relationship between the use of man's environment implicit in the proposed operation of Indian Point Unit No. 2 and the actions that could be taken to maintain and enhance the long-term productivity. The uses of the environment by succeeding generations must be considered as well as the extent to which present use might limit or enhance the range of beneficial uses in the future.

A. ENHANCEMENT OF PRODUCTIVITY

The benefits of production of electrical energy for the metropolitan New York area and the use of the Indian Point site for that purpose are identified in Chapters X and XI. The use of the site for nuclear power plants will enhance the productive and beneficial uses of this region and its resources. The area served is highly developed and includes a center of commerce of great importance. Supplying adequate power to this area will improve the beneficial services provided for commercial activities. With the present state of technology, this site will continue to be a good site for energy production, although the capacity of the Hudson River to absorb waste heat will limit the number of plants dependent upon the river for cooling water.

As discussed in Chapter X, the production of electricity is directly related to meeting the needs of residential customers. The customers of the applicant are primarily residential, commercial, and industrial users. The inability of the applicant to meet the electrical demands of its customers, primarily the people of New York City, would cause a serious hazard to the health and safety of the public.

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[*] The CEQ says that Section 102(2)(C)(iv) "in essence requires the agency to assess the action for cumulative and long-term effects from the perspective that each generation is trustee of the environment for succeeding generations." The "Declaration of National Policy" in NEPA sets the national objectives, related to this section of the detailed statement: "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations" [Section 101(b)(1)]; "assure for all Americans...productive... surroundings" [Section 101(b)(2)]; "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences." [Section 101(b)(3)]

Therefore, without Indian Point Unit No. 2 on line for summer 1972, the applicant had to purchase 920 MW(e) additional reserves and reduce planned retirements of unreliable fossil-fuel plants totaling 425 MW(e) to maintain a reserve margin of 24.9%.[1,5] Analysis of the peak load, capacity, and reserve margin for November 1972 through April 1973 shows that the applicant will not be able to meet its monthly load except December 1972 and February 1973; and in these two months, the applicant will not have the 600 MW(e) operating reserve required as a partner in the New York Power Pool. With Unit No. 2 at 100% of full power, the net dependable capability of the applicant's system would be about 10,929 MW(e); but with high deratings and high forced outages, the applicant will operate with a margin at a deficiency of 671 MW(e) in January 1973 and 46 MW(e) in March 1973. For average deratings and forced outages, the corresponding months would show excess reserve margins of 739 MW(e) and 754 MW(e), respectively, which are only about 150 MW(e) in excess of the 600 MW(e) for operating reserve required in the New York Power Pool. Without Indian Point Unit No. 2 on line to make up any power losses,[6] any forced outages of the applicant's older fossil-fueled plants cripples the supply of needed power to the metropolitan New York area.

As indicated in Chapter X, Indian Point Unit No. 2 is needed in the next year to meet the power demands of the applicant's service area and in the long-term to increase the standard of living, particularly for people living in the slum areas of New York City. The increase in electrical production by the applicant will enhance the well-being of the people and communities it serves, both in the near future and in the long-term.

The existence of a nuclear power plant will tend to attract some tourists; the applicant has recognized this by building a visitors' center on the site for Unit No. 1. Since the center was built in 1959, educational benefits have resulted from the exhibits, displays, and lectures on the subject of energy needs and principles of atomic power. The applicant plans to build a larger visitors' center within the next year and to develop gardens and nature trails through the 80-acre forested woodland on the site. The applicant also plans to enhance the beauty of the site through landscaping and planting after construction of Unit No. 3 is completed.

B. USES ADVERSE TO PRODUCTIVITY

The local effects of construction and operation of a nuclear power plant might reduce environmental productivity through impacts on land, water, and air. Land consumed for the Plant could, in some cases, alter the use of surrounding areas. Water resources and air are usually affected in some degree by materials and heat discharged from the Plant. These impacts are caused by all types of power plants, the effects differing mainly in degree. The staff considered all potential deterrents to productivity in this case. Only those that are significant or need explanation are summarized below.

1. Land Use

About 35 acres of the 239-acre applicant-owned tract is used for the Indian Point facilities. Transmission lines for Unit No. 2 will use existing rights-of-way.[2] The use of land for these purposes is insignificant in comparison with the energy produced and is, therefore, a reasonable allocation of productive capacity. Furthermore, the range of productive uses of surrounding areas will not be reduced by normal Plant operations.*

Use of the 239 acres of land within the applicant's boundaries for a power Plant should have no impact on the growth of commerce, industry, agriculture, or population in Westchester County. This land has been zoned only for industrial purposes and does not appear to have other potential uses that would be of equal or greater value to the local economy. The assessed valuation of Unit No. 2 at present will yield about $2 million in taxes per year to the Town of Cortlandt, Village of Buchanan, and the local school district.[3] If the increased availability of electricity or other factors were to stimulate rapid economic growth in Westchester County, the nonavailability of the land in the Indian Point site would not retard such growth.

Although use of the site seems reasonable for the 40 years of power Plant operation, the degree of usefulness of this land after operations are terminated and the possible curtailment of long-term

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* NEPA enjoins that the nation "attain the widest range of beneficial use of the environment." [Section 101(b)(3)]

productivity should also be considered.* The Commission requires that, upon decommissioning, all source, special nuclear, and by-product materials not exempt from licensing under Parts 30, 40, and 70 of Title 10, Code of Federal Regulations, must be removed from the site or secured and kept under surveillance. The applicant[4] has not identified specific actions which would be taken for decommissioning the Plant, but Section V.G discusses decommissioning the Plant.

Decommissioning plans for other nuclear plants include removal of all nuclear fuel, radioactive wastes, and unbound radioactive contamination on plant equipment. Further action may vary, depending upon the degree to which areas of the site will be held within a controlled zone. These alternatives have estimated costs ranging from $5 to $10 million (in terms of present value for decommissioning 40 years hence, including maintenance of control and surveillance in perpetuity). In some cases, no visible structures would remain; in others, major structures would be left, secured or converted for other uses. Costs of completely removing all Plant features and restoring the Indian Point site have not been estimated, but restoration could be attained if the value of the land justified it.

2. Water Use

The range of ground and surface water use, in the long term, will not be curtailed in the least except for the possible degradation of the ability of the Hudson River to support aquatic organisms, as discussed in detail in Chapters V and VII and Appendices V-2 and V-3. Commercial and industrial uses of the river, as well as public and recreation uses, should not be affected by the operation of Unit No. 2 except that discharge of heat while this Unit employs a once-through cooling system will limit the extent to which future industries in the immediate vicinity could further heat the water. So, the productivity of the river could not increase in this respect as long as the Plant is in operation. The value of such a future loss would be difficult, at best, to assess quantitatively. The immediate proposed use for cooling Unit No. 2 has a value and benefit, to the welfare of people in the applicant's service area, in terms of providing needed power.

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[*] A national objective declared by NEPA is to "maintain, wherever possible, an environment which supports diversity and variety of individual choice." [Section 101(b)(4)]

From the impacts and alternatives discussed in Chapters IV, V, VI, VII, X, and XI, the staff has concluded that the major effect of operation possibly inimical to the objectives of NEPA with respect to productivity is the potential for further degradation of the Hudson River estuary, which is the spawning and nursery area in the life cycle of many marine aquatic organisms that spend much of their adult life in the coastal areas of northern New Jersey, New York, and Long Island. Such degradation would over the long-term diminish the productivity of the area to a large extent. The ultimate economic impact on commercial and sport fishing has not been estimated; however, the rate of potential decline of the Hudson River fishery has been estimated to be highly significant. Further quantification of long-term effects seems irrevelant to the basic objective of preventing significant damage to the fishery resources of the Hudson River. The staff's proposed program for limited operation of the once-through cooling system, data collection, analysis of biological impact, and installation of an alternative cooling system can probably be carried out without loss of long-term productivity.

The long-term effect of the chemical effluents that will be discharged from the Plant cannot be forecast with exactness. Some chemicals, such as phosphates, tend to promote long-term growth of plankton even in modest amounts. Similarly, other chemicals are detrimental to either the short-term or long-term use of water by fish in the spawning and juvenile stages. The Plant will probably not discharge amounts of chlorine or phosphate greater than that from the sewage systems of nearby municipalities. However, further use of the Hudson River as a dumping place for chemical wastes can be minimized by alternatives that have been outlined in Chapter XI and by regulating the concentration, frequency, and length of time of the intermittent chemical treatment during Plant operation. Proper restrictions on chemical discharges during the next 100 years are necessary to preserve and maintain the Hudson River as a valuable natural resource of the United States.

An improved ecological monitoring program, which will be conducted by the applicant over many years of Plant operation, will assess the potential impacts that may occur over the long-term. The applicant will be required to assess the long-term adverse effects of Plant operation and to modify the Plant design and operation before serious degradation of the environment occurs.

The applicant and other members of the New York Power Pool, which have power plants on the Hudson River, have ongoing environmental studies of the long-term effects of power plants of all types on the water quality and biota of the Hudson River. Coordinated efforts to look at the overall effects of power plant operation on the Hudson River need greater emphasis and study before new power plants are located on the river. Such an effort should be conducted in cooperation with the New York State Department of Environmental Conservation and Public Utilities Commission and with Federal agencies, including the commercial and sport fish and wildlife services. The applicant uses the advice of the Hudson River Policy and Technical Committees as well as the Fish Advisory Board to plan for fish protection and for types of environmental monitoring programs and to investigate the potential effects of Plant operation on the Hudson River. However, an improved coordinated effort should be carried out with industrial, government, and other organizations to assure that discharges of all types into the river are restricted and that ecological studies are conducted from which positive steps can be found to alleviate the degradation of the Hudson River.

REFERENCES FOR CHAPTER VIII

1. Letter from T. A. Phillips, Bureau of Power, Federal Power Commission to R. S. Boyd, Division of Reactor Licensing, U.S. Atomic Energy Commission, December 22, 1971.

2. Consolidated Edison Company of New York, Supplement No. 1 to Environmental Report, Indian Point Unit No. 2, Section 2.1.2(c), September 9, 1971.

3. Letter to P. A. Morris, U.S. Atomic Energy Commission from W. J. Cahill, Jr., Consolidated Edison, on Responses to Questions on Environmental Aspects of Indian Point Units Nos. 1 and 2, October 28, 1971.

4. Consolidated Edison Company of New York, Supplement No. 1 to Environmental Report, Indian Point Unit No. 2, Section 2.6, September 9, 1971.

5. Testimony of B. Schwartz, Consolidated Edison Company of New York, Inc., on "Effects of Delay in Operation of Indian Point Unit No. 2," May 18, 1972.

6. Testimony of L. M. Stuzin, New York Department of Public Service, on "The Need for Additional Capacity for the Consolidated Edison Company," May 17, 1972.

IX. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

In this Chapter the commitments of resources to the construction and operation of Unit No. 2 are discussed, although only the latter would be affected by the proposed issuance of an operating license. Irreversible commitments generally concern changes in environmental resources that could not be restored at some later time. Irretrievable commitments are generally the use, consumption, or destruction of resources that are neither renewable nor recoverable for subsequent utilization.

The staff is concerned with the extent to which resource use contributes to or impairs the attainment of the widest range of beneficial uses of the environment.* The staff is also concerned with the need to enhance the quality of renewable resources and to fully utilize depletable resources.** The commitments identified here are those inherent in environmental impacts, which are discussed in Chapters IV, V, VI, and VII; commitments that involve local long-term effects on productivity are discussed in Chapter VIII.

A. COMMITMENTS CONSIDERED

There is wide range of possible resource commitments for nuclear power plants, many of which will be similar for all plants of the same size and type. The types of resources of concern in this case are:

(1) material resources: materials of construction, renewable resource materials consumed in operation, and depletable resources consumed;

(2) nonmaterial resources, including the range of beneficial and nonbeneficial uses of the environment.

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*The national objectives stated in the NEPA include "attainment of the widest range of beneficial uses of the environment without degradation risk to health or safety, or other undesirable and unintended consequences." [Section 101(b) (3)] The CEQ adds: "This requires the agency to identify the extent to which the action curtails the range of beneficial uses of the environment."

**A further NEPA objective is to "enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources." [Section 101(b) (6)]

Resources that would be irretrievably committed by the operation are:

(1) construction materials that cannot be recovered and recycled with present technology;

(2) materials that are rendered radioactive and cannot be decontaminated;

(3) materials consumed or reduced to unrecoverable forms, including uranium-235 and -238;

(4) space for long-term storage of radioactive materials;

(5) water used for disposal of heat and certain waste effluents;

(6) air used for disposal of minor quantities of wastes;

(7) capital investment of physical Plant facilities.

B. MATERIAL RESOURCES

Construction materials are almost entirely in the depletable category. Concrete and steel constitute the bulk of these materials, but there are numerous other mineral resources incorporated in the physical Plant. Commitments are not being made at this time on recycling these materials when their present use terminates. Economics clearly favors recycling for some materials but not for others. Plant operation will result in radioactive contamination of only a small portion of the Plant to such a degree that decontamination would be needed to reclaim and recycle the constituents. The quantities of materials that could not be decontaminated for unlimited recycling are very small fractions of the resources available in kind and in broad use in industry. If these quantities indeed become irretrievably lost, their expenditure is justified by the benefits of the electrical energy produced.*

Uranium is the principal material irretrievably consumed in Plant operation. Other materials that will, for practical purposes, be consumed are fuel cladding materials, reactor control elements, other replaceable reactor core components, chemicals used in processes such as water treatment and ion exchanger regeneration, ion exchange resins, and minor quantities of materials used in

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*This is a qualitative judgment based upon a general knowledge of plant design. Materials that are used in the Plant should be checked against a list of minerals for strategic stock piling.

maintenance and operation. Except for the uranium-235 and -238, the resource materials are used widely; therefore, their use in the proposed operation must be reasonable with respect to needs in other industries. The major use of the natural isotopes of uranium is for production of useful energy.[1] Considering the reserves of all depletable fuels, consumption of uranium in the proposed operation is a reasonable productive use of this resource. Estimated resources of nuclear fissile fuel exceed the reserves of fossil fuels, which also are useful raw materials for other industries. The estimates of energy resources and demands for the United States compiled by the Bureau of Mines[2] show that the total recoverable resources, expressed as theoretically available equivalent energy, amount to 26×10^{18} British thermal units (Btu) for all forms of fossil fuels, 39×10^{18} Btu for uranium, and 37×10^{18} Btu for thorium. Electrical generation by utilities in 1968 accounted for only 23% of the total use of depletable energy resources, which attests to the significant demands for the fossil fuels, particularly petroleum and natural gas, in other industries.

About 40,000 kg of uranium-235 and 30,000 kg of uranium-238 will be consumed, i.e., converted into non-fissile products, in Unit No. 2 during its operating life.[3] The nuclear fuel will be reprocessed after removal from the reactor to reclaim essentially all unconsumed uranium, namely, 96% of the total uranium introduced as new fuel.[4] About 10,000 kg of fissionable plutonium-239 will be produced and well be recovered in fuel processing and recovery facilities.

C. STORAGE SPACE

Radioactive wastes generated at the Plant will be released to the environment or shipped to licensed repositories. Reprocessing of spent fuel from this Plant will generate additional wastes, which will eventually be deposited in a long-term Federally-approved repository. The entire nuclear fuel cycle (from mine to waste repository) depends upon a highly developed system of interdependent facilities that have already been established for supporting the nuclear energy program in this country. As use of nuclear fuel increases, additional facilities needed supporting services. The licensing of privately owned facilities (such as the Midwest Fuel Recovery Plant) and the establishment of government-owned facilities (such as high-level waste repositories) will be the subject of detailed statements on environmental, resource, and other aspects of those facilities.

It is appropriate, however, to point out that onsite waste management programs for operation of Unit No. 2 will affect commitments of resources for ultimate waste storage and commitment of the environs of this Plant for radioactive wastes released routinely during operation. The Commission's policy is to keep the level of radioactivity of effluents from Unit No. 2 and similar plants as low as practicable, with the consequence that more storage space in repositories must be committed than would be required under more permissive release policies. The volume of wastes expected to be shipped to repositories from Unit No. 2 is estimated to be 29,000 to 44,000 ft^3 for 40 years of operation.[4] These low-level solid wastes are described in Chapters III, V, and VI. The general commitment of suitable storage space for such wastes is irreversible, but the staff does not expect detailed commitments on the ultimate disposal of Unit No. 2 wastes to be made at this time, so that a diversity of choice can be retained for the future.*

D. WATER AND AIR RESOURCES

The expected releases of chemicals, radioactive materials, and heat from Unit No. 2 and their consequences are discussed in Chapters III and V. Plant operation necessarily uses both air and water resources at Indian Point to disperse these discharges. However, this use is not a matter of consumption;[5] furthermore, the use does not curtail the range of beneficial uses of these environmental resources except as already mentioned in Sections V.B, V.C, and VIII. The proposed action has a potential for significantly affecting the aquatic organisms essential to maintenance of the fish population of the Hudson River as well as that along the Long Island Sound, New Jersey coast, and the New York Bight; the population could deteriorate beyond the point of rehabilitation. In this event, operation of the Plant could entail an irreversible commitment of the river as a resource. Details of the problem of biological impact have been described in Chapters V and VII and Appendices V-2 and V-3.

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*NEPA instructs that the nation should "maintain, wherever possible, an environment which supports diversity and variety of individual choice..." [Section 101(b)(4)]

E. FINANCIAL RESOURCES

The total investment of the applicant in the Plant is $178,250,000 as of February 1972,[6] which includes both costs of depletable and renewable resources and costs for non-resource-connected services. Another commitment is the time of over 6 years to build the physical plant. Construction of Unit No. 2 started in December, 1965; completion is expected by summer 1972.

F. CONCLUSION

The staff concludes that the proposed operation, if carried out under the radiological and non-radiological ecological surveillance program to be required by the Technical Specifications and described in Sections V.D and V.E of this Statement, will achieve the objectives of the National Environmental Policy Act with respect to use of resources. The environmental monitoring program will serve to provide a means for assessment of any damage to the environment and can be used to predict any irreversible or irretrievable damage to the environment. Alternate Plant design and operating procedures described in Chapter XI are available to avoid degradation of the environment beyond repair, and to optimize Plant operation with minimal damage to the environment.

REFERENCES FOR CHAPTER IX

1. Bureau of Mines, U. S. Department of the Interior, "Mineral Facts and Problems," 1970 Edition, p. 230.

2. Bureau of Mines, U. S. Department of the Interior, "Mineral Facts and Problems," 1970 Edition, p. 14.

3. Consolidated Edison Company of New York, Supplement No. 1 to Environmental Report for Indian Point Unit No. 2., September 9, 1971, Section 2.7.

4. Consolidated Edison Company of New York, Inc., Indian Point Generating Unit No. 2, Final Facility Description and Safety Analysis Report, Table 1.4.1.

5. Consolidated Edison Company of New York, Supplement No. 2 to Environmental Report for Indian Point Unit No. 2, October 15, 1971, Section 2.3.2.3.

6. Consolidated Edison Company of New York, Supplement No. 3 to Environmental Report for Indian Point Unit No. 2, February 15, 1972.

X. THE NEED FOR POWER

A. POWER DEMAND IN THE APPLICANT's SYSTEM

The area serviced by the applicant consists of the five boroughs of New York City and most of Westchester County, New York, and encompasses a population of 8,760,000 (1970).[1] The power needs of this region have been well known, particularly since the applicant actively recommends, through its "Save a Watt" program, increased efficiency of public use of electricity. The heaviest concentration of electric load occurs in Manhattan.

Figure X-1 shows the consumption of electricity by four major classes of users for the 1960-70 period in the applicant's service area. It can be seen that, during this decade, residential use of electricity increased about 95%, commercial and industrial use increased by 70%, and governmental use increased 96%. In general, the load requirements of the applicant's system differ from the national average in that most of the energy is distributed to residential and commercial customers and relatively little goes to large industrial users. For example, in 1968, about 22% was for residential use, about 44% for commercial use, and only 7.2% for industrial use, as compared with national averages of 27.7, 18.0 and 41.1%, respectively. The applicant in its Supplement No. 3 to the Environmental Report predicts a long-range forecast of sales of electrical output from Unit No. 2 to include 30.0% for residential use, 53.6% for commercial and industrial use, and 16.4% for railroad and governmental uses. Thus, the loading of the system tends to be closely related to the activities of individual residents and commercial establishments; loads are low during late night hours and on weekends and holidays and high during 8:00 a.m. - 5:00 p.m. working hours. The ratio of the maximum to the minimum system load during a 24-hr period may be as high as three to one, so that much of the capacity needed to meet the daytime peak sits idle or not loaded a good part of the time. The applicant has responded on May 30, 1972 in Appendix XII-23 that gas turbine units and some fossil-fueled plants will be used to meet the power needs during peak hours. However, the nuclear power plants will be used only as baseload facilities and will be operated continuously except during scheduled maintenance periods or forced outages.

Another special characteristic of the area serviced by the applicant is the slow growth of the population. The population remained essentially constant between 1950 and 1960; from 1960 through 1968 it increased only about 0.5% per year. The demand increase shown in Fig. X-1 is attributable to the development of new commercial and residential facilities and to the modernization of older facilities.

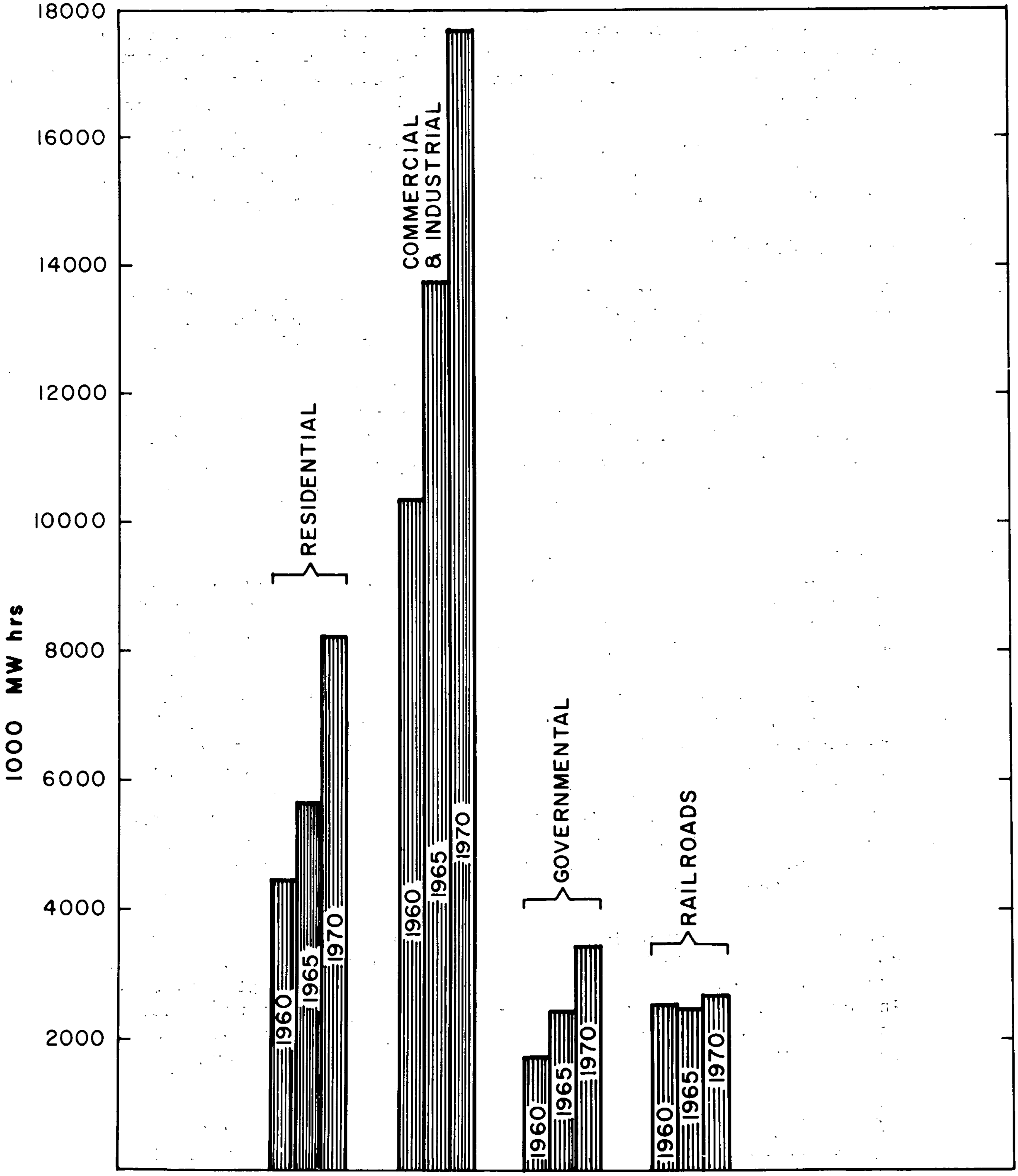

Fig. X-1
Consumption of Electricity by Classes of Customers in the Area Serviced by Consolidated Edison Company.

The peak demand in the applicant's system occurs in summer, largely for air-conditioning. Actual and projected peak demands for summer and winter shown in Table X-1, indicate an average estimated increase in demand for electric power of 5.0% per year (summer peak) and 4.5% per year (winter peak) during the period 1971 to 1980.[2] This is to be compared with 5.7% per year, the approximate growth rate in the New York area (Federal Power Commission [FPC] Coordinated Study Area B) during the period 1960 to 1970 inclusive.

B. PLANNED CAPACITY ADDITIONS

To meet the increasing demand, the applicant plans to increase the system capacity as shown in Table X-1. If the planned additions of capacity are on schedule, the gross reserve margin will be in the general range of 17 to 28% for the summer peaks and 36 to 62% for the winter peaks. The New York State Department of Public Service considers these reserves, particularly for summers, to be "so low as to be critical in the whole 1971-1975 period and the situation appears to be deteriorating instead of improving."[2] These reserves are to be compared with the generally used reserve criterion of 20% of peak load.

According to the FPC the criterion for reserve margin of 20% of peak load, which includes allowances for scheduled maintenance, forced outages, errors in load forecasting, and spinning reserve requirements, should be viewed as an approximate rule which may be modified upwards or downwards, depending on the actual conditions prevailing in individual systems. Due to the high percentage of older and less reliable generating units on its system, the applicant has found that the 20% margin is generally not adequate for system reliability. The largest unit now in service in the applicant's system is the 1,000 MW(e) Ravenswood Unit No. 3.* To maintain system reliability when large increments of generating capacity may be lost by forced outages of large units, correspondingly large system reserves are required. Recent experience indicates that frequent forced outages of new large generating units may be expected during the initial months of their operation.

Although the projected reserves on the applicant's system under normal circumstances would appear to be adequate, the applicant has experienced so many prolonged outages of major equipment and delays in new facilities during recent years that major maintenance has had to be deferred. This has created an extensive backlog of maintenance required to return the existing equipment to a normal state

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*The Wall Street Journal reports (August 17, 1972) this unit operating at 60% of capacity due to continuing generator problems.

TABLE X-1

APPLICANT'S LOAD, CAPACITY AND RESERVES FOR SUMMER AND WINTER PEAKS, 1971-1980

Year	Total Available[1] Capacity MW(e)		Peak Load MW(e)		Reserve MW(e)		Reserve % Peak Load	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
1971	9,509[2]	8,500	7,800[2]	6,225	1,709	2,275	21.9	36.6
1972	10,031[3]	9,823[4]	8,550	6,500	1,481	3.323	17.3	51.1
1973	10,585	9,247	8,950	6,800	1,635	2.447	18.3	36.0
1974	12,050	11,505	9,400	7,125	2,650	4,380	28.2	61.5
1975	12,050	11,460	9,850	7,475	2,200	3.985	22.3	53.3
1976	12,459	11,969	10,300	7,825	2,159	4,144	21.0	53.0
1977	13,544	12,701	10,750	8,175	2,794	4,526	26.0	55.4
1978	14,180	13,507	11,200	8,550	2,980	4,957	26.6	58.0
1979	14,095	13,412	11,650	8,950	2,445	4,462	21.0	49.9
1980	15,105	14,442	12,100	9,350	3,005	5,092	24.8	54.5

[1] Represents the applicant's forecast as of 1971 if all plans are implemented on schedule. Data from reference 2.

[2] Actual summer 1971 data.

[3] Actual data for summer 1972 show about 10,495 MW(e) available.

[4] These figures have been changed by delays in new capacity and by deferring retirement of older facilities. See discussion in text.

of dependability. An intensive maintenance program is planned by the applicant during the winter 1972-73 in an effort to provide greater equipment reliability for the peak load expected in summer of 1973.

The generating capacity of the applicant's system at the present time is provided by 66 baseload generating units, supplemented by gas turbines for peaking capability. This baseload totals 8,258 MW(e). Of the baseload units, 36 units, representing about 2,104 MW(e) or 25% of the baseload capability, are over 30 years old. Many of these are considered obsolete from the standpoint of efficient use of fuel and operating reliability. Also, in recent years all of the coal-fired units have been converted to oil or gas in order to meet air pollution criteria for New York City. Continued dependence upon over-aged generating equipment, with no new baseload capacity additions, can only lead to the increased possibility of system catastrophe with attendant loss of supply to large portions of the service area and the consequent hazards which accompany such a condition. Lost capacity due to average deratings and forced outages may total almost 3,000 megawatts during the winter 1972-1973.[3,4]

Toward the end of 1969, a 10-year plan[1] prepared by the applicant for the FPC called for the construction of new hydroelectric pumped storage, fossil fuel, and nuclear capacity; construction of new transmission lines and upgrading of existing lines; the purchase of power from other systems [total of 1,975 MW(e), 1969 through 1972]; and the retirement of selected units totaling about 2,300 MW(e). The schedule included addition of Indian Point Unit No. 2 in 1971 (delayed due to fire on November 4, 1971 and other construction difficulties) and Unit No. 3 in 1974, together with 2,100 MW(e) of gas turbine capacity in 1970-1972. No new baseload capacity has been added since 1969, while the load has continued to grow. In terms of the present situation, the power picture has changed since these plans were made but the overall conclusion for the critical need for Unit No. 2 remains the same.

C. EXPERIENCE IN MEETING DEMAND

1. Past Experience

The experiences and problems encountered by the applicant since 1969 are illustrative of the difficulties that operation of Indian Point Unit No. 2 is intended to help alleviate. For example, the applicant[5] experienced two severe power shortages during the 1969 summer season, one due to extreme weather conditions and the other to an abnormal amount of forced outages coupled with difficulties in purchasing power owing to schedule slippage elsewhere. As a result, the applicant requested customers using large blocks of power to reduce their load voluntarily and the general public to conserve power. Even then the applicant was forced to institute voltage reductions on 8 different days, and on 2 occasions to the maximum allowable reduction of 8%.

Voltage reductions were instituted on 15 days during the summer of 1970. On one occasion it was necessary to interrupt service to about 67,000 customers. During this occurrence, 425 MW(e) was gained by the voltage reduction, and an additional 390 MW(e) was gained by an appeal to the public to reduce power, but a disconnection of 57 MW(e) was still necessary - 13 MW(e) in Westchester, affecting 6,980 customers, and 44 MW(e) in Staten Island, affecting 59,953 customers.[6] As of September 9, 1971, the voltage on the system had been reduced 13 times during 1971.

2. The Summer 1972 Situation

To meet the anticipated demand during the summer of 1972, the applicant had to arrange for additional purchases beyond those already firmly made because Unit No. 2 was delayed due to construction difficulties and was not available for the summer of 1972 as the applicant had originally planned early in the winter. The applicant's capacity included the output of Bowline Unit No. 1, (600 MW(e), in which a total of 200 MW(e) has been purchased), 348 MW(e) of new barge-mounted gas turbines, 270 MW(e) of power purchased from Rochester Gas and Electric Company (from the Ginna Nuclear Power Plant), and 150 MW(e) of power purchased during daily peak loads from the Power Authority of the State of New York (up to September 29, 1972). Purchase of another 300 MW(e) from Ontario Hydro from May 1 - September 3, with possible extension through October 28, 1972 - the end of the summer capability period - was also negotiated by the applicant.[3] The applicant had been purchasing, on a week-to-week basis, approximately 95 MW(e) under a temporary export license granted by the National Energy Board to Long Sault, Inc., but this license expired on June 30, 1972. Consequently, a total of about 920 MW(e) had to be purchased to meet the anticipated summer peak load demand and to compensate for the unavailability of Indian Point Unit No. 2.

In addition, the applicant had to provide partial replacement of capacity through deferral of planned retirements.[3] A total of 452 MW(e) of retirements was deferred. (These deferred units are inefficient with much less reliability and desirability because of their excessive pollutant emission.)

The summer 1972 situation in the applicant's system is summarized in Table X-2. The tabulation also shows the situation in the New York Power Pool (see later discussion). The difference in the

TABLE X-2 1972 SUMMER PEAK SITUATION

	Consolidated Edison Company		New York Power Pool	
	June 1	August 1	June 1	August 1
Conditions without Indian Point Unit No. 1				
Net Dependable Capability--MW(e)	9,293[1]	10,495[2]	22,474[1]	23,901[2]
Net Peak Load--MW(e)	8,400	8,400	19,510	19,510
Reserve Margin--MW(e)	893	2,095	2,964	3,891[4]
Reserve Margin--Percent of Peak Load	10.6	24.9	15.2	19.9
Needed Reserve Margin Based on Criteria of 20 Percent of Peak Load--MW(e)[5]	1,680	1,680	3,902	3,902
Reserve Excess/Deficiency at 20 Percent Margin--MW(e)[5]	- 787	+ 495	- 938	- 11
Conditions with Indian Point Unit No. 2 [436MW(e)]				
Net Dependable Capability--MW(e)	9,729	10,931	22,910	24,337
Net Peak Load--MW(e)	8,400	8,400	19,510	19,510
Reserve Margin--MW(e)	1,329	2,531	3,400	4,327[4]
Reserve Margin--Percent of Peak Load	15.8	30.0	17.4	22.2
Indian Point Unit No. 2 [873MW(e)]				
Net Dependable Capability--MW(e)	10,166	11,368	23,347	24,774
Net Peak Load--MW(e)	8,400	8,400	19,510	19,510
Reserve Margin--MW(e)	1,766	2,968	3,937	4,764[4]
Reserve Margin--Percent of Peak Load	21.0	35.4[3]	20.2	24.4[3]

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[1] According to FPC analysis of May 10, 1972, this is the expected dependable resources as of June 1, 1972; applicant's resources include 8,823 MW(e) dependable generating capacity plus 470 MW(e) firm power purchases.

[2] According to the New York State Department of Public Service Analysis of June, 1972, the applicant's dependable resources include 748 MW(e) additional new capacity and purchase of 920 MW(e).

[3] Reserve margin must consider the amount of generating capacity that will be unavailable because much of the generating capacity is beyond normal retirement age. Much of the reserve capacity cannot be expected to be available. Based on last summer's experience it is estimated that an average of 2,350 MW(e) will be unavailable because of unscheduled outages. This represents 255 MW(e) more than the estimated reserve of 2,095 MW(e).

[4] Includes deduction of 500 MW(e) down for scheduled maintenance.

[5] Although a 20% minimum as a reserve margin capacity is an appropriate general rule in many situations, it is not appropriate for the applicant because of reasons already outlined in footnote 3.

applicant's capability and percent of reserve margin between the two months as shown in Table X-2 is reflected in the changing power picture because of the purchases and reduction in retirements and the unavailability of Unit No. 2. The reserve margin of 2,095 MW(e) without Unit No. 2 on line could be in jeopardy in view of the fact that, during the period June through September 30, 1971, unscheduled forced outages and plant deratings averaged 2,350 MW(e),[7] or 255 MW(e) more than the estimated reserve. According to the New York State Department of Environmental Conservation's comments in Appendix XII-11, the amount of daily unavailable power this past summer could range between 1,450 MW(e) and 3,250 MW(e) on any given day. As shown in Table X-2 the availability of Unit No. 2 at 50% and 100% of rated power would have alleviated this situation. Thus, the FPC[8] from its analysis of the power needs "concludes that all reasonable efforts should continue to bring this unit (Unit No. 2) into service at the earliest possible date. The need for added capacity against the contingencies of forced outages, as well as the desirability of implementing scheduled preventive maintenance programs, is self-evident."

In spite of the efforts to increase the reserves, the applicant had to institute voltage reductions of three to five percent in its system during the week of July 17 to 21, 1972.[9] If Indian Point Unit No. 2 had been on line during the period, it is likely that no voltage reductions would have been necessary.

3. The Winter 1972-73 Situation

The applicant now estimates that the winter 1972 peak will be 6,425 MW(e),[3] slightly lower than the earlier estimate given in Table X-1. During the period between now and the winter peak (usually occuring in December), the applicant expects to have 240 MW(e) available from the 600 MW(e) Roseton No. 1 (oil-fired, applicant's ownership is 40%). An estimated 663 MW(e) will be added because of increased thermal efficiency during the winter. Additional capability through firm purchases will bring the total up to 10,718 MW(e).[3] The gross reserves during the winter peak will thus be 4,293 MW(e) or 66.8% of the estimated peak demand. Without Indian Point No. 2, this will be reduced to 53.3%.

In commenting on the applicant's power needs, the FPC[9] indicated that the applicant's reserve margin during winter 1972-73 would be roughly 10 percentage points higher than we have noted in the preceding paragraph. The difference is attributable to differences in assumptions concerning what facilities will be available next winter. The FPC assumed the applicant's capability to be 7,384

MW(e) fossil, 2,842 MW(e) gas turbine and diesel, 1,138 MW(e) nuclear, and a purchase of 40 MW(e) making a total of 11,404 MW(e). In the figures given in Table X-3,[4] the retirement of 259 MW(e) and the exclusion of the 40 MW(e) purchase, reduces the capability to 11,105 MW(e). The applicant's testimony[3] apparently assumes 349 MW(e) more retirements than the 259 MW(e) just noted and also assures a firm purchase of 40 MW(e) from Maine Yankee. This reduces the capability at the time of the winter 1972 peak to 10,718 MW(e).

It must be emphasized that, because of the lower winter peak demand, the applicant's gross reserve in the winter is always much larger than in the summer.* Moreover, the applicant needs this larger reserve in order to replace or repair equipment during the lower demand period (roughly, October to May).

In recent years, the applicant's use during the summer of all of its capacity, including units that should have been retired from service, has increased the maintenance work to be performed during the winter months. The applicant states that the monthly maintenance schedule during winter 1972-73 will be between 800 and 1,800 MW(e).[3] This amounts to 11 to 28% of the estimated winter peak load.

During winter 1971-72 the applicant experienced an average daily unavailable capability from all combined causes of 2,608 MW(e), with actual occurrences as high as 3,743 MW(e). From this experience, the applicant estimates for winter 1972-73 an average daily unavailability of 2,600 to 3,100 MW(e).[3] This is 40 to 48% of the estimated winter 1972-73 peak load. If the applicant's experience during this next winter is similar to that of last winter, the unavailability of capacity will, at times, exceed the reserve margin without Indian Point Unit No. 2 in operation.

At the request of the New York State Atomic Energy Council, a representative of the New York State Department of Public Service has outlined the projected load, capacity and reserves for the applicant's system during the months of November 1972 through April

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*This is true throughout the Northeast. The actual gross reserve margin for the Northeast (FPC Power Supply Region I, in December 1971 (winter peak) was 39.4% according to the 51st Semi-Annual Electric Power Survey published by the Edison Electric Institute (EEI Pub. No. 72-28, April, 1972). This is to be compared to 22.8%, the gross reserves during the summer peak of 1971 in the Northeast.

Table X-3. Consolidated Edison capacity, load, and margins – November, 1972–April, 1973

	Nov. 72	Dec. 72	Jan. 73	Feb. 73	Mar. 73	Apr. 73
	Capacity					
Thermal (conventional)	7,125[a]	7,125[a]	6,909	6,909	6,909	6,909
Thermal (gas turbine & diesel)	2,842	2,842	2,842	2,842	2,842	2,842
Thermal (nuclear)	1,138	1,138	1,138	1,138	1,138	1,138
Hydro (conventional)						
Hydro (pumped storage)						
Total controlled	11,105	11,105	10,889	10,889	10,889	10,889
Purchases		40	40	40	40	40
Sales						
Total capacity	11,105	11,145	10,929	10,929	10,929	10,929
	Peak load					
Estimated load	6,225	6,425	6,350	6,250	6,125	6,225
	Margins					
Gross margin (MW)	4,880	4,720	4,579	4,679	4,804	4,704
Scheduled maintenance	730	900	1,150	800	1,450	780
Margin after maintenance	4,150	3,820	3,429	3,879	3,354	3,924
Indian Point delay	(873)	(873)	(873)	(873)	(873)	(873)
Increased maintenance schedule	770					
Delay retirement[b]	259	259				
Additional purchase[c]	240	200	200	200	200	200
Margin after deducting Indian Point, etc.	3,006	3,406	2,756	3,206	2,681	3,251
	Unavailable capacity, past 12 months experience					
Average deratings	1,100	1,200	1,500	1,400	1,300	1,000
Average forced outage	1,300	1,100	1,400	1,300	1,500	1,500
Margin with average unavailability	606	1,106	–144	506	–119	751
High deratings	1,400	1,500	1,800	1,600	1,900	1,300
High forced outage	1,800	1,600	2,400	1,500	1,700	2,000
Margin with high unavailability	–194	306	–1,444	106	–919	–49
Required operating reserve	600	600	600	600	600	600

[a] Includes new units: Bowline No. 1, 400 MW (Consolidated Edison's share); Narrows Gas Turbines, 348 MW; Roseton No. 1, 240 MW (Consolidated Edison's share).

[b] Delay retirement: Hell Gate Nos. 2 and 3, 115 MW; Waterside No. 1, 35 MW; Hudson Ave Nos. 2 and 3, 94 MW; 59th Street No. 7, 15 MW.

[c] Recent purchase agreements: Maine Yankee, 40 MW (Nov. 72 only); Bowline No. 1, 200 MW (throughout the period).

1973.[4] The estimated monthly values of capacity and reserves, given in Table X-3, lead to the same conclusion as the average values noted above, namely, if Indian Point No. 2 is not available, there will be times during next winter when scheduled outages (maintenance), averaged forced outages and deratings may reduce the reserve margin to zero or less. In those periods when the reserve margin is above zero, it may still be less than the 600 MW(e) operating reserve required of the applicant as a member of the New York Power Pool.

Analysis of the information in Table X-3 indicates that, with Unit No. 2 on line and taking into account scheduled maintenance, the reserve margin ranges from 54.6% of peak load in March 1973 up to 66.3% in November 1972. With Unit No. 2 not available and with the increased maintenance schedule, power purchases, deferred retirements and additional capacity of Roseton No. 1, which is from the applicant's share of ownership of this plant, the applicant's reserve margin is reduced to 43.8% in March 1973 and 49% in November 1972. The New York State Department of Public Service, however, has indicated that, after deducting average unavailable capacity because of average deratings and forced outages, the applicant "will be unable to meet its load in January and March 1973."[4] This is because the applicant will be having a deficiency of reserve margins of 144 MW(e) in January and 119 MW(e) in March 1973. Also, in February 1973, the applicant will not be able to maintain the operating reserve of 600 MW(e) required as a partner in the New York Power Pool. If high deratings and high forced outages should occur, the applicant will not be able to meet its load in every month except two (December 1972 and February 1973); moreover, in all these months, the applicant will not have the required operating reserve of 600 MW(e). As a result the Department of Public Service concludes "on the basis of the above analysis, additional capacity is needed for the winter of 1972-1973 to help meet the applicant's load requirements."[4]

The above discussion demonstrates that a careful analysis of gross margins, margins after scheduled maintenance, margins after specified additions and deductions because of delay in retirement, increased scheduled maintenance, margins with average unavailability and with high unavailability is needed before conclusions can be drawn as to the significance of the percent of peak load. Therefore, although the applicant appears to have a high percent of gross reserve margins to meet the winter 1972 power needs, the applicant, however, will be in serious difficulty particularly during January and March 1973 without the availability of Unit No. 2 at any power levels to alleviate the situation as shown on Table X-3. Thus, the statement by the FPC[9] that the capacity of Indian Point Unit No. 2 is not critical to the applicant's reserve capacity for the 1972-73 winter peak period is based on gross reserve margins. FPC has not taken into account the maintenance, delays, forced outages, deratings and other requirements as outlined in Table X-3. FPC did state that the availability of Unit No. 2 can allow for maintenance of other operating units not now possible. Also reliability through testing of Unit No. 2 through the winter will be improved in anticipation of meeting the summer 1973 peak.

4. The Summer 1973 Situation

The load supply situation shown in Table X-4 during next summer has been estimated by the FPC Bureau of Power.[9] To meet the projected peak demand of 8,850 MW(e) (slightly less than the applicant's earlier projection shown in Table X-1), the FPC expects the applicant to have resources of 10,135 MW(e) without Unit No. 2 or 11,008 MW(e) with Unit No. 2. (These latter figures assume net firm purchases of 40 MW(e) from Maine Yankee.) These projections indicate a gross reserve margin during summer 1973 of 14.5% without Unit No. 2 or 24.4% with Unit No. 2. Comparison of these figures with those given for June 1, 1972 in Table X-2 shows that the projected situation for the applicant will be only slightly better than the situation early in the summer of 1972. Since, as noted earlier, the applicant's situation early in 1972 summer was poor, it follows that the need for capacity will remain during summer 1973. Without Indian Point Unit No. 2 in operation next summer, the gross reserve margin will not be sufficient to insure reliable power for the applicant's customers.

Although the applicant had to purchase additional power to make up for the unavailability of Unit No. 2 in the summer of 1972, the FPC[9] points out that in the summer of 1973, the applicant will have to reduce its import power from 1,200 MW(e) to 720 MW(e) from members of the New York Pool, Ontario and New England because of litigation regarding the Rock Tavern-Ramapo 345-kV transmission line. This also means that 480 MW(e) from the Roseton Station will not be available to the applicant.

D. APPLICANT'S PARTICIPATION IN POOLING AND COORDINATION AGREEMENTS

The applicant has been an early participant in intercompany agreements aimed at achieving maximum reliability and economy of service and is one of eight member utilities of the New York Power Pool. Table X-5 lists the members of the Pool.[5] Under the pooling agreement, each member continues to have full responsibility for

TABLE X-4 ESTIMATED 1973 SUMMER PEAK LOAD-SUPPLY SITUATION

	Consolidated Edison Co.	New York Power Pool
Conditions for 100 Percent Power Rating - 873 MW(e)		
Total Resources - MW(e)	11,018[1]	27,490
Net Peak Load - MW(e)	8,850	20,840[2]
Reserve Margin - MW(e)	2,158	6,650
Reserve Margin - Percent of Peak Load	24.4	31.9
Conditons for 50 Percent Power Rating - 436 MW(e)		
Total Resources - MW(e)	10,531[1]	27,053
Net Peak Load - MW(e)	8,850	20,840[2]
Reserve Margin - MW(e)	1,681	6,213
Reserve Margin - Percent of Peak Load	19.0	29.8
Conditions for 20 Percent Power Rating 175 MW(e)		
Total Resources - MW(e)	10,270[1]	26,792
Net Peak Load - MW(e)	8,850	20,840[2]
Reserve Margin - MW(e)	1,420	5,952
Reserve Margin - Percent of Peak Load	16.0	28.6
Conditions for 0 Percent Power Rating - 0 MW(e)		
Total Resources - MW(e)	10,135[1]	26,617
Net Peak Load - MW(e)	8,850	20,840[2]
Reserve Margin - MW(e)	1,285	5,777
Reserve Margin - Percent of Peak Load	14.5	27.7

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[1] Includes net firm purchases of 40 MW(e).

[2] Includes net firm sales of 22 MW(e).

TABLE X-5

NEW YORK POWER POOL MEMBERS

Consolidated Edison Company of New York, Inc.

Long Island Lighting Company

New York State Electric and Gas Corporation

Orange and Rockland Public Utilities, Inc.

Rochester Gas and Electric Company

Niagara Mohawk Power Corporation

Central Hudson Electric and Gas Corporation

Power Authority of the State of New York

*Jamestown Municipal Electric System

*Long Sault, Inc.

*Village of Freeport

*New York State Companies which are not members of the New York Power Pool but which report their load and capability as part of the New York State Interconnected Systems.

maintaining adequate electric generating capacity and transmission facilities within its own service area. In particular, the applicant is required to maintain a reserve margin of at least 18% peak load. Each member must maintain an operating reserve consisting of a spinning reserve, which is capacity that can be available within 5 minutes' time, and a ready reserve, which is the capacity that can be available within 30 minutes' time. The applicant's share of the Pool's operating reserves amounts to about 600 MW(e). The FPC has recommended that, as a general rule, a minimum of 20% reserve margin capacity be maintained for large power pools whose capacity is predominantly from thermal stations.[10] This includes allowance for scheduled maintenance, forced outages, errors in load forecasting, and spinning reserve requirements. In return, under the pooling arrangement, each member of the Pool and the customers it serves receive the benefits associated with fully coordinated planning and cooperation of the systems.

An analysis by the New York State Department of Public Service of the New York Power Pool situation during the period November 1972 to April 1973 (similar to that shown in Table X-3), shows the picture to be brighter.[4] Without Indian Point Unit No. 2, and considering average deratings and average forced outages, the reserve margin ranges from 2,051 MW(e) or 11.8% of peak load for March 1973, to about 3,327 MW(e) or 18% of peak load for January 1973. In both January and March 1973 the reserve margins of 1,297 MW(e) and 851 MW(e), respectively, with, high unavailability will be lower than the required operating reserve of 1,400 MW(e) for the Pool. Then the Pool would be forced to go outside the system in order to purchase capacity and avoid possible load curtailment. The availability of Indian Point No. 2 at any power level would improve the situation in the New York Power Pool.

In addition to being a member in the New York Power Pool, the applicant is also a member of a larger area agreement, the Northeast Power Coordinating Council (NPCC)[11] The latter was formed out of an agreement in 1966 between the large electric utilities in New York, New England, and Ontario, aimed at further strengthening the service reliability of the interconnected company systems in this area. The New York State Department of Environmental Conservation[7] has presented information in Table X-6 updating the original FPC projections of the near-term gross generating capability and reserve conditions in the NPCC area and in the New York Power Pool for the winter of 1972-1973[11] It should be noted, however, that the NPCC is primarily a council for planning, coordination, and protection for the region and not a capacity resource pool for its member companies. The projections shown in Table X-6 include the full generating capability of Indian

TABLE X-6

PROJECTED ELECTRIC LOADS AND SUPPLY CONDITIONS WITHIN THE NORTHEAST AREA AND THE NEW YORK POWER POOL (WITH AND WITHOUT INDIAN POINT UNIT NO. 2)

	Winter 1972-1973
Northeast Power Coordinating Council*	
Planned Capability, MW(e)	59,857[2]
Peak Load	35,652
Anticipated Reserves, MW(e)	13,305[3]
Percent of Projected Peak Load	29.4
Planned Nuclear	2,835
Percent of Anticipated Reserve	21.4
New York Power Pool**	
Planned Capability, MW(e) (Including net of transactions and 873 MW(e) from Unit No. 2)	26,681[4]
Peak Load, MW(e)	18,540
Anticipated Reserves, MW(e)	7,241[3]
Percent of Projected Peak Load	39.1
Necessary Reserve at 20%[1] MW(e)	3,708
Surplus (Deficiency) MW(e)	3,533
Without Indian Point Unit No. 2 (Nuclear, April 1972)	-873

(Consolidated Edison Co. -
Buchanan, New York)

New Capability	MW(e)	25,808
Peak Load	MW(e)	18,540
Reserve	MW(e)	6,368[3]
Peak Load	%	34.4
Necessary Reserve at 20%[1]	MW(e)	3,708
Surplus (Deficiency)	MW(e)	2,660

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*Includes New York, New England, and Canadian members.

**Includes net of sale transactions.

[1] FPC Staff estimate.

[2] With Indian Point No. 2 at 873 MW(e)

[3] Includes deduction of 900 MW(e) for scheduled maintenance.

[4] Winter capacity higher because of improved cooling efficiency.

Source: Evaluation of New York State Department of Public Service made on May 1, 1972, based on Consolidated Edison load and capacity estimates dated March 28, 1972 and report of NPCC dated April 1, 1972.[7]

Point Unit No. 2, 873 MW(e), which represents about 12% of the anticipated reserves of the New York Power Pool for the winter 1972-1973 period. Without Indian Point Unit No. 2, the available gross reserve of the New York Power Pool was projected to drop from 39.1% to 34.1% of peak load during this period. The estimate was also contingent on addition of 1,100 MW(e) of Roseton No. 1 and Gilboa 1 and 2 capability scheduled for winter 1972.

Analysis of the New York Power Pool reserves for the summers of 1969, 1970, and 1971 indicates that actual operating reserves experienced were only 6.0, 4.4 and 10.9%, respectively, after accounting for maintenance, unscheduled outages, and forced unit capacity deratings. Such a low reserve margin is not adequate and threatens system reliability. Further analysis indicates that the contributing factors are concentrated in the applicant's system. No new baseload capacity has been added to this system since 1969, while load has continued to grow. Some 1,833 MW(e) of gas-turbine peaking capacity has been added; however, extended operation of these units has resulted in extensive maintenance problems and reduced availability of the gas-turbine capacity.[12] In this connection, the applicant has stated[3] that its gas-turbine units, "intended for limited hours of operation, perhaps 500-1000 each year,.... have already been required to operate on the average, for the equivalent of 2000 hours per year since the summer of 1971, and will be required to continue operation at this level in the summer of 1972." Until the applicant increases its baseload capacity, the reliability of the New York Power Pool will be less than desirable.

Table X-2 also shows the 1972 summer peak situation for the New York Power Pool. It will be noted that during June and July gross reserves of the Pool (expressed as percent of peak load) are greater than those of the applicant; after August 1, the applicant's reserve margin is higher than that of the Pool.

The estimated 1973 summer peak load situation for the Pool is also shown in Table X-4.[9] As can be seen, the projected gross reserves of 31.9% of peak load of the Pool are greater than the applicant's gross reserve margins provided Indian Point Unit No. 2 is included. Without Unit No. 2 the gross reserves of the Pool drop to 27.7% of peak load. Based on gross reserves, the Pool should have sufficient reserves for winter 1972-73 and the summer of 1973. This does not include forced outages or deratings of plants in the Pool.

E. AVAILABLE ALTERNATE SOURCES

The applicant purchased 920 MW(e) and added 624 MW(e) gas-turbine capacity to its systems in 1971 to meet the shortages expected, particularly during the summer of 1971. In 1972 the applicant contracted for 920 MW(e) of purchased capacity, which included 200 MW(e) from Orange and Rockland's share of the Bowline Point Unit No. 1, scheduled to go on line in July 1972, and an additional 720 MW(e) from other utilities. These purchases are short-term and in some cases for limited hours of the day to meet the peak demand. They are not to be considered a solution to provide reliable power over the long term.

Thus the applicant needs to have Indian Point Unit No. 2 as a baseload facility on line as soon as possible in order to meet the baseload requirements for its own service area and to maintain needed reserve margins with respect to meeting the requirements of the New York Power Pool. The situation would be further complicated if any units scheduled to come on line are delayed.* Without these new plants available, a serious power shortage to the New York Metropolitan area can occur. Furthermore, the environmental impact of the air pollutants from the older fossil-fuel plants, which would have to operate to make up for the lack of availability of Indian Point Unit No. 2, should be added into the picture with the unavailability of Indian Point Unit No. 2. Details of the applicant's available alternate sources, particularly for the long-term, are discussed in Chapter XI.A.

The applicant in its testimony of October 19, 1971,[13] January 24-25, and May 18, 1972,[3] before the presiding Atomic Safety and Licensing Board, details the problems of power purchases to meet these shortages.

F. COST OF DELAY

The cost of delay to the applicant and its customers in placing this Plant on line in time has been reported by the applicant to consist of about $5,500,000 per month, the estimated cost of incremental operation and maintenance and out-of-pocket cost of replacing energy which would otherwise have been produced by Indian Point Unit No. 2 plus about $1,000,000 per month, the amount of interest during construction which would occur during the period of delay.[3] Operation would not only eliminate these costs but would generate electricity for the applicant's customers so as to begin financial return on capital investment. Taxes then paid by the applicant on the income obtained would support beneficial activities in the local communities.[3]

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*The units involved here include those in other systems from which the applicant plans to purchase capacity.

G. CONCLUSION

Since the applicant's original decision to schedule the addition of Indian Point No. 2 to its system to meet the demand for electricity in the 1970's, voltage reductions and service interruptions have occurred; these events, taken together with new and more stringent air pollution restrictions and environmental protection concerns, have tended to increase the pressures on the existing capacity. Moreover, the availability of alternate sources of baseload capacity is limited to short-term purchase commitments. In view of this, the staff believes that the need for the additional baseload capacity represented by Indian Point Unit No. 2 has been clearly demonstrated.

REFERENCES FOR CHAPTER X

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2. Power Division of the New York State Department of Public Service, "The New York Power System Generation and Transmission Plans 1971-1980," December 1971.
3. Testimony of B. Schwartz, Consolidated Edison Company of New York, Inc., on "Effects of Delay in Operation of Indian Point Unit No. 2," May 18, 1972.
4. Testimony of L. M. Stuzin, New York State Department of Public Service, on "The Need for Additional Capacity for the Consolidated Edison Company" May 17, 1972.
5. Consolidated Edison Company of New York, Inc., Supplement No. 1 to the Environmental Report for Indian Point Unit No. 2, September 9, 1971.
6. Consolidated Edision Company of New York Service Interruption Report (Rendered in connection with Public Service Commission Order to Case 3729). Report for the week of September 20, 1970, to September 26, 1970, and Report for the week of September 27, 1970, to October 3, 1970.
7. Comments from the New York State Department of Environmental Conservation on the Draft Detailed Environmental Statement, June 1, 1972.
8. Letter of T. A. Phillips, Federal Power Commission to L. R. Rogers, U. S. Atomic Energy Commission, May 10, 1972.
9. Letter of the Federal Power Commission to D. R. Muller, U. S. Atomic Energy Commission, August 1, 1972.
10. Letter from John N. Nassikas, Chairman of the Federal Power Commission, to Glen T. Seaborg, Chairman of Atomic Energy Commission, September 24, 1970.
11. Letter from J. N. Nassikas, Chairman of the Federal Power Commission, to J. R. Schlesinger, Chairman of the Atomic Energy Commission, October 15, 1971.

12. Letter from T. A. Phillips, Bureau of Power, Federal Power Commission, to R. S. Boyd, Division of Reactor Licensing, U. S. Atomic Energy Commission, December 22, 1971.

13. Consolidated Edison of New York, Inc., Testimony Supporting Motion to Test Up to 50% Power in the Hearing Before the Atomic Safety and Licensing Board, October 19, 1971, presented in the Hearing on Indian Point Unit No. 2, (Docket No. 50-247) on November 17, 1971.

XI. ALTERNATIVES TO PROPOSED ACTION AND COST-BENEFIT ANALYSIS OF ENVIRONMENTAL EFFECTS

A. DESCRIPTION OF ALTERNATIVES

The present and future demands for electrical energy in the metropolitan New York area have been described in Chapter X of this Statement. The generating capacity now available to the applicant to meet its commitments to the approximately 9 million customers in its service area and to the New York Power Pool is quite inadequate without operation of Indian Point Unit No. 2. Although the applicant, through its membership in the New York Power Pool, can arrange for distributing the needed power to the New York area in certain emergency situations, this arrangement in the long run will not satisfy the long-term projections of the applicant to meet the load demands of its own service area. It may also result in affecting other areas of the State where shortages may also exist. Furthermore, although the applicant and its partners in the New York Power Pool can exchange available power between each member, there is an increasing probability for the next year or two that sufficient power will not be available through the inter-ties to satisfy the needs of the Pool if forced outage of a major generating unit occurred in the period of peak demand. In this case the Pool would be forced to curtail energy to some part of its load or reduce voltage throughout its system. Operation of the Indian Point Unit No. 2 will lessen this probability. Furthermore, any forced outages of older fossil-fuel plants, many of which should have been retired years ago, would further hinder the applicant in providing the needed electricity to the New York area. A critical shortage of electricity in this area of the nation would have serious repercussions throughout the nation and the world since New York City is both a national and international center of commerce and industry. In addition, the lack of reliable power would cause hazards to the welfare and the health of the people of New York City. The alternative of load reduction as considered by the applicant, in terms of trying to reduce the shortage of electricity, has not been a satisfactory method to have sufficient reliable electrical power available in the long term for its service area, and certainly it would not be sufficient to replace the power that would be obtained from Indian Point Unit No. 2.[1] Failure to provide power is not considered a feasible alternative in view of the applicant's obligation under its charter from the State.

Permanent curtailment of the operation of the Plant would result in the irretrievable loss of most of the resources committed to the construction of the Plant without removing impacts already created by construction. In addition a large part of capital investment at the Indian Point site would be unrecoverable and probably be borne by the investor and the customer in higher rates. A replacement plant would cost at least twice as much as the abandoned facility[2] and would create an additional environmental impact at the same or other site.

Based on comparative costs and availability of nuclear fuel versus oil or gas fuel, operation of the Indian Point Unit No. 2 as a nuclear plant should be financially preferred over the older oil-fired plants. The Indian Point Unit No. 2 will result in lesser adverse effects on air quality than older oil-fired plants which need to be retired or to be used to a lesser extent because of higher maintenance costs, low efficiency, and poor reliability. These plants, originally coal-fired, were converted to oil to eliminate fly ash and coal handling problems which, at the time, were considered important steps to reduce soot emissions. As they were constructed prior to availability of adequate smoke-abatement equipment, they produce and discharge to the environment considerable quantities of sulphur dioxide, nitrogen oxide, particulates, and other hazardous materials.[3] Although backfitting of these existing oil-fired power plants by installation of modern pollution control equipment can be done, some gaseous effluents will be released.

In choosing the site for the Indian Point Station, the applicant took into account the following types of alternatives: location of the site with respect to load; type of fuel and costs; transportation, primarily of both fuels; method of waste-heat dissipation; and other quantifiable variables of lesser significance. The applicant purchased the Indian Point site after abandonment of the amusement park in the mid-1950s and built Indian Point Unit No. 1 as an oil- and nuclear-fueled steam generator unit with once-through cooling of the steam condenser using the Hudson River as the source of the water coolant.

Furthermore, sites for thermal electric plants are also at a premium within this region. The applicant is attempting to overcome this deficiency by entering into joint construction ventures with adjacent facilities; for example, the construction of the Bowline Point Unit 1 with Orange and Rockland Public Utilities Company located about 5 river miles downstream from Indian Point.[1]

In consideration of other available locations, offshore sites were not considered as an alternative during the original site selection process back in the mid 1950s, since the technology for offshore nuclear power plants did not exist. During the mid-1960s a series of studies[4,5] were conducted to determine the advantages of offshore siting and the additional advantages when the power plant is coupled with a desalination plant.[6,7,8] These studies have devoted much effort to various designs for offshore sites,[9,10] but not much attention has been given to thermal discharge problems. More recently, there has been quite a bit of interest shown by a number of utilities in offshore sites. The approaches being considered include man-made islands, barges floating in man-made lagoons, and barges or submarines sunk into prepared ocean bottom areas. The applicant and Public Service Electric and Gas Company have participated in these studies and PSE&G is planning to install two barge-mounted units for commercial operation in 1980 and 1981.[11-13] Obviously, time would not permit construction of an offshore plant as an alternative to the Indian Point facilities in meeting the peak load requirements for 1970's. However, as was pointed out earlier, sites for thermal electric plants are at a premium in the applicant's service area and an offshore nuclear- or an oil-fired plant should be given serious consideration when an additional base load plant is required.

1. Alternative Fuels and Sources

A number of alternatives to the use of nuclear fuel can be considered in light of replacement of Indian Point Unit No. 2. They are natural gas, oil, coal, load reduction, disconnection, and no further expansion of the power generating capacity of the applicant's system.

a. Coal

Coal could be a primary alternative fuel source and could have been the fuel type chosen by the applicant to replace the nuclear fuel in Indian Point Unit No. 1. This is particularly true when a power plant existing at a site is committed to the use of coal since certain auxiliary features, such as coal yards, coal handling equipment, and the extensive railroad equipment necessary for handling large quantities of coal would already be available. However, for a site such as the Indian Point site, coal is not a reasonable alternative. From an economic point of view, the cost of coal used by utilities in the New York area would be excessive. This is primarily due to costs of transportation, since most of the coal is obtained from eastern Kentucky, West Virginia, and southwestern Virginia.[14] In addition, the use of coal requires additional capital investment for coal-handling and for pollution abatement equipment. Even today the latter may prove inadequate to reduce particulate and gas emissions to the level required by increasingly restrictive air quality standards.

The use of coal as a fuel at the Indian Point site would have necessitated the commitment of a much larger area of land for coalyards and coal handling equipment and for flyash storage. This would have led to the destruction of a sizeable segment of the land used at this site. The environmental impact on the land would have been more severe. Also, the environmental impact on the Hudson River might also have increased because some of the large amount of flyash could fall from the river banks into the river. In terms of the radiological impact, recent studies indicate that coal-fired plants may lead to radiation exposures to the general population at a level similar to or greater than exposures derived from operation of power plants using pressurized water reactors.[15-18] This is due to the presence in the emissions of a coal-fired plant of the radioactive daughter products of uranium and thorium which occur naturally in coal. The environmental impact due to radiological considerations may therefore be as great for coal-fired power plants as for nuclear powered plants depending upon the concentrations of radioactive elements in the coal and on the gaseous effluent control built in the coal-fired plant. Modern fossil-fueled plants with current emission control equipment are designed to limit the amount of emissions and thus reduce the amount of radioactive releases from the uranium and thorium in coal.

b. Oil and Gas

Because of the critical air quality in the New York metropolitan area, the applicant has converted the fossil plants located in New York City to oil-fired and gas-fired plants, thereby reducing the air pollutants from coal-fired plants. Of the applicant's 10 major facilities formerly burning coal up to 1970, only 2, the Arthur Kill and the Astoria Plants, generated an appreciable amount of energy from burning coal.[19] Since then, these plants have been converted to burn oil.

Fuel oil is not necessarily an economically competitive fuel in the New York area due to the long distance from the principal sources which are: the southcentral states of Texas, Louisiana, and Oklahoma; central Canada; Venezuela; northern Africa; and the Arabian peninsula. Since the domestic consumption of oil far exceeds the combined United States and Canadian production,[20] imported oil from overseas is necessary. Evaluation of the use of oil as an energy source for proposed power plants must therefore include the shipping costs associated with ocean-going tankers and possibly more important the reliability of delivery from foreign sources in today's troubled world.

Developing shortages of domestic coal and foreign fuel oil has thus resulted in a difficult fuel supply problem. Furthermore, on October 1, 1969, New York City imposed restrictions on sulfur dioxide limits in which the sulfur content of fuels burned by utilities in the New York City area would be 1%.[19] This restriction plus the shortage of natural gas limited the applicant as to the availability of energy sources to select. Because of the political situation influencing the foreign fuel oil market, the applicant is definitely limited as to obtaining dependable and reliable energy sources to meet both the short-term and the long-term power demands of its service area. The applicant also investigated the economics of importing liquified natural gas as a solution to the public controversy over the expansion of its Astoria Plant. This alternative to domestic natural gas appears to be economically prohibitive. Thus, from the above discussion, any plan to build a fossil-fueled plant in lieu of the Indian Point Unit No. 2 would fail to create the generating capacity which is needed to meet the 1972-1973 winter and 1973 summer season. Any fossil-fueled plant would necessarily add to the particulate and gaseous pollutants entering the atmosphere of the applicant's service area. The use of Indian Point Unit No. 2, therefore, offers important environmental advantages with respect to air quality in the New York area.

Furthermore, other new plants are not feasible to meet the present and future power needs of the applicant's customers. Fossil-fueled plants require an estimated 4-6 years to complete, and an alternative nuclear power plant would require an even longer time. Gas turbines, which are discussed below, are not technically reliable alternatives for base-load plants such as Indian Point Unit No. 2. The installation of gas turbines requires more than 1 year even on a crash basis, so that the earliest that gas turbines equivalent to the capacity of Indian Point Unit 2 could be installed would be after the summer of 1972.[1] Although the applicant has a number of gas turbine facilities in its system, such facilities are used primarily for peaking purposes. The availability of natural gas supply is also limited. Over 70% of the natural gas produced in the United States in 1968 came from sources in Louisiana and Texas, while the industries of the States of Louisiana, Texas, Arkansas, and Oklahoma accounted for the consumption of about one-third of the total nationwide production. Small, gas-turbine generating units used for peaking purposes in local situations provide for flexibility of operation and dispersion of environmental impacts, but do not contribute to the base-load capability of the system. Therefore, natural gas is not a reasonable economic choice for large power plants that must depend on interstate delivery of the gas by long pipelines from the principal continental sources.

c. Hydroelectric Power

Hydroelectric power from natural sites is not a practicable alternative since the remaining available sites in the New York area would provide only small incremental increases in generating capability. In addition, environmental impact of man-made reservoirs on natural waters would be a poor tradeoff for the small increments of power made available. Pump storage hydroelectric generation facilities can be built in a way that natural waters are not unduly disturbed. However, this type of facility requires an off-peak capacity for the pumping phase which was not available when the Indian Point Unit No. 2 was undertaken. The Cornwall pump storage hydroelectric project rated at 2,000 MW(e) would reduce some of the pressure on the existing old fossil-fueled plants in the system but could not replace the Indian Point facilities as a base-load Plant. The fact that off-peak is required for pumping river water to the reservoir is strictly limited to a peaking facility. The FPC[1,21] has stated that there are no other suitable sites for conventional hydroelectric pump storage plants available within a radius of approximately 100 miles from New York City.

d. Purchase Power

Since operation of Indian Point Unit No. 2 at full power will not be available until the end of 1972 at the earliest, purchase power is a necessary alternative to meet the potential power shortage of the applicant's service area for summer and fall of 1972. Consequently, the applicant[22] will not only need to increase its purchases from other utilities for this period but also delay various planned retirements and maintenance of older unreliable and inefficient plants. As a result, the applicant has commitments for purchase of a total capacity of 920 MW(e) for the summer of 1972, which included a total purchase of 200 MW(e) from the Orange and Rockland's Bowline Point Unit No. 1 scheduled to go in commercial operation by July 1, 1972, 270 MW(e) from the Rochester Gas and Electric Ginna

Nuclear Unit, 150 MW(e) during daily peak load periods from the Power Authority of the State of New York, (May-September 29) and 300 MW(e) from Ontario Hydro (May 1-September 3). The applicant is also depending on the availability of 348 MW(e) from barge-mounted gas turbines by July 15, 1972. The applicant is owner of 400 MW(e) of the 600 MW(e) Bowline Point Unit No. 1 and thus will purchase an additional 75 MW(e) besides the 125 MW(e) purchased earlier to meet the peak load during the summer of 1972. Thus a large part of the capacity available on this contingent basis depends on the timely completion of the Bowline Point Unit No. 1.

Because of the unavailability of Indian Point Unit No. 2 for the most part of the summer of 1972 the applicant had to defer an additional 244 MW(e) of retirements along with 208 MW(e) initially planned for retirement, for a total of 452 MW(e) of reduction in retirements. However, these older plants are inefficient, unreliable, and have high maintenance costs.

Furthermore, one major deterrent to the applicant's purchasing large blocks of power from upstate New York, the northeastern states and Canada is the limitation of the upstate-southeast transmission capability. This limitation is controlled by the lines between the Pleasant Valley and Millwood Substations which cannot transfer enough power to the applicant from the upstate area during the summer periods. During the summer of 1970, there were times when excess capacity was available upstate or in Canada but transmission limitations prevented its transfer and the applicant was forced into voltage reductions.[23] Therefore, purchase of power cannot be considered as a reliable source, even for emergency situations until the existing transmission network is upgraded. The higher cost per kilowatt hour for purchase power is also a deterrent to this alternative. Purchase power as a long-term alternative for Indian Point Unit No. 2 is also not practical until the advent of a national power grid system. For the winter of 1972-73, the applicant has planned to purchase 200 MW(e) from the Bowline Unit No. 1 and 40 MW(e) from the Maine Yankee Nuclear Plant if it is in service during the winter 1972-73 period. However, this nuclear plant has encountered delays and there is no assurance that it will be available for the winter period. In testimony presented by the New York State Department of Public Service on May 17, 1972,[1] the capacity, load, and margins including purchase power for both the applicant's and the New York State's requirements have been presented on a monthly basis from November 1972 through April 1973. The results indicate even with the purchase of 240 MW(e) and the availability of new capacity of 400 MW(e) from Bowline Unit No. 1, 348 MW(e) from gas turbines, and 240 MW(e) from Roseton Unit No. 1, and allowing for scheduled maintenance, average unit deratings and forced outages, the applicant will be unable to meet its load in January and March, 1973 and will not have the required operating reserve of 600 MW(e) in the New York Power Pool because of outages and deratings. During these same two months, the New York State electric utilities including the applicant will not be able to meet the required operating reserve of approximately 1,400 MW(e). Thus Indian Point Unit No. 2 with its 873 MW(e) capacity would be needed for the winter of 1972-1973 to help meet the applicant's load requirement and improve the New York State and the New York Power Pool power needs.

e. Long-Term Alternatives of Power Sources to Meet the Need of Power

Long-term alternatives, to meet the need for power, as discussed in Chapter X, include not only the construction of Indian Point Units Nos. 2 and 3 but also the construction of 4 fossil-fueled generating units on the Hudson River at Bowline Point and Roseton. Bowline Point Unit No. 1 is scheduled to be in service by the summer of 1972. Roseton Unit Nos. 1 and 2 are scheduled for service prior to the summer of 1973 and Bowline Point Unit No. 2 is scheduled for the summer of 1974.[1]

Even with these additions, the applicant has plans for an additional base-load fossil-fueled plant that the applicant has proposed to build in New York City in 1974 at its Astoria Plant. Thus, if Indian Point Unit No. 2 were not available it would be necessary to replace that unit with other new resources. In order to replace Unit No. 2 with a new unit, a site better than the Indian Point site would have to be found; however, as stated above, there is a shortage of available sites to meet the projected load growth even with the Indian Point Units No. 2 and 3 in service. In order to obtain permission to construct a new fossil-fueled unit at its Astoria plant inside New York City, the applicant had to enter into an agreement with the City of New York in which the City of New York said that it was agreed that no more fossil-fueled boilers for electric generating plants would be located in New York City.[9]

Gas turbines are not a feasible alternative to supply base load power. Although the applicant has installed in its system about 2,300 MW(e) of gas turbines,[1] approximately only 200 MW(e) of this capacity was planned by the applicant to serve as an emergency startup and transit capacity. The remaining 2,100 MW(e) were planned to provide peak capacity for the early 1970s as compensation for delays incurred in constructing the Cornwall Pump Storage Plant and to replace capacity loss due to equipment deterioration at older plants which had been used for peaking purposes. Peaking capacities supplied by these gas turbines is electricity furnished for only a limited number of hours per year when demand for electricity is unusually high because of seasonal increases in demand. This is particularly true during the summertime when there is a shortage of electricity to meet the demand. Therefore, the gas turbine capacity that has already been planned for the system would be required to operate more hours than would normally be the case for gas turbines which were intended solely for peaking capacity. It is difficult to project the expected performance in using gas turbines in providing base-load capability for continuous reliable service.

The applicant also has begun to arrange for purchasing 1,300 MW(e) of power in 1977. This consists of 500 megawatts from the Breakabeen Pump Storage Project of the Power Authority of the State of New York and 800 MW(e) from Hydro Quebec.[1] This pumped storage project has not yet been licensed by the FPC and must still be considered as only a possible source of power. The transaction with Hydro Quebec may involve a seasonal exchange or a straight purchase and a contract has recently been signed. The applicant is a participant in a study by the New York Power Pool, the Ontario Hydro and Hydro Quebec to determine the long-term feasibility of major interconnection with Canada to New York to import power. Assuming these purchases are made, they will be necessary to meet the load growth of the applicant and are not available as a replacement for Indian Point Unit No. 2. power transmission from Hydro Quebec to the United States may be complicated by the fact that a license has to be obtained to export power from Canada to the United States. Other possible sources for purchase are from the Canadian Hydroelectric Development Project at Churchill Falls, but the entire output at this facility would be required for anticipated load growth in Canada. The plans for major expansion of the Canadian Hydro resources in the early 1980s have prompted the applicant to reinvestigate this possibility for long-range large purchases and discussions leading to such purchases have been held.[1] However, it cannot be assumed that any significant amounts of power resources will be available on a firm basis until the 1980s at the earliest.

2. Alternative Heat Dissipation Systems

a. Once-Through Cooling

The heat dissipation system as discussed in Chapter III.E.1 of this

Statement is the once-through cooling system most likely to cause the most significant adverse impact to the environment. The heat dissipated by this system is about 6.35 x 10^9 Btu/hr, which results in thermal discharges of about 15°F during cooling water flow of about 2,650 cfs at the outfall at the confluence with the Hudson River. During 28 of the first 100 months that Indian Point Unit No. 1 was in operation, fish kills on the intake screens were observed by the applicant. Indications are that several million fish were killed.[24-26] The applicant in Section 2.5 of the Supplement No. 1 and Appendix B in Supplement No. 3 to the Environmental Report[27] outlines some of the alternatives for fish protection which have been considered and the results obtained, most of which have been unsatisfactory. However, the applicant has employed consultants from this country and abroad to look into the problems of fish kills and alternatives for the Plant condenser intake discharge structure to protect fish from damage due to the intake structure.

The primary cause of the impingement of fish on the screens has been excessive water intake velocities. The applicant[27] has proposed in the Supplement No. 3 a new screening structure for all three Units, at cost of $12-15 million, to be located offshore, with an intake channel closed by a sheet piling wall. The screening structure would be sized to maintain intake velocities below 0.3 fps during the winter season, when the fish kills have been most serious. Furthermore, the applicant plans to reduce the intake flow from 140,000 gpm per pump to 84,000 gpm per pump by recirculation during winter 1972-1973.[25]

Although the proposed modifications[29] to the intake structure might eliminate or drastically reduce fish kills due to impingement, the problem of entrainment of small organisms in the water still remains. The absolute number of fish killed is not so important as the effect of any kill on the compensatory reserve of the species involved. Reduction of the flow of cooling water through the condensers when ambient river water temperatures permit would assist in reducing impingement losses and entrainment.

Indian Point Unit No. 2 will not have the sheet piling or the ice wall which presented a problem for Indian Point Unit No. 1. Indian Point Unit No. 2 will have a fixed screen of the type which the applicant believed proved satisfactory for Indian Point Unit No. 1 in reducing the mortality of larger fish. The extension of the discharge is also applicable to Indian Point Unit No. 2 because all the Indian Point

Units use a common discharge canal and outfall structure. Furthermore, this extension avoided the problem of water recirculation through the cooling system.[30]

In addition, an underwater hole in front of the Indian Point Unit No. 2 intake was filled in 1971, at a cost of approximately $90,000.[1] A newly designed air bubble curtain is being tested at the intake of Indian Point Unit No. 1.[27] The applicant is also studying the effectiveness of moving the travelling screens to the intake opening and running the screens continuously to reduce fish impingement. However, the intake velocity of the travelling screens is about 2 fps and this would result in greater fish impingement.

The applicant has made the statement in its Supplement No. 1 to Environmental Report for Unit No. 2[1,24] that it would be willing to replace any loss of fish by replenishment from hatcheries it would construct and operate for this purpose. The staff believes that there is some question concerning the effectiveness and real value of transplanting juvenile fish at that site. Also, a more thorough evaluation needs to be made to determine if fish hatchery technology is adequate to rear the specific species of concern. The feasibility and advisability of such a fish rearing and transplant activity shall be evaluated.

The alternative of shutting down the Plant in the event of entrainment of fish impingement problems requires a balancing of competing factors. A shutdown of the Plant would produce a serious power shortage and increased emissions of air pollutants in New York City. If, for purposes of analysis, the power shortage problem can be ignored, environmental trade-off between air pollution in New York City and fish protection at Indian Point would need to be taken into account to determine whether such an action would be warranted.

b. Wet Cooling Towers

Among possible alternatives to the once-through condenser cooling water system are closed-loop systems that would utilize one or more cooling towers to dissipate the waste heat to the atmosphere.[31] Two major types of cooling towers are in use today; one is the wet tower that carries away heat by evaporation and sensible heat transfer and the other is the dry tower that relies on air to carry away heat and, in principle, functions like an automobile radiator. The two types of wet cooling towers, mechanical-and natural-draft, when operated in the closed-cycle mode, require makeup water to compensate for losses sustained through evaporation and drift. As evaporation occurs, the natural salts in the cooling water become concentrated; to prevent buildup and deposition on the components of the system, they are periodically returned to the source of cooling water supply by blowdown. Chemicals used in treating the cooling water to prevent growth of algae, freezing, etc., are also discharged during blowdown, and their effect upon the ecology of the receiving waters must be taken into account. (See Appendix XI-1). In general, mechanical-draft towers are relatively low structures, and the drift may cause fogging, misting, and icing that could be hazardous to motorists if highways, roads, or streets are within their reach. Natural-draft towers, on the other hand, are tall hyperbolic structures, about 400 feet high, which minimize the effects of drift at ground level. However, rain and snow have been observed to occur under the visible plume as well as local acid rains at fossil-fired plants when wind conditions caused the boiler stack plume to mix with the cooling tower plume. The plume behavior is governed only by the ambient atmospheric conditions and its own heat and moisture content. However, when the wind is strong, the plume may be caught in the aerodynamic downwash surrounding the tower structure and be carried directly to the ground. This phenomenon has been found to occur with smoke stack plumes when the ratio of the stack emission speed to the wind speed is less than unity.[43] Observers,[44] in studying large natural-draft cooling towers, have found that downwash does not occur until the ratio is significantly less than 1. However, when brackish or seawater is used as the coolant water, downwash drift from these cooling towers could be a problem if the salt is deposited on a relatively small land area. The severity of the damaging effects would be governed by the duration of the downwash phenomenon. Other factors to be considered such as visual impact, noise levels, chemical effects from blowdown, increased generating costs, etc., are discussed in the benefit-cost analysis and in Chapter XII.

The size of the cooling tower will be dependent upon the amount of waste heat to be dissipated by evaporation. Evaporation of about 1 pound of water will transfer 1,000 Btu to the atmosphere.[32] Thus at least about 6,350 gpm would be evaporated from Indian Point Unit No. 2. Evaporation of 1% of water volume will result in a reduction of the water temperature by approximately 10°F. Drift, the carry over of water droplets by air, accounts for a small loss of water. In present cooling tower technology, discharge of about 0.37% of cooling tower as blowdown is effected per 10% of cooling rate to prevent the development of concentrations of solids in the recirculated water at concentrations exceeding 3 or 4 times that of the makeup water. The applicant in its Benefit-Cost Analysis discusses both types of cooling towers, operating in either the open-or closed-cycle mode. The method of an alternative preferred by the applicant is the closed-cycle natural-draft cooling tower. See Section XI-B for further details.

c. Dry Cooling Towers

Dry cooling towers have been used in Europe for fossil-fueled plants and chemical processing plants but have not gained widespread acceptance in the United States. Hence, the principal manufacturers of large-capacity dry cooling towers are located in Europe. The use of this type of cooling tower offers the advantage of increased flexibility in siting thermal power plants, since a large source of cooling water would no longer be necessary. A disadvantage is that back-pressure turbines for pressures in the range of 8-inches Hg absolute, which must be used with dry cooling towers, are not manufactured in the United States. Another disadvantage is that the thermal efficiency is lower, since it is governed by the dry-bulb rather than the wet-bulb temperature of the air. These dry cooling towers require much more heat transfer surface because of inefficiencies in heat transfer adding to the cost of installation and space requirements. The infancy of the art of large dry cooling towers is obvious in estimates of capital and operating costs, which have ranged from \$20 to \$50 per kilowatt[33] capacity for a nuclear plant, and in estimates of the increased cost to the consumer, which have ranged from 2% to 10%. Details on siting, performance and economics of dry cooling towers are described by Smith and Larinoff,[33] who point out the advantages and disadvantages of this cooling system for dissipating heat to the atmosphere. The applicant has estimated an additional cost of \$45 million to the Plant if Unit No. 2 had been initially designed with dry cooling towers. Dry cooling towers may not be a practical short-term alternative for the Indian Point complex for the reasons stated above but with advances in technology, the applicant should give it further thought for the long-term solution to potential environmental damage of the Hudson River using the present once-through system.

d. Cooling and Spray Ponds

Cooling ponds[34-37] and spray ponds are practical alternatives to once-through cooling systems or cooling towers for large nuclear reactors. However, the surface area required for cooling ponds is large (1 to

3 acres per megawatt of electricity)[38] and would be difficult and costly ($1 to $10 per kilowatt)[38] to obtain in the Indian Point area. A cooling pond for use at Indian Point would require about 2,700 acres. Since there are only 239 acres in the site, this alternative is not practical for this site. Spray ponds, though similar to cooling towers in operation, depend upon local temperature, humidity, and wind conditions, and thus their reliability is variable. The loss of land and the capital cost required for this alternative may not be justified for a benefit whose reliability is questionable, particularly during the summer months, when the peak electrical load is experienced. The applicant states in its Supplement No. 1 that a spray pond for use at Indian Point No. 2 would require about 30 acres at a design temperature rise of about 25°F. The costs of such a cooling pond was estimated by the applicant to be $7-10 million for Indian Point Unit No. 2.[1]

There are adverse environmental effects associated with a spray pond at Indian Point. If the scenic wooded area to the north were to be used, the land would require defoliation and clearing. During winter operation, drift and spray would result in local icing. The effect of salt content of the spray is not known but it is likely that the local flora would be affected. Under adverse humidity conditions, local fogging can occur. See Section XI.B for further discussion of this alternative.

e. Waste Heat

An alternate to ambient heat sink cooling is to use the heat available in the turbine exhaust for low grade thermal requirements such as domestic and temperature process requirements. These uses require temperature levels generally corresponding to condensed pressures and temperatures not compatible with the design of the existing Indian Point Unit No. 2 turbine generator system. Furthermore, there are no potential users of waste heat in the quantity available within reasonable proximity of the Plant.

3. Alternative Chemical Discharge Techniques

a. Chemical Wastes

Chemical wastes resulting from treatment of the primary, secondary, and auxiliary systems of Units Nos. 1 and 2 are released to the discharge canal, where they are diluted by the cooling water before entering the Hudson River. The chemicals used are listed and discussed in Chapters III.E.3 and V.B and D of this Statement. The applicant in Appendix D of its comments to the Draft Statement outlines the procedure used during chlorination of the condensers of Unit Nos. 1 and 2. The staff's assessment of the chemical waste disposal system shows that the releases to the Hudson River will meet the New York State water quality standards, which are written in general terms without specific limitations as to the concentrations of the various chemicals to be discharged. The applicant has established its own concentration criteria, based in part upon bioassay work performed by the Raytheon Company and New York University.[39] Chemical discharges are also subject to regulation by the New York State Department of Environmental Conservation in accordance with Section 1230 of the Public Health Law.

Sodium hypochlorite is used for treatment of fouling organisms in the cooling and service water intake bays of the intake structures, the pumps, and the condenser tubing. The solution is pumped from storage tanks through flow control valves to the inlet bays in a cycle that doses 1/2 of the inlet water boxes of the cooling water bays for 30 minutes and then the remaining half for another 30 minutes and then the service water intake bay. These injections are initiated by an automatic programmed control system. The estimated maximum concentration of residual chlorine in the cooling water as it leaves the discharge structure and enters the Hudson River is 0.5 ppm; the residual chlorine concentration will exceed minimum toxic levels within the thermal plume and in the river during periods of low flow. This chlorine will react with substances in the water and undergo gradual decay. Chloramine compounds are a major by-product and have been found to inhibit reproduction of aquatic organisms when present in amounts greater than 0.003 ppm.[40] It is not known at this time what quantity of chloramines will be formed or the magnitude of the impact to the biota in the Hudson River. Alternatives to the sodium hypochlorite system as designed would be to reduce the amount of sodium hypochlorite per dose or to increase the time interval between doses, either of which would impair the effectiveness of the system and only delay the ultimate impact.

A more effective interim alternative would be to limit dosing cycles to daylight hours and periods of peak tidal flow. This modified operating procedure would reduce the impact of the chlorine on the aquatic biota in two ways. First, the highest concentration of toxic chlorine compounds will be in the thermal plume, which forms a layer at the surface. Thus the exposure of many planktonic crustaceans and larval fish will be reduced because of their vertical diurnal migration patterns. Second, peak tidal flows will permit maximum available dilution of the residual chlorine; when the peak tidal flow exceeds 300,000 cfs, the concentration will be reduced below the level that is toxic to sensitive organisms. Mechanical or thermal cleaning systems are also available[41,42] and would eliminate the need for the sodium hypochlorite biocide and the discharge of toxic chlorine compounds to the estuary.

b. Sanitary Sewage

The existing sanitary sewage disposal plant for Unit No. 1 has adequate capacity to serve Unit No. 2. It is described in Chapter III.E.3 of this Statement. At present, the percolation rate from the four 45-foot-square sand filter beds is such that the underdrains are not required. In the event that the influent to the sand filter beds exceeds the percolation rate, the applicant has stated that it will install an automatic chlorination station and discharge the effluent to the Hudson River. An additional sand filter bed would be preferable to chlorination. If warranted, in consideration of 400 employees at the site for all 3 units, the applicant should investigate alternative sewage handling systems such as connection to the municipal sewage disposal system.

B. SUMMARY OF ALTERNATIVES

The applicant has provided a discussion of alternatives and a cost-benefit analysis in Supplement No. 3 to the Environmental Report. In many cases the staff did not agree with the applicant's estimates; these differences are discussed below. The applicant in its Supplement No. 3 followed the Commission's draft guidelines (January 7, 1972) in preparing its analysis.

It should be noted that in following the draft guidelines, the monetized items (in present worth) calculated by the applicant differ from those calculated by the staff. The staff elected to use a discount rate of 8.75% which has been used in most recent environmental impact statements, although 8% was suggested in the original draft guidelines (December 29, 1971). The differences between the staff's calculated values and those of the applicant reflect this difference in procedure.

As discussed in the previous chapters of this Statement, the staff's independent evaluation of the environmental effects of the construction and operation of Indian Point Unit No. 2 disagrees in certain respects with the evaluation made by the applicant and presented primarily in its Environmental Report of August 6, 1970, and Supplements No. 1 of September 9, 1971, No. 2 of October 15, 1971, and No. 3 of February 15, 1972.

The important areas of disagreement between the applicant's analysis and that of the staff are the following:

(1) The staff's detailed review of the Quirk, Lawler, and Matusky heat dissipation and the Alden hydraulic models, developed for and used by the applicant, indicates a number of uncertainties which, the staff believes, might affect the applicant's conclusions. (These have been discussed in Chapter III.E.1.)

(2) Environmental effects from operation of the intake-discharge structure have a potential for long-term significant biological damage to aquatic biota not only in the localized area in the vicinity of Indian Point Unit No. 2, but also in the Hudson River estuary, New Jersey coast and New York Bight. (See Chapter V.D.2.)

(3) The discharge of residual chlorine may result in exposure of biota to toxic levels of residual chlorine or chloramines. (See Chapter V.D.1.c.)

(4) There may be a reduction in the dissolved oxygen in the cooling water across the condenser. (See Chapter V.D.1.b.)

One of the major differences between the staff and the applicant in the evaluation of available information is the impact of entrainment of nonscreenable fish eggs, larvae, and fingerlings. Another is the impingement of fish on the intake structure. The staff does not agree with the small impact of about 2-3% damage to eggs and larvae estimated by the applicant. Details of the staff's disagreements are given in Chapters V.D, VII, and Appendices V-1, -2 and -3. In Appendix XII-23, the applicant has commented on the staff's position on the environmental impact of Plant operation as presented in the Draft Statement.

The alternatives selected for compiling benefit-cost information are described in the following paragraphs:

(1) Alternative 1, the existing Plant, has an 873 MW(e) capacity and construction is virtually completed. It is a pressurized water reactor utilizing once-through cooling in which the condenser discharge water from Unit No. 2 is being mixed with that from Unit No. 1 in the same discharge canal. The Alternative 1 design will limit doses from radioactive material in liquid and gaseous effluents to levels that are within the numerical guides for design objectives and limiting conditions of operation set forth in the proposed Appendix I (dated June 9, 1971) to 10 CFR 50.

(2) Alternative 2, with a minimal water impact, was selected as the present facility with the addition of two natural-draft, closed-cycle cooling towers. It is believed that the water impact would be greater if closed-cycle, mechanical-draft cooling towers were used instead of natural-draft cooling towers because of the greater amounts of chemicals, biocides and corrosion inhibitors, that would be discharged in the cooling tower blowdown. The natural-draft cooling tower option was chosen because of a reduced environmental impact from fog, drift, salt deposition, and chemicals in blowdown. Six alternative cooling systems (in addition to Alternative 1) were evaluated. These are designated as Alternatives 2B, 2C, ... 2G. These are mechanical-draft cooling towers, natural-draft cooling towers, and spray ponds, each operated in the open- and closed-cycle mode.

(3) Alternative 3, as defined in the Commission's draft guidelines (January 7, 1972), is "the conceptual plant design which reduces to the minimum feasible level with available technology detrimental effects to ambient air and land." It is identical with Alternative 1 because Alternative 1 presents very minor interactions with air and land. Except for residual chlorine, the other chemical discharges are considered to be minor. Since the Indian Point site presently accommodates a nuclear power reactor (Unit No. 1) and has a total of 3 Units on the site, no additional community impact from a new industry will occur and no land acquisition is required.

(4) Alternative 4, defined as "that design which results from the applicant's best effort to balance environmental cost reduction with plant modification costs," is also identical with Alternative 1. Therefore only Alternatives 1 and 2 will be discussed.

1. Description of Benefits of Alternative Plant Designs

The benefits discussed below are tabulated in Table XI-1.

a. Power Benefits

The staff elected to report the total electric energy output in megawatt hours produced over the 30-year life of the Plant rather than in dollars of present worth. It is felt that the present worth of power benefits calculated for a 30-year* period includes too many uncertainties to give a meaningful answer.

The applicant has reported that the percentage of load by class of customers is given by the applicant as follows:

Commercial and Industrial	53.6%
Residential	30.0%
Other (Railroad and Governmental)	16.4%

These are based on long-range forecasts of sales by classification of customers. The applicant does not keep separate statistics on commercial customers and industrial customers because they are commingled in several of the rate schedules.

Alternative 1 (Plant As Is)

Assumes nameplate rating of 873 MW(e) for life of Plant (30 years), 8 weeks scheduled maintenance, an immature outage rate of 15% for the first 3 years and a mature outage of 10% for the remaining 27 years.

8760	hours per year
-1344	hours (8 weeks scheduled maintenance)
7416	operating hours per year without forced outages
-1112	(15% immature outage rate)
6304	operating hours/year with outages

$$\text{Capacity Factor (first 3 years)} = \frac{6304 \times 100}{8760} = 72.0\%$$

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*The applicant has applied for a 40-year operating license but the book life is considered to be 30 years which were used in these calculations.

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TABLE XI-1

BENEFIT DESCRIPTION OF ALTERNATIVE PLANT DESIGNS

(All monetized benefits expressed in terms of present value)

1. NAME OF FACILITY: Indian Point Unit No. 2

2. DATE OF REPORT: September 1972

			ALTERNATIVES			
BENEFITS[1+2+3]			1 Plant As Is	2 Minimum Water Impact *	3 Minimum Land/Air Impact	4 Plant License Request
Electric Power Produced and Sold:	Industrial	Total (million MWhr) 30 yr period	173.8	166.5	Same as Alt. 1	Same as Alt. 1
	Commercial					
	Residential					
	Other Uses					
Reliability Index		Increased days per summer loss of load without IP2 (1972)	7	7		
Process Steam Sold			None	None		
Environmental Enhancement:	Recreation	Acres	94	94		
	Navigation		No Benefit	No Benefit		
Increased 1972 emissions if Indian Point No. 2 is not in service	Air Quality: SO_2	Tons	29,000	29,000		
	NO_x	Tons	16,000	16,000		
	Particulates	Tons	1,245	1,245		
	Others					
Education		Visitors/yr to visitors' center	100,000	100,000		
Research		$Millions	12	12		
Regional Gross Product			None Claimed	None Claimed		
Local Taxes		$Million/yr	4.1	6.3		
Employment		$Millions Estimated Incremental Payroll/yr	1.2	1.2		
Other Benefits						

[1] Where a row is not relevant to a particular alternative, insert n.a. for not applicable.

[2] See Section III.A. of the guideline for suggested units of measure of benefits. Applicants should specify the units they use on the form.

[3] Where benefits are the same for each alternative, put same in columns 2, 3 and 4.

*Alternative utilizing 2 natural-draft, closed-cycle cooling towers.

7416 operating hours per year without forced outages
\- 742 (10% mature outage rate)

6674 operating hours per year with outages

Capacity Factor (last 27 years) $= \frac{6674 \times 100}{8760} = 76.2\%$

Annual Energy Output:

First 3 years = 873 MW x 6304 hr = 5,503,392 MWhr
Next 27 years = 873 MW x 6674 hr = 5,826,402 MWhr

Total Energy Produced:

3(5,503,392) + 27(5,826,402) = 173,823,030 MWhr

Alternative 2 (Minimum Water Impact)

The two natural-draft, closed-cycle cooling towers derate the Plant by reducing the net output capacity to 836 MW(e).

Annual Energy Output:

First 3 years = 836 MW x 6304 hr = 5,270,144 MWhr
Next 27 years = 836 MW x 6674 hr = 5,579,464 MWhr

Total Energy Produced:

3(5,270,144) + 27(5,579,464) = 166,455,960 MWhr

b. Reliability Index

The applicant normally performs reliability calculations with a loss-of-load analysis confined to the times of maximum exposure to the peak load. This is the hour of maximum load for each weekday from June 15 to September 15. If the capacity available is less than the load at the peak hour it is counted as a day of loss-of-load. A loss-of-load day is one on which the applicant cannot meet its peak load with its own generation plus firm purchases. Thus, a loss-of-load day would occur on any day the applicant was forced to use emergency or supplemental purchases or forced to reduce voltage or to actually disconnect customer load. The applicant does not schedule any maintenance during this peak summer period. Although supplemental purchases or load curtailment measures may be required to meet operating reserve requirements, these are not determined by the loss-of-load calculation.

For 1972, with all units initially scheduled for the summer of 1972 including Indian Point Unit No. 2 in service, and with scheduled retirements completed, the loss-of-load expected would be 2.0 days per summer. Since Indian Point Unit No. 2 will not be in service during the summer of 1972, the expected number of loss-of-load days will increase to 9.2 days assuming that all other planned new units are available as scheduled, but that planned retirements are deferred. Since the reliability index is based on 65 summer days, this represents 14.2% of the summer days. Thus, there would be a 7-day increase in the expected number of loss-of-load days without Indian Point Unit No. 2 in the summer of 1972, even if retirement of older plants were deferred. Expressed another way, this means a 350% increase in the expected exposure of the system to emergency conditions.

Since Indian Point Unit No. 2 will not be available for the summer of 1972, the staff accepts the applicant's method of computing the reliability index and concurs with the 7-day increase in the expected number of loss-of-load days without Indian Point Unit No. 2 during the period from June 15 to September 15, 1972.

Over the long range the reliability index will vary as a function of the applicant's overall program of capacity additions and retirements, but the exclusion of Indian Point Unit No. 2 would have a similar impact on the actual reliability index in any given year. A unit or group of units would have to be added to the applicant's current construction program over the long range to replace Indian Point Unit No. 2 if it were not available.

c. <u>Recreation</u>

As stated in Chapters V and VIII, the applicant has a master plan to improve the appearance and usefulness of the site through development of recreational facilities for public use, including an 80-acre woodland park with a fresh-water lake, gardens, nature trails, picnic tables, and parking facilities. Before construction of Unit No. 3 is completed, a new $7 million visitors' center will be built to replace the first one. This will enhance the educational productivity of the site through exhibits and lectures on peaceful uses of atomic energy and development of nuclear power.

The applicant has also transferred 14 acres at the northwest corner of the site to the Village of Buchanan to be developed by the Village as a public marina. It is anticipated that boat launching ramps will be available at the marina; however, plans are not definite enough to estimate capacities and expected annual user days. There is no doubt, however, that construction of a public marina will enhance water-related activities of the area.

d. Air Quality

The applicant conducted an analysis of the increased emissions from increased generation of fossil-fueled plants to compensate for not having Indian Point Unit 2 available. Thus, without Indian Point Unit No. 2 in service in 1972, an incremental amount of emissions of 29,000 tons of SO_2, 16,000 tons of NO_x, and 1,245 tons of particulate matter would be emitted into the New York City atmosphere above those emissions expected from those same generating stations if Indian Point Unit No. 2 were in service. This analysis was based on all units burning only oil, or gas when available. The oil which would be burned would be of the lowest sulphur content for which contracts could be obtained. The applicant's last coal burning unit was taken out of service for conversion to oil in the early part of 1972. The staff accepts the applicant's estimate of the increased emissions from their fossil-fueled facilities during 1972 with Indian Point Unit No. 2 not in service.

e. Education

Educational benefits will be provided by the new visitors' center to be constructed on the site. Construction of the center is expected to begin in 1973 and to be completed in 1974. The new center will be considerably larger than the previously existing facility and will include more sophisticated exhibits focused on the peaceful uses of nuclear energy. The estimated cost of the facility is $7 million and is expected to attract large numbers of school children on educational field trips. The applicant has estimated a grand total of 100,000 visitors per year to the new center based on visitations to the old center during the eleven years it was in operation.

f. Research

A total of approximately $10.0 million is planned to be spent by the applicant on research for environmental studies relating to the Indian Point site. These studies are all directed toward environmental protection in the Indian Point areas. They are directed toward the entire Indian Point site rather than Indian Point Unit No. 2 specifically. About $1,700,000 has been spent in contract research to date.

The costs for project related studies concerned with environmental effects have been reported by the applicant as follows:

Completed Studies	$ 1,701,312
Five-Year Ecological Study	10,000,000
Other Studies to be Performed	261,000
Total	$11,962,312

g. Regional Gross Product

No benefits are claimed as Westchester County is not considered a poverty or high unemployment area.

h. Taxes - Community Benefits

The applicant estimated annual local taxes of $4,100,100 for Alternative 1 (Plant As Is) and $6,300,000 for subalternative 2E. (Closed-Cycle Natural Draft Cooling Towers). However, the additional local taxes and employment would involve an attendant increase in electrical rates paid by local and regional customers and there may be some increase in local services for the employees at the Plant.

i. Employment

Construction wages were estimated by the staff to be about $100 million. It is estimated that an incremental increase of 100 permanent employees will result because of the existence of Indian Point Unit No. 2. This is based on projected employment for the fully developed Indian Point site and employment patterns at other multi-plant nuclear generating facilities.

The applicant has estimated that 399 full-time employees, primarily from the local communities where any new employee would probably move to, will be maintained at the Indian Point site on the completion of Units Nos. 1, 2, and 3. Some 112 of these are expected to be management personnel with the being operational and maintenance personnel. The average payroll per employee is estimated at $12,000 per year. The applicant's estimated 100 jobs attri-butable to Indian Point Unit No. 2 with an incremental payroll per year of $1,200,000 seems reasonable. Over the life of the Plant, the economic impact from this payroll amounts to $36,000,000. This does not include the impact of construction personnel and their payrolls, nor the extra maintenance personnel that will be required during down times for maintenance.

2. Cost Description of Alternative Plant Designs

The costs, as described below, are tabulated in Table XI-2 and in Table XI-3. The headings below, preceded by numbers, correspond with numbered items in the tables.

a. Generating Costs

The generating costs reported by the applicant have been reduced to reflect the higher discount rate used by the staff.

Plant As Is

Plant Cost: $178,250,000
Discount Rate: 8.75%
Annual Carrying Charge: 13.0%
Present Worth Factor: 10.520 (for 8.75% and 30 years)
Plant Life: 30 years

$C_o = 178,250,000$

$O_t = 0.0004 \times 873,000 \text{ KW} \times 6674 \text{ hr/yr} \times 10.520 = \$24,518,000$

$F_t = 0.00142 \times 873,000 \text{ KW} \times 6674 \text{ hr/yr} \times 10.520 = \$87,037,000$

$TC_g = \$289,805,000$

Incremental Generating Costs

Present Worth Factor (8.0% and 27 years) = 10.935

Present Worth Factor (8.75% and 27 years) = 10.254

$$\text{Multiplier} = \frac{10.254}{10.935} = 0.938$$

Natural-Draft Open-Cycle Alternative = $130,413,000 x 0.938 = $122,327,000

Mechanical-Draft Open-Cycle Alternative = $117,755,000 x 0.938 = $110,454,000

Spray Pond Open-Cycle Alternative = $125,328,000 x 0.938 = $117,558,000

Natural-Draft Closed-Cycle Alternative = $144,902,000 x 0.938 = $135,918,000

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TABLE XI-2
COST DESCRIPTION OF ALTERNATIVE PLANT DESIGNS

(All monetized benefits expressed in terms of present value)

1. NAME OF FACILITY

Indian Point No. 2

2. DATE OF REPORT

September 1972

		ALTERNATIVES 1 Plant As Is	2 Minimum Water Impact	3 Minimum Land/Air Impact	4 Plant License Request
SUBSYSTEMS	Alternative Cooling Systems (I)	A[4]	Nat-Draft Closed Cycle	Same as Alt. 1 n.a.	Same as Alt. 1 n.a.
	Alternative Rad Waste Systems (II)	A			
	Alternative Chemical Effluent Systems (III)	A			
	Alternative ______ System (IV)	A			
	Alternative ______ System (V)	A			
GENERATING COSTS	$Millions	289.8	425.7		
ENVIRONMENTAL COSTS[1+2+3]					
Primary Impact	Population or Resource Affected Btu/hr $\times 10^9$	6.4	1.27		
1. Heat Discharged to Water Body	1.1 Cooling Capacity Acre-ft $\times 10^3$	1.6	<1		
	1.2 Aquatic Biota	Small	~ 0		
	1.3 Migratory Fish	0	0		
2. Effects on Water Body of Intake Structure and Condenser Cooling Systems	2.1 Primary Producers and Consumers	Damage Potential	2.5% of Alt.1		
	2.2 Fisheries	Large	2.5% of Alt. 1		
3. Chemical Discharge to Water Body	3.1 People	0	0		
	3.2 Aquatic Biota	Small	Small		
	3.3 Water Quality—Chemical Chlorine, max. % of std.	100	100		
4. Consumption of Water	4.1 People gal/year	0	0		
	4.2 Property Acre ft/year	0	0		
5. Chemical Discharge to Ambient Air	5.1 Air Quality-Chemical % of standard	25	25		
	5.2 Air Quality—Odor	None	None		

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[1] Where a row is not relevant to a particular alternative, insert n.a. for not applicable.

[2] See Table 3 for units of measure and methods of computation, units should be specified by the applicant on the form.

[3] Where items are the same for each alternative, put same in columns 2, 3 and 4.

[4] A refers to alternative in the Supplementary Forms.

*Includes impingement and mechanical, thermal, and chemical effects on entrained biota.

6. Salts Discharged from Cooling Towers	6.1	People gal/year	0	0	n.a.	n.a.
	6.2	Plants Acres Affected	0	See Text		
	6.3	Property Resources $	0	See Text		
7. Chemical Contamination of Ground Water (excluding Salt)	7.1	People gal/yr	0	0		
	7.2	Plants Acres Affected	0	0		
8. Radionuclides Discharged to Water Body	8.1	People—External Contact man-rem/yr	0.1 Init. 0.08 Mod	0.08 Mod		
	8.2	People—Ingestion man-rem/yr	5 Init. 0.87 Mod	0.87 Mod		
	8.3	Plants Rads/yr ~~Primary Consumers~~ Invertebrates Rads/yr	0.090 1.50	0.338 5.65		
	8.4	Fish Rads/yr	0.042	0.157		
9. Radionuclides Discharged to Ambient Air	9.1	People—External Contact man-rem/yr	10	9.9		
	9.2	People—Ingestion Throid man-rem/yr	>55	>58		
	9.3	Plants and Animals	See Text	See Text		
10. Radionuclide Contamination of Ground Water	10.1	People	0	0		
	10.2	Plants and Animals	0	0		
11. Fogging and Icing	11.1	Ground Transportation hrs of increasing driving hazard/yr	0	0		
	11.2	Air Transportation hrs of airport closing/yr	0	0		
	11.3	Water Transportation hrs which ships reduce speed/yr	0	0		
	11.4	Plants Acres affected	0	0		
12. Raising/Lowering of Ground Water Levels	12.1	People gal/yr	0	0		
	12.2	Plants Acres	0	0		
13. Ambient Noise	13.1	People Residents affected	0	300		
14. Aesthetics	14.1	Appearance	Minor	Major		
15. Permanent Residuals of Construction Activity	15.1	Accessibility of Historical Sites Visitors/yr	0	0		
	15.2	Accessibility of Archeological Sites	0	0		
	15.3	Setting of Historical Sites Visitors/yr	0	Minor		
	15.4	Land Use Acres	0	0		
	15.5	Property $	0	0		
	15.6	Flood Control	None	None		
	15.7	Erosion Control tons/yr	0	0		

COMMENTS

SUPPLEMENTARY FORM - 1

TABLE XI-3

COST DESCRIPTION - ALTERNATIVE COOLING SYSTEMS
(Include Associated Coolant Water Treatment Systems)

1. Name of Facility
Indian Point Unit No. 2

2. Date of Report
September 1972

			ALTERNATIVES						
				Open Cycle			Closed Cycle		
			Once-thru	Nat. Draft	Mech. Draft	Spray Pond	Nat. Draft	Mech. Draft	Spray Pond
INCREMENTAL GENERATING COST		$ x 10^6	XXXX	122.3	110.5	117.6	135.9	113.4	131.3
ENVIRONMENTAL COSTS									
Primary Impact	Population or Resource Affected	Btu/hr x 10^9	6.35	1.27	1.27	See Text	0.13	0.123	See Text
1. Heat Discharged to Water Body	1.1 Cooling Capacity	Acre-ft	1.6 x 10^3	<1	<1		<1	<1	
	1.2 Aquatic Biota		Small	~0	~0	~0	~0	~0	~0
	1.3 Migratory Fish		0	0	0	0	0	0	0
2. Effects on Water Body of Intake Structure & Condenser Cooling System*	2.1 Primary Producers Consumers		Potentially Significant Damage	Potentially Significant Damage	Potentially Significant Damage	Potentially Significant Damage	2.5% of Open Cycle	2.6% of Open Cycle	3.3% of Open Cycle
	2.2 Fisheries		Potentially Large	Potentially Large	Potentially Large	Potentially Large	2.5% of Open Cycle	2.6% of Open Cycle	3.3% of Open Cycle
3. Chemical Discharge to Water Body	3.1 People	Annual user days	0	0	0	0	0	0	0
	3.2 Aquatic Biota		Small	Small	Small	Small	Large	Large	Large
	3.3 Water Quality - Chemical Max. 100% of Standard		Chlorine 100%	100	100	100	No effect	No effect	No effect

* Includes impingement and mechanical, thermal, and chemical effects on entrained biota.

SUPPLEMENTARY FORM - 1

COST DESCRIPTION - ALTERNATIVE COOLING SYSTEMS
(Include Associated Coolant Water Treatment Systems)

TABLE XI-3 (Cont'd)

1. Name of Facility
Indian Point Unit No. 2

2. Date of Report
September 1972

		ALTERNATIVES						
		Open Cycle				Closed Cycle		
		Once-thru	Nat. Draft	Mech. Draft	Spray Pond	Nat. Draft	Mech. Draft	Spray Pond
ENVIRONMENTAL COSTS (Cont'd)								
4. Consumption of Water	4.1 People gal/yr	0	0	0	0	0	0	0
	4.2 Property Acres	0	0	0	0	0	0	0
5. Chemical Discharge to Ambient Air	5.1 Air Quality - Chemical % of Std SO_2	25	25	25	25	25	25	25
	NO_x	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	5.2 Air Quality - Particulates (% of Std)	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	Odor	None	None	None	None	None	None	None
6. Salts Discharged from Cooling Towers	6.1 People gal/yr	0	0	0	0	0	0	0
	6.2 Plants Deposition on Land - Acres	0	See Text	0	1200	See Text	0	1200
	6.3 Property Resources $	0	See Text	Moderate	Moderate	See Text	Moderate	Moderate
7. Chemical Contamination of Ground Water (Excluding Salt)	7.1 People gal/yr	0	0	0	0	0	0	0

SUPPLEMENTARY FORM - 1

COST DESCRIPTION - ALTERNATIVE COOLING SYSTEMS
(Include Associated Coolant Water Treatment Systems)

TABLE XI-3 (Cont'd)

Name of Facility
Indian Point Unit No. 2

2. Date of Report
September 1972

		ALTERNATIVES Open Cycle Once-thru	 Nat. Draft	 Mech. Draft	 Spray Pond	 Closed Cycle Nat. Draft	 Mech. Draft	 Spray Pond
NVIRONMENTAL COSTS (Cont'd)								
	7.2 Plant Acres affected	0	0	0	0	0	0	0
8. Radionuclides Discharged to Water Body	8.1 People - External Contact Man-Rem/yr	0.1	0.08	0.08	0.08	0.08	0.08	0.08
	8.2 People - Ingestion Man-Rem/yr	5	0.87	0.87	0.87	0.87	0.87	0.87
	8.3 Invertebrates Rad/yr	1.5	1.5	1.5	1.5	5.6	5.6	5.6
	Plants	0.09	0.09	0.09	0.09	0.34	0.34	0.34
	8.4 Fish Rad/yr	0.04	0.04	0.04	0.04	0.16	0.16	0.16
9. Radionuclides Discharged to Ambient Air	9.1 People - External Contact Man-Rem/yr	10	9.9	9.9	9.9	9.9	9.9	9.9
	9.2 People - Ingestion Man-Rem/yr	<55	<58	<58	<58	<58	<58	<58
	9.3 Plants and Animals Rad/yr	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

SUPPLEMENTARY FORM - 1

COST DESCRIPTION - ALTERNATIVE COOLING SYSTEMS
(Include Associated Coolant Water Treatment Systems)

TABLE XI-3 (Cont'd)

1. Name of Facility
Indian Point No. 2

2. Date of Report
September 1972

		ALTERNATIVES						
		Open Cycle				Closed Cycle		
		Once-thru	Nat. Draft	Mech. Draft	Spray Pond	Nat. Draft	Mech. Draft	Spray Pond
ENVIRONMENTAL COSTS (Cont'd)								
10. Radionuclide Contamination of Ground Water	10.1 People Man Rem/yr	0	0	0	0	0	0	0
	10.2 Plants	0	0	0	0	0	0	0
	Invertebrates Rad/yr	0	0	0	0	0	0	0
	Fish	0	0	0	0	0	0	0
11. Fogging and Icing	11.1 Ground Transportation Hrs of increased driving hazard/yr	0	0	0	4,030	0	88	5,340
	11.2 Air Transportation Hrs of airport closing	0	0	0	3,150	0	88	4,820
	11.3 Water Transportation Hrs of reduced speed/yr	0	0	0	5,610	0	175	6,570
	11.4 Plants acres affected	0	0	0	Moderate	0	0	Moderate
12. Raising/Lowering of Ground Water Levels	12.1 People gal/yr	0	0	0	0	0	0	0
	12.2 Plants acres	0	0	0	0	0	0	0

SUPPLEMENTARY FORM - 1

COST DESCRIPTION - ALTERNATIVE COOLING SYSTEMS
(Include Associated Coolant Water Treatment Systems)

TABLE XI-3 (Cont'd)

1. Name of Facility
Indian Point Unit No. 2

2. Date of Report
September 1972

			ALTERNATIVES						
			Open Cycle				Closed Cycle		
			Once-thru	Nat. Draft	Mech. Draft	Spray Pond	Nat. Draft	Mech. Draft	Spray Pond
ENVIRONMENTAL COSTS (Cont'd)									
13. Ambient Noise	13.1	People Residents affected	0	300	4500	Minor	300	3000	Minor
14. Aesthetics	14.1	Appearance Transmission Facilities	Minor Minor	Major Minor	Moderate Minor	Moderate Minor	Major Minor	Moderate Minor	Moderate Minor
15. Permanent Residuals of Construction Activity	15.1	Accessibility of Historical Sites Visitors per yr.	0	0	0	0	0	0	0
	15.2	Acessibility of Archeological Sites	No Known Deposits	0	0	0	0	0	0
	15.3	Setting of Historical Sites Visitors per yr.	0	Minor	0	0	Minor	0	0
	15.4	Land Use - Acres	0	0	0	0	0	0	0
	15.5	Property $	0	0	0	0	0	0	0
	15.6	Flood Control	None	None	None	None	None	None	None
	15.7	Erosion Control tons/yr	0	0	0	0	0	0	0

SUPPLEMENTARY FORM - 1

TABLE XI-3 (Cont'd)

COST DESCRIPTION -- ALTERNATIVE COOLING SYSTEMS
(Include Associated Coolant Water Treatment Systems)

1. Name of Facility
Indian Point Unit No. 2

2. Date of Report
September 1972

			ALTERNATIVES						
			Open Cycle				Closed Cycle		
			Once-thru	Nat. Draft	Mech. Draft	Spray Pond	Nat. Draft	Mech. Draft	Spray Pond
ENVIRONMENTAL COSTS (Cont'd)									
16. Temporary Impacts of Plant Construction	16.1	Land Disturbance Acres	35	23	20	30	18	19	38
	16.2	Air Quality	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	16.3	Water Quality	Minor Turbidity	Negligible	Negligible	Minor Turbidity	Negligible	Negligible	Negligible
	16.4	Water Diversion	None	None	None	None	None	None	None
	16.5	Waterways Effects	None	None	None	None	None	None	None
	16.6	Spoilage cu. yds.	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
	16.7	Housing	No Known Impact	No Known Impact	No Known Impact	No Known Impact	No Known Impact	No Known Impact	No Known Impact
	16.8	Schools	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

SUPPLEMENTARY FORM - 1

TABLE XI-3 (Cont'd)

COST DESCRIPTION - ALTERNATIVE COOLING SYSTEMS
(Include Associated Coolant Water Treatment Systems)

1. Name of Facility Indian Point No. 2	2. Date of Report September 1972

ENVIRONMENTAL COSTS (Cont'd)

				ALTERNATIVES						
				Open Cycle				Closed Cycle		
				Once-thru	Nat. Draft	Mech. Draft	Spray Pond	Nat. Draft	Mech. Draft	Spray Pond
16.	Temporary Impacts of Plant Construction	16.9	Traffic	Moderate Increase	Moderate Increase	Moderate Increase	Moderate Increase	Moderate Increase	Moderate Increase	Moderate Increase
		16.10	Community Service	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
17.	Transportation	17.1	Fuel Transport Man-Rem/yr	64 Fuel Assemblies 1.8 (rail-3.4 (truck) These doses apply to all alternatives	64	64	64	64	64	64
		17.2	Fuel Storage	64 Fuel Assemblies	64	64	64	64	64	64
		17.3	Waste Products - Man-Rem/yr	90-150 Drums 0.9	90-150 0.9	90-150 0.9	90-150 0.9	90-150 0.9	90-150 0.9	90-150 0.9
18.	Solid Wastes	18.1	Non-Fuel Solid Wastes	100-200 Drums	100-200	100-200	100-200	100-200	100-200	100-200

Mechanical-Draft Closed-Cycle Alternative = \$120,842,000 x 0.938 = \$113,350,000

Spray Pond Closed-Cycle Alternative = \$140,012,000 x 0.938 = \$131,331,000

b. Environmental Costs

The numbered items discussed below correspond to the Commission's draft cost-benefit guidelines. Both short- and long-term environmental effects have been considered insofar as available data have permitted.

1. Heat Discharge to Natural Water Body

As mentioned above the staff does not concur in the applicant's analysis of Item 1 which follows. This difference is detailed in Chapter III.E.1.

1.1 Cooling Capacity of Water Body

Alternative 1. Plant As Is

Environmental Cost: 6.4×10^9 Btu/hr, 1.55×10^3 acre-ft

The values chosen from Table 1.1-1 of the applicant's Supplement No. 3 to represent the environmental costs under Item 1.1 were selected with the consideration that Unit No. 1 is presently operating with once-through cooling and will continue to operate in this manner regardless of the method of operating Unit No. 2. Therefore, the values selected correspond to the difference of the combined effects of operating both Units Nos. 1 and 2 less the effects of operating Unit No. 1 alone. Since the 4F° temperature rise is the standard which applies, these volumes were also selected to represent the environmental costs. Thus, $6,350 \times 10^6$ Btu/hr would be discharged to the present discharge canal from Alternative 1 for Indian Point Unit No. 2. Unit No. 1 also uses this canal, discharging another $1,880 \times 10^6$ Btu/hr. The total volume encompassed within the 4F° rise is given by the applicant as 47 acre-ft of which 42 acre-ft is attributed to Unit No. 2.

The staff's calculations based on the applicant's model show that about 1.55×10^3 acre-ft will be within the 4°F isotherm. Using Appendix K, Figure S-1 of the applicant's Supplement No. 1 to the Environmental Report for the critical summer condition, the volume enclosed was calculated to be 3.6×10^3 acre-ft for the 3-Unit operation. Since the volume varied as a function of the flow, the fraction of the input from Unit No. 2 was used to determine its impact. The contribution is $0.43 \times 3.6 \times 10^3$ acre-ft or 1.55 $\times 10^3$ acre-ft for Unit No. 2 (once-through).

Alternative 2. Cooling Tower and Spray Pond Alternatives

Environmental Cost: 1.27×10^9 Btu/hr, <1 acre-ft (open-cycle)
1.28×10^8 Btu/hr, <1 acre-ft (closed-cycle)

The procedures employed here are as described for Alternative 1 and these were repeated for the following subalternatives: 2B--Natural-Draft Cooling Towers, Open-Cycle; 2C--Mechanical-Draft Cooling Towers, Open-Cycle; 2E--Natural-Draft Cooling Towers, Closed-Cycle; and 2F--Mechanical-Draft Cooling Towers, Closed-Cycle. Spray ponds were not evaluated because of the lack of specific data. The values chosen to represent the environmental cost for Alternative 2 are those for subalternative 2E and 2F, although the amount of heat to be introduced from subalternate 2G spray ponds, closed-cycle would be less (see Section XI.B.6).

2B. Open-Cycle Cooling Tower, Natural-Draft

2C. Open-Cycle Cooling Tower, Mechanical-Draft

Calculations were carried out by the staff, using values for average river temperatures from Figure 4, Appendix J, and Table B-5 of Appendix J of the applicant's Supplement No. 1 are shown below.

	Summer Conditions °F	Remainder of the Year Conditions °F
Average River Temp.	74*	49
Avg. Rise Across Condenser	14.6	14.6
Condenser Outlet Temp.	88.6	63.6
Avg. Wet Bulb Temp.	65	35
Approach	11	15
	76	50
Tower Inlet Temp.	88.6	62.6
Tower Effluent Temp.	76	50.0
Range	12.6	12.6

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*The applicant reported on page S-3 A32 of Supplement No. 3 the average river temperature of 70°F for summer conditions.

$\frac{12.6}{14.6}$ = 0.86 or 86%. Because of the uncertainty, it is assumed 80% of the heat will be dissipated to the atmosphere while 20% of the 6.35 x 10^9 Btu/hr or 1.27 x 10^9 Btu/hr will be released to the river. Since the tower effluent is elevated less than 4F° above the river temperature, less than 1 acre will be within the 4F° isotherm.

2E. Closed-Cycle Cooling Towers, Natural-Draft

The methods used were similar to the above calculations.

	Summer Conditions °F	Remainder of the Year Conditions °F
Average River Temp.	74*	50
Avg. Rise Across Condenser	15.1	15.1
	89.1	65.1
Avg. Wet Bulb Temp.	65	35
Approach	30	33
	95	68
River Temp.	74	49
	21	19

Therefore, the average ΔT of the blowdown water will be 19.5°F above ambient.

Btu's/hr discharged to the river will be 6.56 x 10^6 lbs/hr x 19.5° = 0.13 x 10^9 Btu/hr. There will be less than 1.0 acre within the 4°F isotherm.

2F. Closed-Cycle Cooling Towers, Mechanical-Draft

The value used for the Mechanical-Draft Closed-Cycle cooling towers is that of the applicant. No detailed analysis was conducted to verify this figure. As mentioned above, spray ponds were not evaluated because of the lack of specific data.

The selection of a closed-cycle cooling tower suboption rather than the closed-cycle spray pond to represent Alternate 2 was based on the

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*The applicant reported on page S-3 A32 of Supplement No. 3 the average river temperature of 70°F for summer conditions.

significantly higher consumption of water caused by excessive drift from the spray pond. The total water consumption, drift plus evaporation, of closed-cycle cooling tower arrangements is estimated to be 15,000 gpm (0.1% drift) for mechanical-draft and 14,000 gpm (0.0025% drift) for natural-draft cooling towers while that from a closed-cycle spray pond would be between 23,000 gpm (1% drift) and 58,000 gpm (5% drift). This extra water consumption, 9,000 gpm to 44,000 gpm, from spray ponds represents a significant loss of water. As the thermal impact would be essentially the same for both closed-cycle cooling tower options, the natural-draft option was selected for the minimum water impact alternative because of lower environmental impact from fog, drift and salt deposition.

None of the open-cycle subalternatives were selected because each would discharge substantial quantities of heat (see Table 1.1-1 of the applicant's Supplement No. 3) into the water body.

Thus, the staff estimated that the volume enclosing the 4F° isotherm for Alternative 1 would be 1,550 acre-feet rather than 42 acre-feet estimated by the applicant. Also, for open-cycle cooling towers the staff estimated that 1.27×10^9 Btu/hr would be released to the river rather than 5.08×10^9 Btu/hr estimated by the applicant. For closed-cycle towers the staff's estimate of heat dissipation into the river is 0.13×10^9 Btu/hr rather than 2.03×10^8 Btu/hr estimated by the applicant.

1.2 Aquatic Biota

Alternative 1. Plant As Is

Environmental Cost: Small

According to the staff, the amount of damage will be different for each alternative. Since the areas affected for all cooling alternatives are small, no significant impact is expected to result. For the once-through alternative, in view of the low tolerance of many of the species to increases in temperature and the high probability of exposure to elevated temperature, some thermal effects are anticipated.

The applicant has supplied the following estimates. The applicant's estimate is based on the considerations described in pp. S3-25 to S3-31 of Supplement No. 3:

0.24 lb Alewife/year, 0.03 lb Bay Anchovy/year, 1.00 lb American Shad/year, 0.03 lb Carp/year, 0.47 lb American Eel/year, 0.10 lb

Hogchoker/year, 0.04 lb Blueback Herring/year, 0.01 lb Atlantic Sturgeon/year, 0.31 lb Striped Bass/year, 0.57 lb Atlantic Tomcod/year, 0.19 lb White Catfish/year, 2.9 lb White Perch/year.

While the applicant made these estimates, according to Supplement No. 3, it stated that studies indicate zero costs. The staff agrees that the environmental cost would be small for aquatic biota from thermal discharges alone. However the combination of thermal and chemical discharges could cause more of an impact (see introduction to Section XIB).

Alternative 2. Minimum Water Impact

Environmental Cost: ∿0 (Applicant's and staff's estimate)

The environmental cost of approximately zero is appropriate to the subalternative cooling system chosen, 2E natural-draft cooling towers, to minimize water impact. The same cost applies to all other alternative cooling systems because of the major reduction of the thermal discharge to the Hudson River.

1.3 Migratory Fish

All Alternatives

Environmental Cost: 0

In all cases under consideration, the applicant does not anticipate plumes of a 4F° isotherm, to extend across the Hudson River. According to the applicant, the maximum situation is for the once-through cooling system (Alternative 1) and would have the 4F° isotherm extending 590 feet, or less than 1/5 of the way across the Hudson River. The staff believes that only actual operating experience in which an adequate monitoring program is carried out in cooperation with the State and Federal agencies will determine whether Alternative 1 - Plant As Is - will be able to meet the New York State criteria of 4F° and 90°F, particularly during the summer time when the plume will spread on the surface and the ambient river temperature may be greater than the 79°F temperature which the applicant has used as the maximum summer temperature. This also will have to be verified, particularly with a change in the submerged jet from 18 feet to 12 feet. Subalternative 2E results in the 4F° isotherm reaching only 290 feet from the east shore. The numbers were obtained by scaling. Regardless of the outcome of the thermal monitoring program, the staff does not believe that a thermal barrier will develop across the river that would inhibit migration and prevent migratory fish from reaching their spawning areas upstream of Indian Point.

2. Effects on Water Body of Intake Structure and Condenser Cooling System

2.1 Primary Producers and Consumers

Alternative 1. Plant As Is and All Open-Cycle Alternatives

Environmental Cost: Potential Significant Damage

In Chapter V.D., the staff's analysis indicates that significant changes could occur in the phytoplankton community as a result of Plant operations. However, the staff has not quantitatively assessed the magnitude of the possible changes or the probability of their occurrence based on available information. The staff has estimated the maximum possible consequence which would result from a yearly reduction of 17% of phytoplankton productivity at Indian Point. Similarly the staff's analyses shows that significant damage to zooplankton from effects of chlorinantion, entrainment, and exposure to the thermal plume. Experimental data for phytoplankton and microzooplankton relative to this effect have been obtained and projections made for cases of interest by the applicant. The applicant has assumed that phytoplanktonic organisms are anticipated to be killed only as a result of chlorination and in makeup water for other alternatives. Based on this information, the applicant estimates that no environmental cost of phytoplankton will result from Alternative 1. Samples of microzooplankton consisting of 84% adult Copepods, 12.2% cladocerans, 2.7% barnacle larvae, and 1.1% copepod nauplii were air dried at 50°C and weighed to estimate the weight of an individual microzooplankter. This estimate (1.14×10^{-5}) was used to calculate the approximate microzooplankton kills per year resulting from Alternative 1. The number of organisms per year estimated to be killed is 1.48×10^{13}. The estimated kill is 3.7×10^{5} lb/yr of microzooplankton. The applicant believes that such minor impacts would not be expected to cause any significant shifting in the species present. However, the staff feels a shifting in species may be significant, and, again, that only from actual operating experience and study can this be determined.

All Closed-Cycle Alternatives

Environmental Cost: Expressed as a percentage of the open-cycle alternatives computed as the ratio of the withdrawal rates.

Withdrawal = Blowdown and consumption (drift + evaporation)

Blowdown	21 cfs
Withdrawal for Closed Cycle Alternative:	Natural Draft = 21 + 28 = 49 cfs Mechanical Draft = 21 + 30 = 51 cfs Spray Pond = 21 + 42 = 63 cfs

Once-through Withdrawal = 1933 cfs*

Closed Cycle Operation		% Impact Compared To Open Cycle
49/1933 Natural Draft Cooling Tower	=	2.5
51/1933 Mechanical Draft	=	2.6
63/1933 Spray Pond	=	3.3

2.2 Fisheries

Alternative 1. Plant As Is and All Open Cycle Alternatives

Environmental Cost: Potential for large fish damage per year

As discussed in Chapter V.D and Appendix V-2 of this Statement, the staff disagrees with the applicant's estimate of 0 fish/year. The major adverse impact of the operation of Indian Point Unit No. 2 from the intake and discharge structure will result in significant damage to anadromous and catadromous species from entrainment and impingement. The fish kill of February 29, 1972 when only 2 pumps of Indian Point Unit No. 2 were being tested plus experience with fish kills of Indian Point Unit No. 1 are indicative of the potentially serious effect of Plant operation to aquatic biota from Unit No. 2. Furthermore, the effect of Unit No. 2 operations from entrainment of fish eggs and larvae from spawning is in order of magnitude greater than that predicted by the applicant. See Section XI-B, item 2 for the staff's position regarding damage to biota from impingement and entrainment. Details of the staff's analysis are presented in Chapters V.D., Appendix V-1 on chlorination and other chemical effects and Appendices V-2 and V-3 on entrainment effects of operation of Indian Point Unit No. 2.

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*The maximum flow rate through the 6 pumps is 840,000 gpm and 30,000 gpm through the service water system.

Entrainment can be reduced by a reduction in the volume of water used by closed-cycle alternatives as indicated in Item 2.1. Impingement is not easily reduced, because the factors responsible are not as well understood. It appears, however, to be related to intake velocity, and volumes of cooling water flow, ambient water temperature, size of the fish, fish density and the physiological conditions of the fish.

The applicant's estimate on impingement effects and methods to alleviate damage from impingement is based on considerations described in pp. S3-25 to S3-31 of Supplement No. 3.

All Closed Cycle Alternatives

Environmental Cost: Expressed as a percentage of the open cycle alternatives

As stated above (Alternate 1) a number of factors influence the extent of impingement of fish. All closed-cycle cooling alternatives will result in a substantial reduction in numbers of fish impinged annually due to a reduction in withdrawal of cooling water. The net effect will be a reduction in environmental costs which will approximate the percentages computed for 2.1 above.

The following is a summary with the staff's comments of possible alternatives suggested by the applicant to minimize the damage of fishkills from impingement.

1. Vertical traveling screens straight line in the river.
   Cost: $11,500,000.

   The proposal calls for use of a common intake structure farther out in the river with a single row of vertical traveling screens parallel to the river flow. This would reduce intake velocities to below 0.3 fps during colder parts of the year and to 0.5 fps during the summer.

2. Horizontal traveling screens straight line in the river.
   Cost more than $11,500,000.

   Will result in lower intake velocity as with 1. The operation of the screens will move impinging fish to the side of the intake rather than toward the surface of the water.

3. Vertical traveling screens VV shape with bypass in the river.
   Cost: $14,600,000.

Will allow fish to be withdrawn through the bypass where they are returned to the river by pumping (fish pumps) or by lifting. Testing has indicated fish mortality of 5 to 50%.

4. Vertical traveling screens relocated to the front of the forebays at Units Nos. 1 and 2. Cost $1,000,000 for Unit No. 2, Unit No. 1 has higher costs.

   The relocation will allow lateral movement along the screen surface to avoid impingement. Continual operation of the screens instead of periodic operation will result in a lowered mortality rate for impinged fish.

5. Vertical traveling fish basket. The cost is unknown. Neither effectiveness nor practability for Indian Point has been demonstrated.

6. Air bubble screen. Cost: $12,000/bay.

   The effectiveness in preventing fish from moving toward the screen is uncertain. This device is presently being tested at Unit No. 1.

   In terms of entrainment, the potential for serious damage exists as discussed in Section V.D and Appendix V-2 for all open-cycle alternatives.

Closed-cycle alternatives would be expected to have a reduced impact proportional to the reduced water intake:

Natural-draft towers	2.5% as great
Mechanical-draft towers	2.6% as great
Spray ponds	3.3% as great.

3. Chemical Discharges to Water Body

The chemicals which will be discharged from Indian Point Unit No. 2 are identified and the amounts to be released are described in Chapters III and V, and Appendix V-1.

3.1 People

All Alternatives

Environmental Cost: 0 Annual user days

The discharge of chemicals to the river is not expected to have any effect on human use of the river. The staff agrees with the applicant on that point.

3.2 Aquatic Biota

All Alternatives

Environmental Cost: Large during chlorination periods
Net cost small

Chemicals expected to be released into the discharge canal will have sufficiently low concentrations (after dilution by the discharge water) so as to protect aquatic biota from lethal or sublethal effects due to long-term or chronic exposure. An exception, however, is the discharge of residual chlorine combined with increased temperature. The staff's analysis indicates that the effect of residual chlorine and chloramines may be great on entrained organisms. (See Section V.D.2 and Item 3 for staff's discussion of entrained biota.) According to the applicant, the effect will probably not be great. Cooling tower chemicals and concentrations are not available from the applicant at this time and thus the effects on biota are unknown.

3.3 Water Quality - Chemical

All Alternatives

Environmental Cost: Up to 100% of the New York State allowable limits (the staff's estimate)

(See discussion of 3.2 above.)

4. Consumption of Water

4.1 People

All Alternatives

Environmental Cost: 0 gal/year

The Hudson River near and below Indian Point is not used for drinking water purposes.

4.2 Property

All Alternatives

Environmental Cost: 0 acres

The Hudson River near and below Indian Point is not used for irrigation purposes.

5. Chemical Discharges to Ambient Air

5.1 Air Quality - Chemical

All Alternatives

Environmental Cost: 25%

The staff has verified the applicant's annual average concentrations estimated for the emissions for the two "package boilers" at Unit No. 2. However, Unit No. 1 has a superheater and 3 boilers that must be taken into account to evaluate the effects of the total emissions from the two Units being discharged through the superheater stack of Unit No. 1. The applicant's values were then scaled, based on the rated capacity of the units, and new percent of standard values (Federal Air Quality Standards) computed as follows:

SO_2	25%
NO_x	6.3%
Particulates	4.3%

Effects of emissions from construction equipment were considered negligible.

5.2 Air Quality - Odor

All Alternatives

Environmental Cost: None

Although a few chemicals of an organic nature are anticipated for use in the Plant, the amounts will be so small and their concentrations in the atmosphere and in discharge waters will be so low that no perceptible ordors will be experienced at offsite locations. Thus, the staff concurs with the applicant's assessment that there will be no perceptible odors at offsite locations.

6. Salts Discharged from Cooling Towers

Alternative 1 does not have a cooling tower and is therefore not considered.

6.1 People

In order to assess this impact, it is necessary first to have estimates of the salt deposition resulting from the cooling alternatives. Independent calculations by the staff were in reasonable agreement with the deposition estimates calculated by the applicant. These values are tabulated in Table XI-4 for the sector having the highest deposition and for the entire area between radii of 0-1, 1-2, 2-3, 3-4, 4-5, and 5-10 miles of the site. These values were calculated using (1) estimates of salt deposition already obtained for natural-draft cooling towers calculated for Indian Point and (2) the factors employed to estimate the dispersion of airborne radioactivity from the site.

The theoretical equations used to estimate salt deposition are based on equations developed for estimating the dispersion and deposition of radioactivity from elevated stacks[2]. The important parameters in these equations are (1) the salt discharge rate into the atmosphere, (2) the effective height of the plume, (3) the distance from the source, and (4) the average ambient weather conditions which include the stability, the wind velocity, and the wind direction. The factors for estimating the dispersion of airborne radioactivity are ratios of the groundlevel concentration of atmospheric radioactivity at a given point to the rate of radioactivity discharge from the site. Deposition is assumed to be proportional to groundlevel concentration so these factors are also applicable to estimating salt deposition. However, the factors were calculated for a groundlevel release and for an effective plume height of about 290 feet. These effective heights for radioactivity are, of course, not applicable to the cooling towers. The theoretical equations indicate that the logarithm of the radioactivity factor at a given location should be proportional to the square of the effective plume height, and this scaling was used to correct the radioactivity factors for the effective plume heights corresponding to the mechanical-draft cooling towers (about 400 feet). The spray ponds are essentially groundlevel releases while the effective plume heights for natural-draft towers are in excess of 1,000 feet so that this would require extrapolation beyond the confidence of the scaling.

TABLE XI-4 APPLICANT'S SALT DEPOSITION RATES

Alternative[a]		Salt Discharge Rate, lb/year	Salt Deposition Rates, lb/(acre-year)											
			0-1 miles		1-2 miles		2-3 miles		3-4 miles		4-5 miles		5-10 miles	
			Maximum Sector	Entire Circle	Maximum Sector	Entire Circle	Maximum Sector	Entire Circle	Maximum Sector	Entire Circle	Maximum Sector	Entire Circle	Maximum Sector	Entire Sector
1A	OTC	0	0	0	0	0	0	0	0	0	0	0	0	0
2B	NDO	5.4×10^5	0.1	0.01	0.4	0.05	1	0.1	1.3	0.1	1	0.1	0.2	0.02
2C	MDO	2.1×10^7	212	64	101	30	48	14	28	9	18	6	6	3
2D	SPO	2.1×10^8	2.6×10^5	1.0×10^5	0	0	0	0	0	0	0	0	0	0
2E	NDC	1.1×10^6	0.3	0.02	0.8	0.07	1.8	0.2	2.7	0.3	2	0.2	0.4	0.03
2F	MDC	4.2×10^7	423	127	202	60	95	29	57	17	35	12	13	6
2G	SPC	4.2×10^8	5.2×10^5	2.1×10^5	0	0	0	0	0	0	0	0	0	0

[a]

OTC	Once-Through Cooling
NDO	Natural Draft Cooling Tower, Open Cycle
MDO	Mechanical Draft Cooling Tower, Open Cycle
SPO	Spray Pond, Open Cycle
NDC	Natural Draft Cooling Tower, Closed Cycle
MDC	Mechanical Draft Cooling Tower, Closed Cycle
SPC	Spray Pond, Closed Cycle.

Drift assumed to be 0.0025% of cooling water flow for natural draft towers, 0.1% for mechanical draft towers, and 1% for spray ponds.

According to the applicant, because of the difficulties in extrapolating the radioactivity factors to the plume heights of natural-draft towers, these factors could not be used with confidence to calculate the salt deposition from the towers. The earlier estimates of salt deposition were for natural-draft towers but these estimates were only for the sector showing the maximum deposition rates and were based on different salt discharge rates from the tower. These earlier estimates were scaled with the salt discharge rates of the applicant's Supplement No. 3 for natural-draft towers in order to obtain the depositions for the maximum sector. The scaling was directly proportional to the discharge rate. In order to estimate the average deposition rate for the entire area within given radii, the radioactivity factors were scaled to the effective plume height corresponding to the natural-draft towers. The average factor for all the sectors within the given radii was calculated and the ratio of this average factor to the factor for the maximum sector within the given radii was determined. This ratio was then multiplied by the salt deposition rate for the maximum sector to provide the estimate of the average deposition rate. The calculation of this ratio did not require as much confidence as the direct calculation of the deposition rate so that the scaling with the plume height was satisfactory for this purpose.

The salt deposition values for the mechanical-draft towers and the spray ponds were calculated as the product of a salt discharge rate, a deposition velocity equivalent to 5 cm/sec, and the radioactivity factor for the given sector and distance from the site. The salt discharge rate used for the 0-1 mile distance was the value at the tower or pond. The total amount of salt deposited within 1 mile was then subtracted from the tower or pond discharge and this difference was used as the salt discharge rate for calculating the deposition within the 1 to 2 mile radii. This process of reducing the discharge rate was continued until the rate became zero. The results of these calculations indicated that about 5% of the salt discharged from mechanical-draft towers would be deposited within 10 miles while all of the salt discharged from spray ponds would be deposited within 1 mile. The definition of the radioactivity factors was not fine enough to calculate the exact radius within which all of the salt from the spray ponds would be deposited. Therefore, the average deposition rates for spray ponds were calculated with the assumption that all of the salt would be uniformly deposited on the area enclosed by the 1-mile radius.

Cooling Subalternative 2E (Natural-Draft, Closed-Cycle Cooling Towers)

Environmental Cost: 0 gal/year

Intrusion of salts from cooling tower drift into ground-water is considered improbable. The only public water supply served by wells averages about 550 gpm. A few wells, serving private homes, are still in use along the fringes of the area. Both the Stony Point System wells and the private wells are in unconsolidated deposits with depths ranging from 35 to 50 feet. However, on both sides of the river the ground elevations are considerably higher than at the Plant site, and water should flow to the river.

The data indicate that the maximum rate of salt deposition from the cooling towers under this subalternative will occur 3 to 4 miles from the Plant. The rate was calculated to be about 3 pounds salt per acre per year. Percolation of this material into the ground will depend upon rainfall. The annual rainfall in this region averages about 36 inches, and so the average salt concentration in percolating groundwater would be about 0.36 ppm. Since this is a factor of 700 below permissible water quality criteria for chloride and sulfate (250 ppm) as recommended for public water supplies, any salts from the natural-draft cooling towers that might reach underground wells will have negligible effect on the water supply.

Cooling Subalternative 2B (Natural-Draft Cooling Towers, Open-Cycle)

Environmental Cost: 0 gal/yr

This subalternative cooling method will discharge less salt Subalternative 2E. Therefore, it will not affect local groundwater supplies.

Cooling Subalternatives 2C (Mechanical-Draft Cooling Towers, Open-Cycle) and 2F (Mechanical-Draft Cooling Towers, Closed-Cycle

Environmental Cost: 0 gal/yr

Most of the salt deposition from these mechanical-draft cooling tower subalternatives will occur within 2 miles of the Plant. The calculated deposition rates, while appreciably higher than for natural-draft cooling towers, would still result in peak average salt concentrations in precolating groundwater at 2 miles of 25 ppm. On the basis of the discussion presented for cooling Subalternative 2E, no effect on local groundwater supplies would occur.

Cooling Subalternatives 2D (Spray Pond, Open Cycle) and 2G (Spray Pond, Closed Cycle)

Environmental Cost: 0 gal/yr

Much more salt is available for deposition from these subalternatives than from the cooling tower subalternatives because of the higher drift values. However, the rate calculations indicate that the deposition will be confined to an area within 1 mile of the site. Since there is no use of well water in this area, no loss of water supply will occur.

6.2 Plants

Although it was possible to obtain estimates of the magnitude of salt deposition for the various cooling alternatives, it was not possible to obtain enough specific data to allow a detailed assessment of the potential effects of the salt deposited on the vegetation within the Plant's sphere of influence. However, data from highway salting research indicates that salt deposition rates of 500 lb/acre/year could be detrimental to roadside vegetation and deposition rates of 1,000 lb/acre/year would cause damage to roadside vegetation. Using this range of deposition rates and the data for the various cooling alternatives, estimates were made for the acreage which could suffer potential detrimental effects from salt deposition.

Cooling Subalternatives 2B, 2C, 2E, and 2F

Environmental Cost: 0 acres

Since the data show no salt deposition rates in excess of 500-1,000 lbs/acre/year, there will be no environmental costs to plant life in the area associated with these alternatives.

However, the natural draft towers are subject to the downwash phenomenon that carries the plume directly to the ground. Downwash starts when the ratio of the stack emission speed to the wind speed is less than unity and when occurring, would spray the nearby terrain with cooling water droplets with salinity ranging up to 14 ppt which could cause severe damage to plants.

Cooling Subalternatives 2D and 2G

Environmental Cost: 1,200 acres

The predicted salt deposition rates from the spray pond alternatives greatly exceed the 500-1,000 lbs/acre/year. Based on the salt deposition rates calculated by the applicant, the only alternatives that would cause salt deposition in excess of tolerance (∿100 ppm for irrigation) would be the spray ponds.

Furthermore, the calculations predict that all the salt would be deposited within a 0-1 mile radius of the spray ponds. Consequently, either of these two alternatives could be expected to present an extreme hazard to terrestrial plant life particularly in the immediate Plant site environs, and to a lesser extent, up to 1 mile from the spray ponds.

Within the 0-1 mile radius from the spray ponds are some 1,206 acres of land with approximately equal utilization by industrial activities and residential usage. The environmental cost to the plant life on these 1,206 acres from either spray pond alternative could be potentially substantial.

6.3 Property Resources

The staff concurs with the applicant's reasoning that the mechanical-draft towers and spray pond alternatives could result in a moderate environmental cost. Downwash from the natural draft towers, though intermittent, could result in increased maintenance costs at the Buchanan Substation.

Cooling Subalternative 2B and 2E

Environmental Cost: 0 dollars

From the standpoint of the Subalternative 2E, salt deposition rates are relatively low. The highest deposition rate occurs in the maximum sector of the 3 to 4 mile radius, which is almost entirely over the Hudson River proper. Consequently, there would be very little, if any, property resources in this sector to be exposed to the deposited salt.

The highest salt deposition rates from Subalternative 2B also occur in the maximum sector of the 3 to 4 mile radius, and deposition rates are essentially one-half those of Subalternative 2E.

Cooling Subalternatives 2C (Mechanical-Draft Cooling Towers, Open-Cycle; 2D, Spray Pond, Open-Cycle; 2F, Mechanical-Draft Cooling Towers, Closed-Cycle; 2G, Spray Pond, Closed-Cycle)

Environmental Cost: Moderate

Of the other cooling alternatives evaluated for minimum water impact, the spray pond alternatives (2D and 2G) represent the greatest potential threat to property resources in the area. It is predicted that all the salt will be deposited in a 1-mile radius from the Plant site. While most of the salt should be deposited near the ponds, the town of Verplanck is located within the 1-mile radius and would be expected to receive some of the deposited salts. Thus, the potential for damage to property resources in the area would be greatest from the spray ponds.

The mechanical-draft cooling tower alternatives (2C and 2F) would have the next greatest potential for damage to surrounding property resources. The highest salt deposition rates occur in the maximum sectors of the 0-1 mile radius which includes the town of Verplanck and the 1-2 mile radius. Consequently, some damage to property resources in this area could occur from the salts deposited by the mechanical-draft cooling towers.

7. Chemical Contamination of Groundwater

7.1 People

All Alternatives

Environmental Cost: 0 gal/year

No environmental cost will occur from any of the alternatives for this category because the few wells that may provide drinking water to nearby residents are shallow and at ground elevations that are considerably higher than the Plant site. Thus groundwater at the site flows to the Hudson River.

7.2 Plants

All Alternatives

Environmental Cost: 0 acres

Chemical discharges from the Plant, for each of the alternatives, are made at the beginning of the Station cooling water discharge canal and consequently travel with dilution directly into the Hudson River. Under Alternative 2, residual chlorine, following condenser chlorination treatment at levels of 0.1 to 0.5 ppm might be realized during passage of the cooling water through each of the alternative systems. A chemical reaction will form chloramines which, with residual chlorine, result in damage both lethal and sublethal to phytoplankton.

8. Radionuclides Discharged to Water Body

The staff's estimates are summarized in Chapter V.D on doses to biota and Chapter V.E on doses to man which differ with the applicant's doses because of a source term different from that of the applicant's was used. The estimates provided by the applicant are presented in its Supplement No. 3. The staff's estimates are as presented below.

8.1 People - External Contact

Environmental Cost: 0.12 (initial, 0.08 (modified) man-rem/year (swimming), for all alternatives

8.2 People - Ingestion

Alternative 1. Plant As Is

Environmental Cost: 5.0 (initial), 0.87 (modified) man-rem/year (fish), for all alternatives

8.3 Primary Producers and Consumers - Plants and Invertebrates

8.4 Fish

Organism	Once-Through Cooling* and Open Cycle	Closed Cycle*
Plants	0.090 Rads/year	0.338 Rads/year
Invertebrates	1.50 Rads/year	5.65 Rads/year
Fish	0.042 Rads/year	0.157 Rads/year

The radiation doses shown for the once-through cooling and open-cycle alternatives are for organisms living in the discharge canal (see Table V-1). No detailed evaluation was made for the closed-cycle alternatives. These doses were estimated on the assumption that the dose to organisms in the vicinity of the discharge would be about 3.75 times the open cycle doses.

9. Radionuclides Discharged to Ambient Air

Estimates on doses to the individual and the whole population were provided by the applicant in its Supplement No. 3. See Chapter V.E for the staff's estimates as presented below.

9.1 People - External Contact

All Alternatives

Environmental Cost: 10 (initial, 9.9 (modified) man-rem/year (1970) by immersion in a cloud (for all alternatives)

9.2 People - Ingestion

All Alternatives

Environmental Cost: <55 (initial), <58 (modified) man-rem/year (1970) - food chain for all alternatives)

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*For modified radwaste system.

9.3 Plants and Animals

All Alternatives

Environmental Cost: Unknown

Sufficient information is not available to allow the determination of a meaningful number.

The following is a summary of the staff's dose estimates.

Annual Integrated Whole-Body Dose to the General Population (1970) from the Operation of the Indian Point Station

Source	Population	Initial Dose (man-rem)	Modified Dose (man-rem)
Cloud (immersion)	16,000,000	10	9.9
Fish	160,000	5.0	0.87
Swimming	160,000	0.12	0.08
Visitors' Center (direct radiation)	100,000	< 7	< 7

10. Radionuclide Contamination of Groundwater

10.1 People

All Alternatives

Environmental Cost: 0 Rem/yr

The absence of an environmental effect on groundwater supplies is based on the known hydrology of the Indian Point site area. The ground surface elevations of the adjacent land are considerably higher than the Plant site. Thus, the direction of groundwater flow is towards the river, and this precluded the possibility of contamination of these supplies through groundwater flow.

10.2 Plants and Animals

The environmental costs would be zero for all alternatives for the same reasons stated for people above.

11. Fogging and Icing

11.1 Ground Transportation

Alternative 1. Plant As Is

Environmental Cost: 0 hours of increased driving hazard per year

Since once-through cooling discharges heated water onto the river surface in which the heat is transferred into the air, whispy fog may form, but as discussed in Chapter V, it is not expected to presist and thus no increase in the annual occurrence of fog or ice on roads is anticipated.

Alternative 2. Minimum Water Impact

Environmental Cost: 0 hours of increased driving hazard per year

Fogging and Icing

The staff accepts the following assumptions and calculations by the applicant as being representative of average year-round conditions.

In order to assess this impact and the impacts listed under Item 11.2, 11.3, and 11.4, it is necessary to estimate the increase in the annual number of hours of fog due to the cooling alternatives at locations surrounding the Indian Point site. In Table 11.1-1 of the applicant's Supplement No. 3 values were calculated using (1) the annual frequency of saturation deficits over Poughkeepsie and (2) the radioactivity dispersion factors used to estimate salt deposition (see Item 6.2) and radiation doses (see Item 9). The confidence in the radioactivity factors for natural-draft towers is not good because of difficulties in scaling the radioactivity factors of the effective plume heights of the towers. These difficulties were discussed in Item 6.2. However, because the effective plume heights are so large (in excess of 1,000 feet), the estimates for fog at river level due to natural-draft towers are essentially zero so that the inaccuracies in the factors do not effect the conclusion that there is no river-level fog from natural-draft towers.

The theoretical equations used to calculate the increase in annual hours of fog are similar to the equations for estimating dispersion of radioactivity as discussed in Item 6.2. The excess humidity (above ambient at a given location was calculated as the product of the rate at which water is discharged into the air and the radioactivity factor corresponding to the location's sector and distance from the site. The cumulative frequency for which the saturation deficit is less than or equal to this excess humidity was then determined from the Poughkeepsie data. The water in the plume would tend to evaporate if the saturation deficit was greater than the excess humidity. Therefore, the cumulative frequency for which the deficit is at or below the excess humidity is a measure of the cumulative frequency of fog (condensed water). Part of this fog would coincide with periods of natural fog. The occurrence of natural fog was assumed to be the frequency of zero deficit (when the air is saturated with water vapor). This frequency of zero deficit was therefore subtracted from the cumulative frequency corresponding to the excess humidity in order to arrive at the frequency of increased fog due to the cooling alternatives. The product of this latter frequency and the number of hours in a year (8,760) is the estimate of the increased hours of fog due to the cooling alternative.

As already mentioned, the confidence in the calculations is not good for natural-draft towers but the fog estimates are essentially zero so that possible errors in the calculations are not significant. The confidence in the calculations for spray ponds is also not good for distances greater than 1 mile because the calculations do not account for rainout of the condensed water. The calculated vales of excess humidity would indicate that large amounts of rainout could occur within 1 mile during most of the time. This rainout would remove excess water from the plume so that locations beyond 1 mile would have a much lower frequency of fog than was calculated (see Table 11.1-1, Reference 27). However, those values can be considered as upper-limit estimates of fog beyond 1 mile while the lower-limit estimates would be zero fog beyond 1 mile.

In assessing the environmental cost, it was noted that a major highway runs within 1 mile of the site, but not necessarily in the direction of the maximum sector. Therefore, the environmental cost was taken as the average increase in the annual hours of fog within 1 mile of the site, and this was also taken as the hours of increased driving hazard. For reasons discussed in the introductory section on alternatives, the natural-draft cooling tower operating in a closed cycle, Subalternative 2E, was chosen as Alternative 2. The increase in the annual occurence of fog within 1 mile of the site for this alternative is 0 hours. The increase is also zero for Subalternatives 2B and 2C, 88 hours for Subalternative 2F, 4,030 hours for Subalternative 2D, and 5,340 hours (60% of the time) for Subalternative 2G.

It should be noted that fog at the river level may not be the maximum. In fact, the maximum increase in fog would occur at about the plume height. Since the terrain is hilly in the area and the effective plume height for mechanical-draft towers is only about 400 feet, it is possible that some locations could receive increases in the occurrence of fog that are greater than the values calculated. For elevations approaching 400 feet above the river, the increase in annual hours of fog from mechanical-draft towers could approach the values for spray ponds. However, the increases in fog at the river level were felt to be the best representation of the environmental cost of the alternatives.

11.2 Air Transportation

Alternative 1. Plant As Is

Environmental Cost: Airport closed 0 hours per year

Since once-through cooling does not discharge any water into the air, there will be no increase in the annual occurrence of fog at airports and, thus, no closing of airports due to Alternative 1.

Cooling Tower and Spray Pond Alternatives

Environmental Cost: Airport closed 0 hours per year

In assessing this environmental cost, it was noted that there is a seaplane base at Verplanck, approximately 1.57 miles south of the site. The sector having the maximum frequency of fog is also toward the south. Therefore, the environmental cost was taken as the maximum increase in the annual hours of fog between 1 to 2 miles of the site, and this was assumed to equal the hours during which the airport would close. The increase in the annual occurrence of fog within 1 to 2 miles of the site for Subalternatives 2B, 2C, and 2E is 0 hours, 88 hours for Subalternative 2F, 3,150 hours for Subalternative 2D, and 4,820 hours for Subalternative 2G. The spray pond values are upper-limit estimates beyond 1 mile. Also, as previously mentioned in Item 11.1, the effect of elevation may be significant in that there may be an increase in occurrence of clouds at the 400-foot level for mechanical-draft towers and at the 1,000-foot level for natural-draft towers. These increases could approach the values for spray ponds.

11.3 Water Transportation

Alternative 1. Plant As Is

Environmental Cost: Ships reduce speed 0 hours per year

Cooling Tower and Spray Pond Alternatives

Environmental Cost: Ships reduce speed 0 hours per year

In assessing this environmental cost, it is significant that the site is located on the Hudson River which is navigable. Also, the sector having the maximum frequency of fog tends to be in a southerly direction over the river. Therefore, the environmental cost was taken as the maximum increase in the annual hours of fog within 1 mile of the site, and this value was assumed to equal the hours during which ships on the river must reduce speed. The increase in the maximum annual occurrence of fog within 1 mile of the site is zero hours for Subalternatives 2B, 2C, and 2E, 175 hours for Subalternative 2F, 5,610 hours for Subalternative 2D, and 6,570 hours for Subalternative 2G.

11.4 Plants

Alternative 1. Plant As Is

Environmental Cost: 0 acres

Alternative 2. Minimum Water Impact Design

Environmental Cost: 0 acres

While there is very little experimental evidence on which to base an accurate assessment of the potential effects on plant life from the fogging and icing conditions produced by the various cooling alternatives, some general statements can be made concerning the nature of some of these effects. For instance, evaporation and drift losses from the cooling towers and/or spray ponds could result in an increase in the relative humidity of the area. Since the vapor pressure gradient between the atmosphere and the moist plant surfaces would be lowered, a reduction in the rate of evaporation and transpiration could possibly occur. Also, the increased moist air conditions could favor certain fungi which might become serious pests on higher plants in the area.

The estimated environmental cost for each cooling subalternative is given below and expresses the number of acres exposed to increased fog frequencies and hence some possible detrimental effects on plant life. Concerning icing phenomena, ice formation on vegetation could occur during those periods when ambient temperatures are below freezing. Temperature statistics for New York City indicate that the monthly mean low temperature is below freezing for only 3 months of the year -- December, January, and February. However, the monthly mean high temperature for these months is above freezing. Therefore, as an approximation, it may be assumed that the potential for icing occurs only about 12.5% of the time on an annual basis.

Cooling Subalternative 2B, 2C, 2E, and 2F

Environmental Cost: 0 acres

Since there are no increases in groundlevel fog frequencies predicted for Subalternatives 2B, 2C, and 2E, there would be no environmental costs to surrounding vegetation. Very little, if any, damage to plant life would be expected to result from the increases in the frequency of ground fog predicted for Subalternative 2F.

Cooling Subalternatives 2D and 2G

Environmental Cost: Moderate

These subalternatives would produce the greatest potential for damage to surrounding plant life resulting from fogging and icing. From the fog frequency data, it can be seen that the area encompassed by the 0-1, 1-2, and 2-3 mile radii would be subjected to significant increases in fogging conditions.

Within this 3-mile radius of the Plant site are some 11,762 acres of land with approximately the following utilization:

Residential - 7,238 acres
Recreational - 3,619 acres
Industrial - 905 acres.

The plant life on these 11,762 acres could suffer potential detrimental effects from the fogging conditions attributed to these two cooling alternatives.

12. Raising and Lowering of Groundwater Levels

12.1 People

All Alternatives

Environmental Cost: 0 gal/year

None of the alternatives use fresh water make up, therefore, the availability of drinking water will not be decreased and the functioning of existing wells will not be impaired.

12.2 Plants

Alternative 1. Plant As Is

Environmental Cost: 0 acres

For the same reasons stated under people above, trees and other deep-rooted vegetation will not be affected and the environmental costs are zero.

13. Ambient Noise

13.1 People

Alternative 1. Plant As Is

Environmental Cost: 0 Residents affected

No residents, schools, or hospital beds within area will have noise increased above present levels.

The ambient noise levels now existing in the area were measured by the applicant at locations which were chosen to document noise levels at its property line and also at locations in the surrounding area where noise might affect the residents or where other noise sources exist. However, the design of the Indian Point Unit No. 2 facility is such that no significant noise sources are expected to be introduced by its operation so that the existing noise levels in the surrounding areas are expected to be virtually the same with Indian Point Unit No. 2 in operation.

Cooling Tower and Spray Pond Alternatives

Each of the six cooling subalternatives which were considered in determining the minimum water impact design are examined separately. The staff accepts the applicant's estimates of the environmental cost.

Subalternatives 2B and 2E

Environmental Cost: About 300 residents subjected to noise levels in the normally unacceptable range

The alternative involves construction and operation of 2 natural-draft cooling towers--open-cycle, each 515 feet in diameter and 500 feet high. It is expected that the noise generated by these towers would be almost white (broad-band) in character, and--because the natural-draft cooling towers do not employ powered fans to move air--that the noise levels generated will be relatively low. Estimates of the noise emitted from the natural-draft cooling towers have been made and the results indicate that the noise levels will be in the unacceptable region for a distance of 2,500 feet from the center of the tower complex. Thus, an area of about 0.7 square miles would experience noise levels in the unacceptable range, and about 300 residents would be involved.

The following was stated by the applicant:

Note: "These costs are in conformance with assumptions made in the guidelines. Our studies indicate that the estimated noise at the Broadway property line is 58 dB(A)* and the costs will be zero, in that the expected noise from the two hyperbolic cooling towers will:

(a) not exceed the local noise ordinance of the Village of Buchanan along the Broadway property line.

(b) be less than the existing background noise level along Broadway due to vehicular traffic which exceeds 60 dB(A) for more than 50% of the time. Refer to Figure 13.1-2 of the applicant's Supplement No. 3.

(c) be within the 65 dB(A) limit for "Discretionary-Normally Acceptable" category for external noise exposure standards for new construction sites as outlined in the U. S. Housing and Urban Development

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*dB(A) = noise levels in air expressed as decibels.

(HUD) Transmittal Noise 1390.2, (subject: "Noise Abatement and Control: Departmental Policy, Implementation Responsibility, and Standards." Reference 13a is a contractor's report to HUD and does not represent official policy.)

(d) produce broadband white noise (similar to the noise generated by falling rain) that will serve to mask the intrusion in transient environmental noise."

In addition, the noise radiated from the two hyperbolic cooling towers will be limited within the boundary lines of the site with the exception of the Broadway boundary line.

The staff agrees that the noise along the Broadway boundary line in this case is probably considerable.

Subalternative 2C

Environmental Cost: About 4,500 residents subjected to unacceptable noise levels

Alternative 2C would involve 67 mechanical draft cooling cells operating in the open cycle mode. Each cell is expected to have an electric motor-driven fan rated at 200 horsepower, a total of 13,400 horsepower. Of all alternatives, this will be the noisiest. Ignoring the directional effects of the cell layout, the predicted noise generated by the mechanical-draft cooling towers will produce a sound level of 50 dB(A) at a distance of 6,200 feet from the cooling cell complex. This means that an area of approximately 4.3 square miles will be in the unacceptable zones as defined by the Department of Housing and Urban Development. Approximately 4,500 residents are in this area.

Of this area, approximately 0.1 square mile in the immediate vicinity of the cells will be in the "clearly unacceptable" classification, with the remainder of the unacceptable area falling in the "normally unacceptable" classification. The latter would constitute approximately 4.2 square miles, and encompasses portions of Peekskill, Buchanan, and Verplanck.

These predicted acoustic levels are those which are emitted from the louvered face of the cells. The sound level on the cased face of the cooling cell is expected to be from 5 to 10 dB(A) lower, so the corresponding areas will experience lower noise levels. Therefore, the noise levels are conservatively high.

Subalternative 2D

Environmental Cost: Minor

This subalternative requires the use of an open-cycle spray pond. This subalternative will probably generate less noise than the mechanical-draft cooling towers because of the absence of the large outside fans. The acoustic power generated by the spray pond should be proportional to the hydraulic power dissipated, but insufficient information is available to enable the noise level to be predicted accurately. The character of the noise generated will be almost white (broad-band) in nature.

Subalternative 2F

Environmental Cost: About 3,000 residents subjected to unacceptable noise levels

This subalternative involves the use of 38 mechanical-draft cooling cells operating closed cycle. Each cell will have an electric motor-driven fan rated at 200 horsepower, giving a total of 7,600 horsepower. The noise generated by these cooling towers is predicted to produce a sound level of 50 dB(A) at a distance of 5,000 feet. Consequently, an area of approximately 2.8 square miles will be in the unacceptable zones as defined by HUD. Of this area, about 0.1 square mile in the immediate vicinity of the cells will be in the "clearly unacceptable" classification. This unacceptable zone encompasses portions of Peekskill, Verplanck, and Buchanan, and it is expected that about 3,000 residents would be subjected to noise levels in the unacceptable category.

As mentioned under Alternative 2C, the predicted acoustic level is that emitted from the louvered face of the cell. The levels would be 5 to 10 dB(A) less from the cased side of the cooling cell, so the noise levels are conservatively high.

Subalternative 2G

Environmental Cost: Minor

This subalternative requires the use of a closed-cycle spray pond. Comments under Subalternative 2D apply.

14. Aesthetics

14.1 Appearance

The aesthetic appearance or quality of the environment is determined by value judgments made by members of society. Because individuals vary in their perception of the environment, it is often difficult to quantify and reach a consensus of their views. In this report certain aesthetic standard were used that have a sensitivity toward the environment and social values, so that it was possible to analyze aesthetic considerations on a relative basis. The staff concurs with the applicant's assessment of each of the alternatives.

Aesthetic impacts from Indian Point Unit No. 2 were determined by considering the overall aesthetic composition of the area and four elements which define this composition: water, air, fauna and flora, and man-made objects. Each of these considerations was systematically analyzed to determine any aesthetic changes either favorable or adverse.

As transmission lines from Indian Point Unit No. 2 use existing rights-of-way, the impact was judged to be minor.

Alternative 1. Plant As Is

Environmental Cost: Minor

The overall aesthetic impact of Unit No. 2 of Indian Point is negative in direction, but minor in magnitude. (See Section III.)

Cooling Tower and Spray Pond Alternatives

Subalternatives 2B and 2E

Environmental Cost: Major

It is expected that the overall impact from the natural-draft towers on the aesthetic composition of the Hudson Valley would be negative in nature and major in magnitude.

Two natural-draft cooling towers between 400-500 feet high are proposed for Indian Point. These towers would be located in an area immediately to the southeast of the structures for Units Nos. 1 and 2. Some of the natural vegetation in this area would be eliminated with the construction of these towers.

Natural draft towers would dominate the landscape of the valley and the towns in the immediate vicinity of the site. The towers and their plume would be visible for many miles in all directions from Indian Point. Because many individuals use the Hudson Valley for recreation, these conditions would pose a major conflict with the natural environment and would produce an aesthetically displeasing situation.

Subalternative 2C and 2F

Environmental Cost: Moderate

The net impact on the aesthetics of the area is negative in direction and moderate in magnitude.

The mechanical-draft cooling towers for the nuclear power plant would be located in an area immediately to the southeast of Units Nos. 1 and 2. Because this area is elevated and only partially buffered with natural vegetation, these towers would be visible to individuals near the site. In the placement of these towers, some of the natural vegetation in the area would be removed.

The water vapor emissions from these towers and the resulting ground fog would be noticeable from many locations in the valley. On some days the ground fog would probably cover most of the Plant site.

Subalternative 2D and 2G

Environmental Cost: Moderate

It is expected that the overall impact of the spray pond and the relevant impacts from Alternative 1 would be negative in direction and moderate in nature.

The spray pond would be located in an area southeast of Units Nos. 1 and 2. Because this area is elevated and only partially buffered with natural vegetation, it is expected that some of the pond and the pipes would be visible to individuals near the site.

The fogging conditions created by the pond would call attention to its location and interaction with the natural environment. These fogging conditions are also expected to be visible to individuals in the town of Verplanck which is adjacent to the pond.

15. Permanent Residuals of Construction Activity

15.1 Accessibility of Historical Sites

All Alternatives

Environmental Cost: 0 visitors per year

Although several historical sites are located in the vicinity of the Indian Point Station, no access routes to these sites use any portion of Station land. Power transmission lines associated with the Station do not interfere with public land use and cross only one public road immediately east of the Station.

The staff agrees with the applicant's position that the Indian Point Station does not interfere with the access routes to any historical sites.

15.2 Accessibility of Archaeological Sites

All Alternatives

Environmental Cost: None

Construction activity at the Indian Point site has revealed no evidence of items having archaeological value. No other indication of important archaeological activity in the general area could be located. Thus, the Plant site probably contains no valuable archaeological deposits.

15.3 Setting of Historical Sites

Alternative 1. Plant As Is

Environmental Cost: 0 visitors per year

To nearest designated historical site is Stony Point Battlefield, located 2 to 3 miles from Indian Point on the opposite side of the Hudson River. It is doubtful that the existing plant can be seen from this location, but if such is the case the most noticeable feature would be the stack for Unit No. 1. Thus, Unit No. 2 structures have very little if any additional impact, and no effect on visitations to this historical site or to others which are more distant should occur.

Cooling Tower and Spray Pond Alternatives

Environmental Cost: Minor

The tall natural-draft cooling towers associated with cooling Subalternatives 2B and 2E should be visible from the Stony Point Battlefield site and perhaps from the U. S. Military Academy and the Van Cortlandt Manor which are both approximately 6 miles from Indian Point. No visitation figures have been obtained for these three sites, so it can only be stated that the environmental effect will be negative. The staff accepts the applicant's assessment that the natural draft cooling tower alternatives would be visible from some historical sites in the area and would cause a minor impact.

The mechanical-draft cooling towers associated with Subalternatives 2C and 2F are low profile structures which should be no more visible from the nearest historical site than the Plant itself. The environmental cost value for these subalternatives should be zero. This impact would also apply to Subalternatives 2D and 2G which utilize a spray pond.

15.4 Land Use

All Alternatives

Environmental Cost: 0 acres

None of the alternatives would require additional land since the Indian Point Unit No. 2 with its associated transmission facilities are essentially complete and additional land on the site is available. Transmission lines for Unit 2 were constructed on existing rights-of-way.

15.5 Property

Alternative 1. Plant As Is

Environmental Cost: 0

Most of the land use in the vicinity of Indian Point Station is zoned for both residential and industrial purposes. As the applicant's Indian Point property has been used as a nuclear power station since 1962 and since additional land is not required, there should be no effect on adjacent property values. The Unit No. 2 is situated on the same property and transmission lines for this plant have utilized existing rights-of-way.

Each of the cooling subalternatives from which Alternative 2 was selected produce some adverse effects which could affect property values in the vicinity. The natural-draft towers are large and present a major aesthetic impact. Mechanical-draft cooling towers cause higher noise levels and lead to increased fogging and icing frequencies. The spray pond may cause excessive fogging and icing and high localized salt deposition. It is very difficult to predict property value losses for these situations on a monetary basis since the impacts of the adverse effects are not uniformly quantified. Therefore, qualitative ranking of potential losses will be made which takes into account the area or population affected and the type of effect. Three types of effects to be considered in their order of importance are: (1) health and safety, (2) damage to real property, and (3) landscape deterioration.

Cooling Subalternatives 2B and 2E

Environmental Cost: Minor

Both salt deposition and fogging potential exists from these two subalternatives in quite low compared to the other cooling methods. Noise levels (Section 13.1) apparently would be relatively low. Thus, probable effects on health and safety and property damage would be minimal, even near the Plant. Aesthetically the natural-draft towers have a major impact, but since this is considered third in relative importance, the overall ranking is classified as minor for each subalternative.

Cooling Subalternatives 2C and 2F

Environmental Cost: Minor

These two subalternatives are intermediate in their salt deposition rates and fogging (icing) frequencies. Open-cycle operation (2C) would yield less salt and less fog. However, the noise levels for this subalternative would be more severe and noise from both these subalternatives apparently would reach normally unacceptable levels at populated locations offsite. Thus, definite effects on health and safety and on property damage could result in the vicinity of the Plant site. The moderate aesthetic impact would be of little importance compared to these major effects.

Cooling Subalternatives 2D and 2G

Environmental Cost: Major

These two subalternatives offer considerable more potential for extensive salt deposition and fogging (icing) frequency than any of the others. Although salt deposition should be localized, the wide area affected by fog and the implication of this to health and safety and to property damage suggests a major effect on property in the region would occur. The minimal expected effects of noise and the moderate aesthetic impact are insufficient to reduce the projected cost.

15.6 Flood Control

All Alternatives

Environmental Cost: None

Flooding at the site is nonexistent. The minimum elevation of the site, 15 feet, is well above the highest recorded flood of 7.5 feet. Therefore, the Plant has no implications regarding flood control.

15.7 Erosion Control

All Alternatives

Environmental Cost: 0 tons per year

Relatively little dredging and filling were required for the construction of the Plant intake and discharge structures. With Unit No. 2 construction nearly complete site restoration has begun. Construction photos show no evidence of a significant erosion problem. Final grading and seeding will prevent future erosion.

16. Temporary Impacts of Plant Construction

16.1 Land Disturbance

Values for the alternatives were estimated by scaling from the plot plans shown on Figs. 2B-2G, pages S3-A3 through S3-A8, of the applicant's Benefit-Cost Analysis.

16.2 Air Quality

Effects of dust and emissions from construction equipment were considered negligible.

16.3 Water Quality

Dredging did cause some disturbance of bottom organisms and turbidity during the construction of the intake and discharge structures. There is a possibility for siltation and turbidity to occur during construction of the open-cycle pond alternative caused by storm discharge if the pond and pipeline trenches are open and interconnected.

16.4 Water Diversion

Diversion of the Hudson River was not required.

16.5 Waterways Effects

Construction activities did not interfere with water transportation.

16.6 Spoilage

It is assumed that there was a negligible amount of spoilage in excavated areas due to erosion. It is also assumed that this will be the case for each of the alternatives listed.

16.7 Housing

Since the site property has been used as a power Station for approximately 10 years, no housing had to be relocated as a result of the construction of Unit No. 2.

16.8 Schools

As the majority of the construction workers commute, there has been no great influx of families to the general area. Therefore, the impact on the schools has been negligible.

16.9 Traffic

The effect of increased traffic at shift changes and delivery of construction materials by truck is judged to have a moderate impact on local traffic.

16.10 Community Services

The impact is considered negligible for the same reasons cited in 16.8 above.

17. Transportation

Alternatives, such as special routing of shipments, providing escorts in separate vehicles, adding shielding to the containers, and constructing a fuel recovery and fabrication plant on the site rather than shipping fuel to and from the station, have been examined. The impact on the environment of transportation under normal or postulated accident conditions is not considered to be sufficient to justify the additional effort required to implement any of the alternatives. The estimated dose due to transportation of irradiated fuel is 1.8 man-rem if transport is by rail and 3.4 man-rem if by truck. The estimate for transportation of waste is 0.9 man-rem.

17.1 Fuel Transport

The applicant's Supplement No. 2 to the Environmental Report states future fuel cycles will require about 64 new fuel assemblies at approximately one-year intervals. For this number of assemblies, from 4 to 6 new fuel shipments will be required.

17.2 Fuel Storage

Assumed to be equal to the number of new fuel assemblies required per year.

17.3 Waste Products - Fuel

The number of units per year from the initial radwaste system and from the modified system will increase from 90 to 150 drums. Reference: Applicant's Supplement No. 2 to the Environmental Report, page S2-4.

18. Waste Products

Based on plants presently in operation, it is expected that approximately 100 to 200 55-gallon drums of solid waste will be transported offsite each year.

C. SUMMARY OF BENEFIT-COST ANALYSES

The monetized benefits and costs and environmental costs of the present Plant and the least-impact alternative are summarized in Tables XI-I and XI-2. In Table XI-3 the various subalternative cooling systems are compared with the present once-through cooling system. It should be noted that the tables are not complete without the discussion in

Chapter XI.B above, and elsewhere in this Statement. Again it is pointed out that the applicant used a discount rate of 8% and carrying charges of 13% that were interpreted as consistent with the draft guidelines. More recent drafts of the guidelines provide a clearer interpretation of common economic practices in which a discount factor of 8.75% for a 30-year lifetime of the Plant is taken into account.

In the case of the closed-cycle, natural-draft cooling tower system, the generating costs will be increased by about $136,000,000 over the 30-year period. This incremental cost would be added to the applicant's customers bills and should be weighed against the differential environmental costs of the different cooling modes of operation.

In regards to benefits for the community, a larger amount of local taxes with a closed-cycle cooling system could be available. However, the overall generating costs which would be paid out of the customers' pockets would more than compensate for the added advantage of increased taxes paid to the community.

Environmentally, the cooling towers offer advantages of reduced waste heat input discharged into the Hudson River, thereby minimizing the influence of the thermal plume on fish and other aquatic biota. Cooling towers also offer the advantage of reduction of volume intake for make-up use as compared to the volume of once-through cooling. Thus the biological impact from entrainment will be correspondingly reduced. If the intake velocity is also reduced, then less damage is done by fish impingement on the screens. However, cooling towers may have distinct disadvantages as discussed in Chapters XI.A and B. If the blowdown has chemicals such as zinc, phosphate, and chromates, these are very toxic to aquatic biota and may cause far more damage than that from thermal discharges. The 400-foot high natural-draft cooling towers would be unaesthetical in appearance and because of their height, they would be visible for miles from the Plant. Added to the cost of the cooling towers would have to be the costs of water treatment of the blowdown. The salty-brackish water of the Hudson River also causes difficulties in operation of cooling towers and could cause salt deposits on the terrain through drift. Furthermore, cooling towers result in higher in-Plant power needs, thereby resulting in less energy available from the Plant. Dry cooling towers have certain distinct advantages and disadvantages compared with wet cooling towers, as discussed in Section XI.A. The applicant, however, did not include this alternative in its cost-benefit analysis.

In regard to the Plant as is, the staff analysis estimates that the Indian Point Units will cause a 30% to 50% reduction of the striped bass larvae that migrate past Indian Point from upstream spawning areas in June and July of each year. Fish impingement against the fixed outer screens of the intake system will cause additional impact especially during the winter months when the Hudson River waters are near the freezing point, the salt water front is positioned just upstream of Indian Point, and fish mobility is at a minimum because of the low temperatures. The applicant also has under consideration a number of fish protection alternatives, as discussed in Section XI.A and XI.B, which can be used to minimize the biological impact of the Plant operation.

As discussed in Chapter X, the need for power in the applicant's service region has been adequately demonstrated, particularly for the summer peak load periods. Operation of Unit No. 2 to provide an immediate increase in the regional power supply will alleviate the situation and serve the welfare of the applicant's customers in the metropolitan New York area. The short-term power benefits (2 to 4 years) from operation of Unit No. 2 would not be expected to cause an irreversible environmental damage to the aquatic biota of the Hudson River. The staff's analysis of the present cooling system on the Hudson River shows that the complex estuarine environment would be irreversibly damaged from long-term operation of Unit No. 2. Therefore, it is essential that operation of the Plant guarantee an acceptable limit to the environmental costs by installation of a closed-cycle cooling system for Unit No. 2 within a period of 5 years after startup of Unit No. 2.

The applicant shall be required to submit to the Commission by July 31, 1973, an evaluation of the economic and environmental impacts of an alternative closed-cycle cooling system that will result in minimal environmental damage. The recommended closed-cycle system shall be designed, built, and placed in operation no later than January 1, 1978. Furthermore, the applicant shall also be required to conduct an effective environmental monitoring program and limit effluent releases, assess and evaluate the data collected in order to identify and predict the magnitude of environmental impacts of Plant operation, and develop, by July 1, 1973, a plan of action to minimize detrimental effects during the interim period of operation of the Plant with the once-through cooling system. This plan should include means of reducing to a practical minimum fish kills from cold shock, entrainment of fish eggs, larvae and plankton, and provide for limited use of toxic chemicals and for corrective measures such as aeration of the cooling water during periods when concentrations of dissolved oxygen in the thermal plume are reduced below 4.5 ppm.

With these provisions, the benefits from short-term operation of the Indian Point Station will outweigh the environmental costs, and the long-term benefits can be realized by suitable environmental control measures which the applicant shall be required to exercise. The Technical Specifications to be provided with an operating license will specify the limitations of specific effluent discharges and the ecological monitoring surveillance program required with the necessary administrative controls, to assure adequate data will be collected for use to assess the biological impact of operation of Indian Point Unit No. 2 on the environment.

The applicant's commitment to meet Federal and New York State water quality standards; to conduct extensive ecological studies in cooperation with the State and Federal Fish and Wildlife Service; and to implement those changes in the operation and design of the Indian Point Unit No. 2 that will minimize damage to aquatic biota, along with the capability of some of the aquatic biota of the Hudson River to recover, could assure that the overall ecosystem of the Hudson River will be preserved for future generations.

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XII. DISCUSSION OF COMMENTS RECEIVED ON THE DRAFT DETAILED STATEMENT ON ENVIRONMENTAL CONSIDERATIONS

Pursuant to paragraph A.6 and D.1 of Appendix D to 10 CFR 50, the Draft Detailed Statement was transmitted with a request for comment to the: Advisory Council on Historic Preservation, Department of Agriculture, Department of the Army, Department of Commerce, Environmental Protection Agency, Federal Power Commission, Department of Health, Education, and Welfare, Department of Housing and Urban Development, Department of the Interior, Department of Transportation, the Governor of the State of New York, New York State Department of Environmental Conservation, Department of Public Service, Department of Commerce, Atomic Energy Council, Westchester County Department of Planning, and Mayor of the Village of Buchanan. In addition, the Commission requested comments on the Draft Detailed Statement from interested persons by a notice published in the Federal Register on April 20, 1972 (37 F.R. 7828) and supplemented on May 2, 1972 (37 F.R. 8897).

Comments in response to the requests referred to in the preceding paragraph were received from the Advisory Council on Historic Preservation, the Department of Agriculture, Department of the Army, Department of Commerce, Environmental Protection Agency, Federal Power Commission, Department of Health, Education, and Welfare, Department of the Interior, Department of Transportation, New York State Department of Environmental Conservation, Attorney General of State of New York, New York Historic Trust, Westchester County Department of Planning, Natural Resources Defense Council, Inc., Citizens Committee for the Protection of the Environment, Environmental Defense Fund, Hudson River Fishermen's Association, Scenic Hudson Preservation Conference, Committee to End Radiological Hazards, Congressmen J. B. Bingham, J. G. Dow, and W. F. Ryan, and Mr. J. M. Burns, III, and Mr. R. L. Ottinger. The applicant in seven separate communications has also responded to comments from these agencies, parties in the proceeding before the Licensing Board, and interested persons.

The staff's consideration of the comments received is reflected in part by revised text in other sections of this Statement and in part by the discussion below. Also in response to comments and for purposes of clarity some of the text presented in the Draft Statement has been rearranged to incorporate the staff's responses to the comments from agencies, the applicant, and others. In particular, information on the hydraulics of the Hudson River estuary has been gathered from Sections III.E.1. and Appendix II-1 in the Draft Statement and is now described in Section II.E.1. of the Final Statement; basic information that was utilized for an evaluation of the ecological impact in Section V.D. of the Draft Statement has been moved into Appendix V-1 of this Final Statement; and that on the staff's cost-benefit analysis in Appendix XI-1 in the Draft Statement has been incorporated into Section XI.B. of this Final Statement.

A. GEOLOGICAL AND SEISMOLOGICAL CONSIDERATIONS OF THE SITE

In its comments relating to the Draft Statement, the New York Department of Environmental Conservation offered the following information: "No faults are known to exist on the proposed site. A major fault has been mapped extending into the Hudson River from the eastern shore in a line approximately 3,000 feet northwest of the site. This fault extends over twenty miles to the northeast of the site and may join faults west of the River which extend into New Jersey to the southwest. One of these faults to the southwest, the Ramapo Fault, separates rocks of Precambrian age (over 800 million years old) from those of the Triassic age (approximately 200 million years old) and represents considerable displacement. On the east side of the river within three miles both north and south of the site are several faults with at least several hundred feet of mappable offset.

As presented in the Preliminary Safety Analysis Report a Modified Mecalli Intensity of VI is considered possible in the area on the basis of study of the seismic history of the region."

The NYS DEC also recommends that for future power plant siting, an investigation involving a seismic monitoring program with analyses of focal mechanisms to determine whether motions observed correlate both geographically and geometrically with known faults. If faults are found which appear to be related to seismic activity, they will have to be mapped in detail. In terms of the Indian Point site, geological studies of the nature recommended by NYS DEC have been carried out by the applicant in the context of site analysis in support of its application for a license from the AEC to construct and operate the Indian Point facility. This analysis is discussed in detail in the Safety Analysis Report and in the staff safety evaluation report.

B. FLOW CHARACTERISTICS OF THE HUDSON RIVER

The New York State Department of Environmental Conservation has offered comments on the staff's description of the net-nontidal flow concept, as follows:

"Item 31. The paragraph on net-nontidal flow recognizes the phenomena, and its usefulness in describing mixing and dilution aspects not accounted for in other ways. However, it is believed, in light of the admitted lack of definitive data to quantify the phenomena, that conclusions should not be drawn on which segments of the flow region participate, and to what extent. Its beneficial effect should be recognized, with qualification and quantification left to field verification studies." In addition, the applicant comments as follows on this subject: "The Draft Statement, in its discussion of net nontidal flow, attempts to summarize and evaluate the application of this concept to the Hudson River at Indian Point. The Statement does not convey a consistent evaluation as to how the concept should be applied."

Table 1 of the applicant's responses to the Draft Statement in its Appendix B-1, dated May 30, 1972, summarizes results of the density-induced circulation studies detailed in References 8 and 9 of Appendix B-1. The table compares the velocity and salinity approaches on determining flow characteristics of the river. In general, the salt approach exhibits several favorable characteristics such as relatively more stable and predictable distribution, more independence of temporary meteorological and local eddy conditions, simplicity and availability of more precise detection instruments. The end result of these advantages is, of course, a more reliable measurement which makes the use of salt more attractive from a practical standpoint. The results of the salt approach were also used to introduce some degree of perspective to the problem and to determine seasonal variation of upper layer flows since most of the available current observations were made during the summer months.

When the freshwater flow exceeds 20,800 cfs at Indian Point, the river changes from a two-layer to one-layer system having a new flow in the downstream direction from top to bottom. This flow value represents the incipient salt flow at Indian Point and may occur during May during certain years. This critical value of freshwater flow may be obtained from Fig. 1, in Appendix B-1 of the applicant's responses of May 30, 1972. The long term monthly average upper layer flows are shown in Fig. 2.

In conclusion several methods of estimating the net-nontidal flow have been evaluated. The staff recommends the use of salinity data in Section II.E.1. of the Final Statement and the applicant concurs. Statistical analyses using different methods of interpreting salinity data lead to estimates of upper layer flow from 35,000 to 92,000 cfs. Since the less accurate velocity method resulted in lower values of upper layer flow, the applicant has used this most conservative value obtained, approximately 21,000 cfs in their evaluation. The applicant's methods of analyses have employed established principles to advance the scientific state of estuarine prediction techniques.

Furthermore, the applicant summarizes its position regarding the net-nontidal flow as follows: "The applicant has demonstrated through extensive analyses using several independent methods (see Chapter V of the Draft Statement, Reference 9), how the nontidal flow depends on freshwater flow. The final two Unit predictions as given in Reference 11 of Appendix B-1 of the applicant's comments use the minimum (most conservative) estimates of the nontidal flow that can be obtained. The efforts of the applicant's consultants represent a significant advancement in methods of modeling such estuaries."

In response to these comments, the staff's view of the net-nontidal flow phenomenon in the Hudson River in general corresponds to that put forth by the New York State Department of Environmental Conservation. With respect to the applicant's comments in this area we have the following response: The two main references which attempt to put a value on the net-nontidal flow are the applicant's Appendix N, dated October 1969, to the Supplement No. 1 of its Environmental Report and the Bowline Report (Reference 4 in Chapter III) dated March 1971. The staff has reexamined Appendix N which was the primary basis for our comments in the Draft Statement and see no reason to alter our conclusions regarding this Statement at this time. Certainly the applicant has presented no substantive counter-arguments which point toward any judgment or factual error made by the staff in its review of Appendix N. Hence our comments on the two-layer flow phenomenon in the Final Statement are naturally the same as appeared in the Draft Statement.

In further study of the Bowline Reports, however, we have carefully examined the pertinent sections of this environmental report, namely, Vol. I, Chapter 4, pages 22 through 71, in which an equation is derived for the upper layer flow rate from the basic mass and momentum balances. This is a fine example of an engineering analysis; however, we may cite the following four assumptions or steps in the development which are either questionable or perhaps require additional verification:

1. The analysis assumes steady state flow whereas the flow phenomena in the river are oscillatory as influenced by the tidal flows. The report fails to provide evidence of the validity of using a steady state analysis for a transient situation.

2. In the continuity equation (water mass balance), the vertical velocity gradient was dropped by virtue of its being small relative to the value of the axial velocity gradient. It may be shown that this is probably not correct for the Hudson River flow.

3. The shearing stress term in the derived momentum balance equation is dropped. There is some question as to the validity of dropping the wall shear stress term.

4. The final result presumes a value for the depth of the upper flow layer of one half of the total depth. While this may appear to be reasonable for many cases, the sensitivity of the final result to this assumed depth ought to be presented by the applicant.

In addition, we must point out that the analysis is intended to be used in a highly unorthodox way rather than as a means for predicting values. Even if no uncertain assumptions or steps were employed, it would still be questionable practice to employ the results of such an untested theoretical analysis for prediction of values for the upper layer flow. The staff does not tend to be overly critical of what appears to be a fine analysis, but we feel that this is a case where field experiments are certainly very much needed.

C. HEAT DISSIPATION SYSTEM AND MODELS

1. Flow Rates Through the Once-Through Cooling System

In regards to comments from the Department of the Army about the total average cooling water flow rate of 1,954 cfs used for Units Nos. 1 and 2 which was submitted in the applicant's application for a Section 13 permit to the Army, the key word is average. The staff has used 2,650 cfs for the maximum water withdrawal rate (or service and cooling requirements for Units Nos. 1 and 2) as per data supplied by the applicant. If one applies an 85% plant use factor to this rate, and additionally assumes that the cooling water flow is cut in half for the three winter months, an average yearly rate of approximately 1,950 cfs is obtained. From its comments, the applicant in Table XII-1 indicates the different cooling water flow rates and the corresponding temperature increases of the cooling water for all three Units operating under different pumping conditions.

In regard to the discharge velocity, the NYS Department of Environmental Conservation states: "Page III-19 - The first paragraph mentions a control weir in the discharge canal to control jet velocity. This is incorrect, as velocity can only be controlled by port opening adjustment, which controls head on the open ports. Further, the head requirements on the circulating water pumps were partially determined by the water elevation in the discharge canal. The weir could only function as a relief to avoid excess head and backpressure."

The staff has only stated that the weir in fact controls the depth of liquid in the plenum from which the jets discharge the cooling water. Hence, it controls the water pressure at the orifice, which together with the orifice area, determines the velocity of the jet.

2. Thermal Discharges and Models

a. Heat Load and Maximum River Ambient Temperature

With respect to the staff's concern of the maximum river ambient temperature and intake temperature, the applicant states the following from Section 2 of Appendix B-1 "Detailed Comments on Thermal Discharges":

TABLE XII-1

AVERAGE TEMPERATURE RISE UNDER VARIOUS FLOW CONDITIONS

Total Flow Through Condenser %		Total Flow Recirculated %		Total Discharged Flow, gpm	Average Temperature Rise, F°
Unit No. 1	Unit No. 2	Unit No. 1	Unit No. 2		
100	-	0	-	280,000	12.6
60	-	0	-	168,000	21.0
60	-	10	-	140,000	25.2
-	100	-	0	840,000	14.9
-	60	-	0	504,000	24.8
-	60	-	10	402,000	29.8
-	60	-	20	336,000	37.2
100	100	0	0	1,120,000	14.3
60	60	0	0	672,000	23.9
60	60	10	10	560,000	28.7
60	60	10	20	476,000	33.7

"The Draft Statement maintains that "Report of Inquiry into Allegation Concerning Operation of Indian Point 1 Plant of Consolidated Edison Company" shows river ambient temperatures of 81°F. Certainly it is clear that an extensive body of temperature data exists beyond this simple source. Our consultants have analyzed all existing data and these analyses have been described in Dr. Lawler's Supplemental Study dated May 1972 (reference 12, pages I-3 through I-5). The comments below are, in part, based on that report.

"The New York State regulations define ambient temperature implicitly in NYCRR 704.1 where estuarine thermal criteria are specified. With regard to the 4°F heating limitation that section reads in part: "... shall not be raised to more than 4°F over the temperature that existed before the addition of heat of artificial origin..." The data presented in the staff's reference indicating a temperature of 81°F were obtained while Lovett and Indian Point were operating and were not measured at the Indian Point site. Thus, these temperatures measure thermal plume effects, not ambient intake temperature. Furthermore, the data were accumulated with uncalibrated thermometers normally accurate to only ± 1°F at best. By contrast the applicant's consultants' data analysis in reference 12 was based on measure ments using Bureau of Standards calibrated thermometers and employed statistical methods in documenting the use of the 79°F maximum ambient river temperature at the site.

"The Draft Statement references Attachment B-3 of the Report of Inquiry referred to above for its finding of the 81°F intake temperature. The same report contains an exhibit designated Attachment B-2 which shows temperatures specifically at the intake of Indian Point 1 for the summer periods of 1967 and 1968. The highest temperature indicated is 80°F which occurred on six days in 1967 and no days in 1968. Since the present outfall structure had not been constructed, recirculation effects would be greater at that time than would be expected from the present configuration. The Draft Statement makes no mention of Attachment B-2.

"The Draft Statement uses the 81°F hypothetical ambient temperature to criticize the applicant's conclusions that the 90°F maximum surface temperature criterion will not be exceeded. The applicant's submerged discharge model is fully explained and documented in the Supplemental Study of May 1972 (reference 12). We understand that this document was not available to the Staff when it prepared the Draft Statement. The model is conservative, uses published parameters where needed, and agrees with physical model results, from the undistorted model of the outfall. The physical model tests are more fully described in the comments below. (See #4.) The models predict a maximum surface temperature of 88°F."

"In summary, the applicant maintains (1) that the maximum ambient river temperature is 79°F, based on statistical analyses of available data; and (2) that the effluent will be diluted to meet the 90°F maximum surface temperature limit."

The applicant in its comments of May 30, 1972, summarizes its position as follows:

"The concern expressed by the staff appears to be associated with the use of uncontrolled data collected for other purposes. See Appendix B-1. The staff uses a maximum river temperature at the plant intake of 81°F (III-35). The temperature at the Indian Point 1 intake is monitored continuously.

"In view of the voluminous data available on this subject, Consolidated Edison considers 79°F (without recirculation) to be the highest water ambient temperature that can be experienced by the Indian Point intake at any time."

The Statement references data contained in the Report of Inquiry on Indian Point Unit No. 1 submitted by the Commission's Division of Compliance in October 1971. These data show three readings at 81°F and the balance of the readings are consistent with Consolidated Edison's analysis. These three readings were not at the plant intake but were out in the river where they were influenced by the thermal plumes from Indian Point and Lovett. The same Report of Inquiry had data on intake temperatures which is not referred to by the Statement."

In response to the matters discussed above, the staff did not intend to claim that 81°F is necessarily the maximum natural river ambient temperature at the site; however, these temperature measurements should be taken into account. The staff's views concerning the maximum intake temperatures to be used was based on examination of the following information in a portion of Table B-3 from the "Report of Inquiry into Allegations Concerning Operation of Indian Point 1 Plant of Consolidated Edison Company," Vol. II, October 1971.

Portions of Table B-3

Sampling Date	Sample Station	Temperature °F Top	Temperature °F Bottom	Depth Ft.
July 16 (1968)	East	77.0	(-)	25
	Mid	77.4	76.8	40
	West	78.1	76.6	20
July 30	East	79.2	78.8	27
	Mid	80.1	79.2	50
	West	78.2	78.4	27
Aug 14	East	80.2	80.1	12
	Mid	81.3	80.6	45
	West	80.6	80.2	26
Aug 27	East	80.6	79.9	13
	Mid	81.3	79.7	52
	West	80.4	79.9	20
Sep 10	East	77.0	76.3	30
	Mid	78.4	76.1	50
	West	76.6	76.1	18
Sep 27	East	75.6	75.2	50
	Mid	75.4	75.4	60
	West	75.7	75.7	30
Oct 8	East	79.8	68.9	75
	Mid	70.5	69.6	75
	West	70.3	70.2	32
May 5 (1969)	East	55.0	54.2	42
	Mid	56.3	54.5	54
	West	55.4	54.4	27
Jun 9	East	70.7	70.	48
	Mid	70.2	69.4	54
	West	70.2	69.8	22

Portions of Table B-3 (Continued)

Sampling Date	Sample Station	Temperature °F Top	Temperature °F Bottom	Depth Ft.
Jul 9	East	77.	76.6	72
	Mid	77.9	76.5	57
	West	77.5	76.6	22
Aug 5	East	78.4	78.4	60
	Mid	78.4	78.3	54
	West	78.6	78.3	19
Aug 26	East (Lent's Cove)	80.6	80.1	17
	East (Near effluent)	83.5	79.1	50
	East (Near east shore)	81.1	80.6	17
	West	80.2	80.1	24

As can be seen from the data, in both 1968 and 1969, the water temperature exceeded 81°F in August. The staff's concern was based on those measurements. The east channel station was located about 135 feet directly out from the intake of Unit No. 1. The mid- and west-channel stations similarly were located directly across from the Unit No. 1 intake. Since the Lovett Plant is located about one mile downstream on the west shore, it is certainly likely that the operation of these plants would affect, respectively, the east and west channel stations. It is less clear whether or not the central station temperature should have been elevated. The staff admittedly did not check the precision and accuracy of the temperature sensors used. Since they were reported by New York University to have precision of 0.1°F, we presumed the accuracy was 0.1°F.

At the applicant's suggestion we have examined the Quirk, Lawler, and Matusky report "Supplemental Study of Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution," May, 1972, Appendix B-2 in applicant's comments of May 30, 1972, and have reproduced here Fig. 3 from that report. Note that the figure refers to data taken at Lovett in

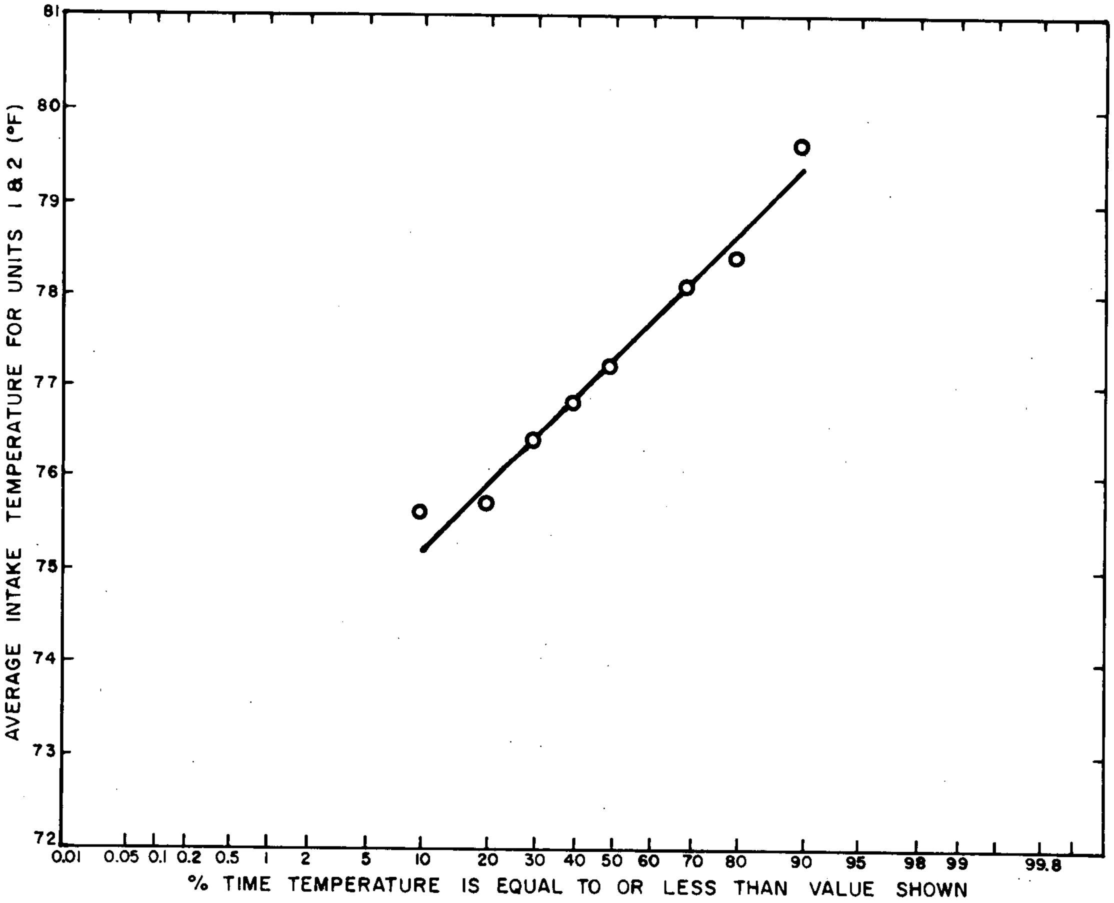

Fig XII-1
FREQUENCY OF OCCURRENCE OF AVERAGE MONTHLY INTAKE TEMPERATURE AT LOVETT, MONTH OF AUG.-1958 TO 1965

August in the 10 years from 1956 to 1965. Note that according to the line in the graph, temperatures exceeded 79.3°F, 10% of the time, which is not inconsistent with an occasional 81°F ambient temperature. The applicant contends that these values may all be high due to recirculation flow at the Lovett Plant. However, the statement is made on page I-4 of Appendix B-2, that the data accompanying Fig. 3 in summary represent "the most extensive survey of ambient river temperatures for the Indian Point-Lovett areas."

The staff feels that, when all the above data are taken into account, it is clear that the maximum intake temperature might indeed be close to 81°F. in reference of Chapter II the applicant states that "During 1969, the July, August and early September temperatures ranged about 72 to 82 degrees F with the peak temperature occurring in August." Other surveys are showing similar results. It is true, however, that these temperatures might reflect in part the intake recirculation from Indian Point Unit No. 1 and the Lovett power plant. This recirculation was not considered in the applicant's original environmental report, but it has been considered in its more recent studies.[1,2]

The staff, therefore, feels that the maximum ambient river temperature might be about 80°F but the issue is still somewhat open. The staff, however, feels that this need not be resolved at this time. As discussed in Section III.E.1.g., we have performed some extensive jet dilution calculations using a variety of methods and assumptions, and find that the dilution of the heated effluent jet is sufficiently large so that the 90°F criterion is not exceeded for Indian Point Units Nos. 1 and 2 even when 81°F is taken as the maximum ambient and intake temperature. The correct maximum ambient river temperature might be important for compliance with the maximum limit of 83°F of the thermal criteria.

b. Submerged Discharge Model

The NYS Department of Environmental Conservation is concerned about the staff's remarks that "The conclusions reached by the applicant in regard to the thermal discharges from Units Nos. 1 and 2 in meeting the New York State thermal criteria throughout the entire year have not been adequately demonstrated by the applicant, especially since the submerged jet depth is being changed from 18 feet to 12 feet below mean water level;" and the DEC assumes that the AEC will pursue this question further with the applicant prior to approval of an operating license. While there may be questions about the actual dispersion patterns, this agency believes that the model studies, calculations, and field studies made by the applicant represent a reasonable effort at appraising likely river conditions. Further modifications, if needed, may be required by the State. Since this organization has stated that there is reasonable assurance the criteria will be met and has adequate follow-up procedures following issuance of the discharge permit, it questions the staff's assertion on this subject.

The staff's concern was based on the fact that in general the surfacing temperature of a jet is higher if its depth of submergence is smaller. The staff was not aware at that time that the bottom slope could interfere with the submerged jet entrainment, nor was this fact mentioned in the applicant's

Environmental Report. Raising the jet depth from 18 feet to 12 feet to overcome this difficulty is understandable, but should be evaluated against the disadvantage of having a smaller plume length which also means a shorter distance for dilution. As can be seen in Section III.E.1.g. of the Final Statement, the staff's independent analysis shows that the 90°F maximum surface temperature criteria will indeed be satisfied in spite of changing the jet depth from 18 to 12 feet.

On the subject of the mechanics of submerged jet entrainment as discussed in items 23-26 of the comments from the NYS Department of Environmental Conservation, the staff in response to items 23 and 24 did not refer to the physical model, but to deficiencies in the mathematical model. The acceptance of the physical model depends on other factors than those discussed in these sections. In response to jet interference in item 25, the error made by the applicant in using a port spacing of 11.25 feet instead of 5 feet was indicated in Section III.E.1.g. and the effect of correcting this error was evaluated by the staff. The applicant's decision later on to use only alternate ports, so that the spacing between ports changed from 5 feet to 27 feet, is indeed very welcome. The staff has never claimed that no dilution will occur after jet interference. This was purely the applicant's assumption and the staff found it necessary to mention that this is indeed an overly pessimistic assumption (last paragraph on page III-36 of the Draft Statement). Furthermore, the staff does take this dilution into account in its independent analysis. In the opinion of the staff, taking this dilution into account is needed to show that the 90°F maximum surface temperature criteria will be met.

Item 26 on page 13 of the DEC comments was practically answered by the staff in the previous items. The 12.4F° surface temperature rise mentioned by the staff is based on the applicant's original assumption that no dilution is considered after jet interference. The staff's independent analysis shows that, if dilution is not considered, the maximum surface temperature rise will be even higher than 12.4 F° for a 5-foot spacing between ports, but as stated, this question need not be of concern now.

c. Far Field Heat Dissipation Model

In response to the following comment (Draft Statement, p. III-37) by the applicant regarding the staff's views on the mathematical model used to predict the far field temperature pattern, "The adjustments made to the original model by arbitrarily using correction factors so that the results will agree with only one set of observed data from operation of Indian Point Unit No. 1 and extrapolating the model to predict the effects of Units Nos. 1, 2, and 3 together is unjustified," the applicant states that it "used all available data to calibrate the models presented. The models have now been tested in numerous applications and have been verified. The model development and verification have at all times been beyond the state-of-the art. The summary analyses in reference 11 of the applicant's comments in Appendix B-1 employ no empirical adjustments; they are theoretical predictive models which show remarkable agreement with the independent physical models."

The above is a summary of the applicant's position; their lengthier statement on this subject was presented by its consultants in testimony in hearings on April 5, 1972, before the Licensing Board.

The question here relates to the validity of the one-dimensional model, the so-called "convection-dispersion" model as employed by the applicant to predict space-and time-average temperatures across the river at the point of thermal discharge. While there are a number of uncertainties in this model, the staff still objects to the use of the multiplication correction factor (termed "f5") which adjust the computed average temperature to the measured value. Two measurements were used to yield two different values for f5. Both were obtained during the operation of Unit No. 1 with a surface discharge. The staff questions the validity of using these values to predict Unit No. 2 average temperature rises in view of the vastly different effluent geometry for Unit No. 2.

The applicant's "Detailed Comments" in Appendix B-1 of May 30, 1972, point out that its newest model does not employ any correction factor. The discussion above refers to the analysis presented by the applicant's consultants, Quirk, Lawler and Matusky Engineers (QLM) in Appendix J dated February 1969 in Supplement No. 1 to the Environmental Report, which was the most recent position on this subject available to the staff during preparation of the Draft Statement. A newer analysis was presented by QLM in two documents: (1) "Summary Report - Effect of Indian Point Units 1 and 2 Cooling Water Discharge on Hudson River Temperature Distribution," dated February 1972, and presented at the Hearings on April 5, 1972, and (2) "Supplemental Study of Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution" dated May 1972. Our Final Statement reflects this added information. Since both Table 6 of Document No. 1 and Table 3 of Document No. 2 continue to report values obtained from the older model, the staff has retained the previous discussion of this model in the Final Statement.

Actually, the density-induced-circulation model appears to be simply a mixed mean temperature equation whenever the total flow assumed to be available for dilution is the sum of the upper and lower flow layers. The staff in this Final Statement continues to disagree that both upper and lower flow layers may be assumed for dilution and holds the view that in neither layer has the flow rate been satisfactorily determined. The amount of thermal stratification needs also to be determined.

d. Hydraulic - Physical Models

The applicant in its Appendix B-1 "Detailed Comments on Thermal Discharges" of May 30, 1972, expressed concern with regard to the staff's lack of emphasis on the extensive physical modeling work that was done by the Alden Research Laboratories as consultants to the applicant and summarizes its position as:

> "4b. Applicant maintains, as in the original 1969 report, that the mathematical and physical models are independent, illustrate remarkable agreement and should be reviewed and interpreted as complimentary predictions."

The applicant's detailed comments regarding the weight that the staff placed on the hydraulic model results in Section 4, Appendix B-1, applicants comments of May 30, 1972, and the Alden Laboratory reports (Appendix O of Supplement No. 1 to the Environmental Report) clearly indicate that the major portion of the physical modeling work was directed toward the determination of the best outlet geometry. The staff never questioned the validity of this work which finally resulted in the elevation of the discharge ports to the 12-foot depth from its original 18-foot depth.

For the following reasons, the staff did not place great significance on the near field and for field temperature isotherms that were measured in the physical model tests: (1) the temperature rise isotherms in the prototype will be mostly dependent on the amount of flow available for dilution of the effluent for the nine months of the year wherein the Hudson experiences the so-called "two-layered flow." The physical model tests could not possibly yield information on the magnitude of the upper layer flow because this flow depends on the dynamics of the entire estuary whereas the model represented a section of the estuary from 4,500 feet above to 4,500 feet below the discharge point; (2) the oceanic salt front penetration, which is an important part of the hydraulics of the Hudson, was not (and probably could not be) simulated in the physical model; and (3) because the model represented only 9000 feet of the river, substantially less than one tidal excusion, the utility of the reported results is seriously limited even for the remaining three months in the spring when the Hudson experiences single-layered flow. In this regard, the above-mentioned Alden report states (p. 25):

> "Therefore the model results yield information about the effect of a continuous release of cooling water from Indian Point within the modeled area for one tide cycle. The effect of buildup of heat over a period of time, corresponding to several tidal cycles, was not modeled."

The staff agrees that more emphasis should have been given to the physical model studies for the submerged jet analysis and recognizes its importance for both design and prediction. This is not true, however, with the near field and far field models for predicting general temperature isotherms because of the limitations mentioned above. The more recent physical studies made during 1971 and 1972 were not submitted to the staff for review.

D. RADIOACTIVE WASTE TREATMENT, EFFLUENT DISCHARGES, AND ENVIRONMENTAL IMPACT

Comments have been received from EPA, Department of Commerce, the NYS Department of Environmental Conservation (Items 32 - 34), and the applicant (Appendix F of its comments of May 30, 1972) on the amount of radioactive material to be discharged to the environment; the applicant is planning to make a number of modifications to the radioactive waste system. In Section III.E.2, the staff has included source terms related to the present system and to the proposed modified system.

In reply to EPA's comment that the applicant should make full use of the radwaste treatment system to achieve the lowest practicable radioactivity releases, the Commission's regulation, 10 CFR 50.34a, requires the applicant to describe the equipment and procedures for the control of radioactive material in effluents to unrestricted areas. Regulation 10 CFR 50.36a requires that the equipment in the radioactive waste treatment systems be maintained and used to control the releases of radioactive effluents as defined by the Technical Specifications. Detailed records of the radioactive waste system operation along with reporting of its operation are required to be presented to the Commission on a semi-annual basis. Throughout the operating life of Unit No. 2, modification of the operating procedures and equipment utilization will be made to accommodate changing conditions of the reactor and the radioactive waste management systems. In response to EPA's comment on description of the proposed modifications of the radioactive waste system, as stated above, Section III.E.2 has been revised to include additional information regarding design, schedule, operation, and performance of the modified system for Units Nos. 1 and 2. This includes additional information on the steam generator blowdown treatment (filter-demineralizer), an additional demineralizer on the waste evaporator condensate line, and the gaseous waste treatment system (charcoal filters on the Plant vent) to reduce iodine concentrations from the auxiliary building and containment purging.

In response to the NYS Department of Environmental Conservation's comment - Item 32 - on the schedule and performance of the modified liquid radioactive waste system, the applicant is committed to complete the modification of this system before the end of the first fuel cycle, in its testimony before the ASLB Board on July 13, 1971. The schedule is the same for both the liquid and gaseous waste systems. The staff's evaluation of the modified system indicates its performance will be in accordance with 10 CFR 50.36a. Besides information on the source term for Unit No. 2, releases of radioactivity in the liquid and gaseous effluents from Unit No. 1 for calendar year 1971 are shown in Tables III-8 and III-10 (see Item 33 of the NYS DEC comments).

The Department of Commerce has expressed concern regarding the gaseous releases from the four large decay tanks which are filled one at a time and which have a capacity to permit holdup time of at least 45 days. As stated above, the applicant shall be required, according to the Commission's regulation 10 CFR 50.36a, to maintain and utilize the radioactive waste equipment to control the releases of gaseous effluents as defined by the Technical Specifications. The radiation doses were calculated using the annual average diffusion model, which applies for average dispersion conditions. It is possible for the applicant to wait for the meteorological conditions favorable for the best possible dispersion of the gases, thereby reducing the man-rem cumulative doses to the population.

Because of the modified radioactive waste system and in response to EPA's comments on dose assessment of radioactive releases from both the present and the modified system, the radiological doses to biota and man have been recalculated and reevaluated. This revised information is provided in Sections V.D and V.E.

The NYS Department of Environmental Conservation, in its comments in Item 45 on page 22, referred to radiation doses of 5 mrem/year and radioactivity releases of 5 Ci/year or 20 pCi/liter limit for as low as practicable limits. Page VII-8 of the Draft Statement is not referred to on page V-64. Table V-9 referred to is concerned with total body dose (in millirem) and the cumulative population dose (in man-rem) as related to the radial distance from the reactor.

In its comments on radiation doses, the EPA stated:

(a) "A limited number of measurements...direct radiation... condensate storage tank...location of tanks...nearest residence and the visitors' information center...estimates of the population radiation dose should be made." The staff estimates of dose to individuals at the proposed visitors' center and nearest residence for direct radiation from the condensate storage tank located approximately 15 meters NE of Indian Point Unit No. 2 are given in Table V-8 of the Final Statement.

(b) "The dose computed from release of liquid effluents assumes a dilution flow from the cooling system of approximately 10^6 gal/min...the statement should discuss the effect of reduced flow on the doses involved both on individual and man-rem bases." The reduction of cooling water flow will occur as a result of the installation of cooling towers or during the winter time. Before this installation is accomplished, the steam generator blowdown purification system should be installed, which will reduce the radioactivity released in liquid effluents by a factor of about 10. Although the estimated concentrations of radionuclides in the discharge canal would be higher due to a decreased flow of cooling water, the concentrations as finally dispersed and diluted in the river would be those used in the Final Statement. Fish caught in the discharge canal would undoubtedly have higher concentrations of radionuclides than those caught across the river from Indian Point. However, the number of fish caught here should be quite small. Furthermore, the estimated doses from such fish would be less than a factor of 10 higher than those values given in the Final Statement since it is unlikely that fish would spend their entire life in the canal and be in equilibrium with the radionuclide concentrations found there. The estimated population dose would change only by the added amount of the few individuals eating fish caught in or near the discharge canal.

(c) "The dose estimates for the ingestion of fish as presented in the statement are not consistent with the liquid effluent discharge estimates given. It appears that effluents due to the discharge of steam generator blowdown, assuming primary to secondary leakages, have been neglected in computing this injection dose. The final statement should discuss the assumptions for liquid effluent levels and concentration factors used to calculate the dose due to ingestion of fish." Inconsistencies in the use of cooling water flow rates, Hudson River dilution factors, and bioaccumulation factors have been eliminated in the Final Statement. The dose estimates for fish ingestion were calculated using the quantities of radioactivity discharged in the liquid effluent as given in Tables III-6, 7, and 8 of the Final Statement. These radionuclides were assumed to be dispersed in an average cooling water flow of 2 x 10^{15} cc/year and further diluted by a factor of 10 in the tidal mixing zone of Indian Point. Fish caught in the vicinity of the effluent discharge might have higher radionuclide concentrations than estimated with the above assumptions. However, the concentrations would be less than a factor of 10 greater since it is unlikely that the fish would spend their whole life at such a location. The bioaccumulation factors used in the estimates of dose appear in Table V-2.

In response to the Department of Commerce's comment on the meteorological data used to estimate the radiation doses from gaseous effluents, these assumptions and data were taken from applicant's Supplement No. 1 to the Environmental Report as given in Tables 3.1 and 3.2 of Appendix D in Vol. I. Appendices C, E, and G were also used in the meteorological data for the site. The applicant has also provided information on the annual average meteorological model used in the calculations in the FFDSAR in answer to Question 11.1. Corrections to the listing of references have been made in the Final Statement. In response to EPA's comment on meteorology, the study of meteorological conditions reported in its Appendix G for November 1969 through October 1970 in Supplement No. 1 to the Environmental Report indicates no substantial change from conditions of the mid-1950's reported earlier. In both cases conservative models have been used to predict the radiation doses.

In response to comments from the Committee to End Radiological Hazards, the allowable concentrations of radionuclides in air and water released from controlled areas into the public domain as specified in the Commission's regulations in 10 CFR 20, Appendix B, Table II, were chosen to conform to the recommendations of the Federal Radiation Council, the National Commission on Radiological Protection, and the International Commission on Radiation Protection. These scientific bodies agree that no detectable effects on man are expected to result from exposure to radionuclides at the specified concentrations of 10 CFR 20. In addition, the estimated doses are less than the guides of proposed Appendix I of 10 CFR 50 which requires releases to be in conformity with the principle of as low as practicable.

The doses which result from the radionuclide releases were determined by methods accepted by a consensus of informed and responsible scientific workers in health physics. The source materials and methods used are listed in the references of Chapter IV in the Final Statement.

In regard to the environmental radioactivity monitoring program, the Department of Commerce has expressed concern about the frequency of sample collections and the analysis of benthic animals. The sample frequency and types of samples to be collected are discussed in the applicant's Supplement No. 1 to the Environmental Report and the Technical Specifications. This includes sampling of bottom sediments. The benthic organisms - which include barnacles, clams, polychaete worms and amphipods, and fish species - will be analyzed for their radioactivity content. The sampling requirements will be spelled out in the Technical Specifications.

E. ACCIDENTAL RELEASES OF RADIOACTIVITY TO THE ENVIRONMENT

In regard to the question of accidental release of radioactivity from the Department of the Interior (DOI) on page 6 of its comments, radioactive liquid wastes in the Indian Point Power Station are contained within Class I structures. Failure of equipment within these structures would not lead to a release of radioactive liquid to the environment. The quantity of low-level liquid radioactive materials outside Class I structures is very small and release of this material would not affect substantially the environmental impact determined for routine operation of the Plant. The doses calculated as consequences of the postulated accidents in Table VI-1 are based on airborne transport of radioactive materials resulting in both a direct and an inhalation dose. Our evaluation of the accident doses assumes that the applicant's environmental monitoring program and appropriate additional monitoring (which could be initiated subsequent to an incident detected by in-Plant monitoring) would detect the presence of radioactivity in the environment in sufficient time for remedial action to be taken if necessary to limit exposure from other potential pathways to man. The small quantities of dispersed radioactive material which might enter the food chain would not be significant in terms of endangering aquatic life.

In regard to the comments by the DOI on Class 9 accidents, the current AEC position is as stated in Section VI.A; namely in view of the low probability of the accident, the environmental risk is extremely small.

A comment was made by the Department of Commerce that the rationale for the meteorological assumptions used in Section VI.A on accidents should be given. The meteorological conditions assumed in the analysis by the staff approximate the dispersion conditions which would prevail at least 50% of the time.

By reducing the probability of occurrence of a particular accident through proper quality assurance, equipment, structures, engineered safeguards, and correct operational procedures, the environmental risk becomes very low for any of the class of accidents considered.

In response to the comments by the Citizens Committee for the Protection of the Environment on radiological risks from accidents, the staff has evaluated the safety aspects of the Indian Point Unit No. 2 as presented in its Safety Evaluation and Supplements, which show that the health and safety of the public will be protected at all times during Plant operation.

F. ACCIDENTAL RELEASE OF RADIOACTIVE WASTES TO THE ENVIRONMENT DURING TRANSPORT OF RADIOACTIVE MATERIALS

Details concerning the procedures to be used when a spilled shipment occurs are presented in the Commission's regulations 10 CFR 71 and in the Department of Transportation's regulations in 49 CFR 170-179. The carrier of the radioactive material will be responsible for handling any accidental spillage of radioactive material. The staff believes the low probability of any radioactive contents being spilled does not justify developing detailed procedures for the wide range of potential conditions that might arise in case of leakage. The staff considers it adequate to provide the general procedures for dealing with spills as set forth in DOT's regulations (49 CFR §§ 171.15, 174.566, 174.588, 175.655 and 177.861). Chapter VI gives further details on safety practices to avoid accidents.

In its comments on the need for additional evaluation of the environmental risk from transportation accidents, EPA noted that the AEC is making a thorough analysis of the probabilities and consequences of such accidents. The staff is making a general analysis of the environmental effects of transportation. A report on this subject is nearing completion and is expected to be issued soon.

G. HUDSON RIVER POLICY AND TECHNICAL COMMITTEE

The Department of Commerce (DOC) offered comments regarding the function of the Hudson River Policy and Technical Committee which required clarification. Where reference has been made to this committee in Chapter I to XI of this Statement, the DOC's comments, regarding the role of this committee, have been taken into account. This committee usually coordinates and provides technical advice to the applicant in conducting its ecological studies of the Hudson River and planning for fish protection methods and different environmental monitoring programs.

The applicant has responded in a letter of August 1, 1972, that "because of problems of contract management and administration and manpower limitations, the Hudson River Policy Committee will, with respect to the Indian Point studies, assume the role of a Study Steering Committee. The Steering Committee, where necessary or desirable, submits recommendations for changes to Consolidated Edison. Consolidated Edison, as contract administrator, will order the changes to be made. The Steering Committee would also review, comment upon, and make recommendations concerning periodic progress reports and preliminary and final findings and recommendations. The Committee will maintain, at no expense to it, a full-time representative on-site whose authority to act for the Committee will be determined by the Committee."

H. PERMITS ISSUED TO THE APPLICANT

The New York State Department of Conservation outlines in Item 10, page 5 of its comments, the dates upon which permits to build, redesign, and modify the discharge structure had been made. See Section I.B for incorporation of dates of issuance of the permits for the discharge structure. On May 19, 1970, a construction permit to change from a surface discharge to submerged discharge structure for the discharge of effluents from Unit No. 1 was granted the applicant. A modified construction permit on December 10, 1970, permitted construction of the multiport submerged discharge structure at an 18-foot depth. Only after the applicant provided evidence on the sufficient ecological and temperature effects of the proposed discharges from Units Nos. 1 and 2 was the concern of the NYSDEC alleviated. A third modified construction permit was issued on November 4, 1971, to allow a change in the submerged discharge structure from the 18-foot depth to 12-foot depth and to allow a change in the design of the adjustable gates. The applicant has completed the construction modifications and flow control gates of the discharge structure. The NYSDEC has inspected the construction to verify that the modifications are complete and in compliance with the construction permit and has to issue an operating license to allow discharges from Unit No. 2

I. GENERAL COMMENTS ON ECOLOGICAL CONSIDERATIONS

The staff has analyzed agency and applicant comments with considerable interest, finding many to be quite helpful in formulating the entrainment analysis as now presented in Appendix V-2 of the Final Statement. Many of the comments provided valid and therefore useful criticism that aided the staff's identification of those aspects of the entrainment concept which needed to be explained in greater detail. In summary, the staff analysis presented in the Draft Statement has been strengthened and expanded in this Final Statement, and the conclusions regarding severity of effects have been substantiated.

In its comments on the staff conclusions, the applicant expressed concern that the "Statement was written on the basis that the Statement should maximize estimates of environmental damage and minimize estimates of lack of such damage," and as a result of this approach that the Statement describes "a speculative maximum damage rather than an impartial objective assessment." The applicant lists as specific examples the entrainment analysis, the impingement analysis, and the concern expressed about dissolved oxygen and chlorine releases. These subjects are discussed in more detail elsewhere but deserve some comment here.

The ultimate goal of an environmental assessment is to provide a foundation for an objective cost-benefit analysis. To fulfill this end, the staff sought to identify, through analysis of the applicant's Environmental Report and Supplements and other information in the open literature, the areas where Plant operation could possibly significantly benefit or damage the environment. The factors associated with Plant activity which appeared most important were the studies and their analyses presented in the Draft Statement. The "impartial objective analysis" referred to in the applicant's comments requires that due consideration be given to the various alternatives before any conclusions can be reached. As a result, no discussion is given on the many factors that can be eliminated as having no importance or relevance to the particular site. However, factors that may result in environmental degradation, and therefore cannot be eliminated, are discussed with great emphasis and in great detail. Thus, in cases where the staff analysis indicates that the potential for causing significant environmental impact is relatively large, most of the detailed technical analysis will deal with negative aspects of the Plant.

The applicant's assertion that the staff analysis of the effects of Plant operation has been carried out in such a manner that the conclusions are the "speculative maximum damage" which might occur is not accurate. The applicant is referred to the discussion of probable biological effects in the Final Statement and to the revised discussion of entrainment. The staff is acutely aware of the importance of its conclusions and expects that many points would be modified with additional information.

1. Comments on Entrainment

Most of the comments about entrainment calculations for passive organisms are covered in the revised Appendix V-2. The applicant has devoted a great deal of time and effort to justify its model for calculating Q_u (upper layer flow) and to discredit Ketchum's model for calculating Q_D (dilution flow). In the staff's opinion the issue is not how precise each model is but which one should be used for the purpose of entrainment calculations. The staff agrees that the use of the term dilution flow created some confusion. As emphasized in the revised Appendix V-2, the important flow for the purpose of entrainment is the net downstream transport flow rate of aquatic organisms toward the ocean. The applicant, on page 24 of its comments of May 30, 1972 in Appendix E, says that "this relationship is given by Equation (4), in which Q_u, the upper layer flow, is the estuary dilution flow." The staff retains its previous conclusion, fully explained in the revised Appendix V-2, that the upper layer flow (Q_u) does not describe the net downstream transport flow.

It is interesting to note that although the applicant's discussion gives a negative impression of Ketchum's approach, the critique is inconsistent, and in fact the applicant agrees with Ketchum's equation in the second paragraph of page 11 of its comments.

Two points need to be made about the citations which were presented to refute the Ketchum approach. The citations relating to Pritchard's works are from papers written 15 to 20 years ago. They fail to mention, however, that Pritchard's later analyses are not in conflict with Ketchum's method of computing dilution flow, and that net dilution flow was used by Pritchard to calculate entrainment for the Calvert Cliffs Plant on the Chesapeake Bay. For this Plant, using a compartment model (where Q_u = 207,500 cfs, Q_L = 166,000 cfs, and Q_R = 41,500 cfs), Pritchard estimated the value of net dilution flow to be 90,000 cfs for a salinity of 16.5 ppt, which is approximately the mean salinity for the specified conditions.[1] Thus, Pritchard's later analyses are quite similar to the earlier, less well-defined concepts advanced by Ketchum.

The other two citations are not pertinent to the applicant's objection to the staff analysis. In fact, they could be better used to defend the analysis. In each citation, the negative aspects of the discussions were directed toward the inapplicability of using the physical relationship to predict the ocean water and fresh water contributions to the dilution flow. The reasons for including these citations are not clear inasmuch as the authors who were being quoted used the observed distribution of salinity in conjunction with a dilution flow model equivalent to that of the staff to reject the tidal prism concept.

The last citation on Ketchum's theory on page 15 of the applicant's May 30, 1972, comments in Appendix E is very clearly not related to the staff's model but instead is related to the modified tidal prism concept, although it would appear to the unfamiliar reader to be directly related to the staff model of dilution flow. This is not the case, and its inclusion raises unjustified doubt about the staff analysis.

The staff is in complete agreement with the comment on page 42 of the applicant's comments concerning the dangers of applying simple models to complex systems. The dangers present are principally related to the importance of the time element in any computation related to estuarine dilution. Techniques that can account for this factor must include both lateral and longitudinal components. The effect of the vertical distribution and convective flow for entrainment computations is discussed in the applicant's comments in Appendix E and is quoted in part as follows:

"The probability of capture per pass, recognizing that roughly half of the organisms reach the upper layer during the darkness hours, will be given by $Q_c/2Q_u$. The number of passes is equal to the number of times the organisms introduced into the seaward directed upper layer pass the plant between the time the particle of water in the lower landward directed layer first reaches the plant from below to the time it finally reaches a point above the plant, at which point the seaward return remains above the plant. This is given as follows:

$$\text{Number of passes past the Plant in the upper layer} = \frac{Q_u \cdot T}{Q_L \cdot 2T - Q_u \cdot T} = \frac{Q_u}{2Q_L - Q_u}$$

[where Q_u is the upper layer flow and Q_L is the lower layer flow].

T is the period of darkness and 2T the daylight period. The denominator [$Q_L \cdot 2T - Q_u \cdot T$] is simply the net upstream movement that takes place each 24 hour day."

Thus, the applicant concluded that, "... the model in which diurnal movement and density flow is introduced, applies essentially to larval organisms originating seaward of the plant."

An interesting consequence of this formulation is that the application of the net velocity computed for some situations will be in error because it assumes that storage effects will not be important. Consider, for example, a situation in which a population of fish spawns upstream from its nursery grounds such that the larval fish must migrate downstream to get to the nursery area below. An additional complication is that their vertical diurnal movement pattern tends to keep them in the lower, inland moving zone for sufficient time that the computed rate of transport as shown by the applicant's consultants indicates that net migration is in the upstream direction.

The error in this particular situation is quite simple; the upstream transport of larval fish in the lower layer depends upon downstream larval concentrations while the downstream transport in the upper layer depends upon upstream concentrations of larvae. Because the larval sources are upstream, there is a longitudinal concentration gradient with the highest concentrations in the upstream direction. For the situation where Q_L and Q_u remain constant, a net downstream transport will occur until sufficient larvae have accumulated in the downstream areas to cause the upstream and downstream transport to be equal. The resulting distribution of organisms would depend upon both the mean vertical temporal distribution and the nature of the variance around the mean. An additional factor which will affect the degree of steady state downstream transport is related to behavioral changes which occur as the larvae grow.

2. Comments on Striped Bass

The applicant has apparently misjudged the key elements upon which the staff analysis is based. Two important considerations provide the framework for the staff's analysis, i.e., the life history of the striped bass and the magnitude of the mortality which may result from operation of the Plant (Appendix V-3). The striped bass were determined to be susceptible to the intake for a period of somewhere between 6 and 8 weeks during June and July; during this time, they occupy a zone in the estuary which extends from mile point 10 to 130 with greater abundance of larvae in areas of low salinity within the Plant segment. In the same length of time, the Plant will have circulated more water through the condenser than is contained within the adjacent 11-mile segment - 30% of the portion of the river which harbors over 90% of the larval bass (Appendix V-3). The effectiveness of plankton nets in catching these larvae and the rather uniform larval distribution shown by the collections indicate the susceptibility of these fish to entrainment. Furthermore, the net longitudinal rate of movement of the larvae has been bounded by the data on their occurrence.

a. Mortality from Condenser Passage

Organisms that pass through a power plant may be killed by thermal shock, mechanical abrasion, pressure changes, and/or toxic chemicals released by the Plant. These factors could have either additive, or synergistic effects such that for some types of organisms the probability of surviving passage through the Plant may be very low. This situation is likely to apply to young striped bass entrained at Indian Point, primarily from the combined effects of thermal shock, pressure changes, and direct mechanical damage.

b. Thermal Shock

The evidence which has been examined by the staff does not clearly demonstrate that the temperature effect either will or will not cause the death of all entrained bass. Most of the available information relates to striped bass that are older and presumably more tolerant than those which will be entrained. However, what data are available indicate that exposure of small bass to temperatures above 90°F will result in substantial mortality as indicated by the following excerpts from a report by Chadwick.[2]

> "In each test an average of 18 fish were placed in each [battery] jar. Most jars had 15 to 22 fish/jar, but the range was 3 to 33 fish/jar.
>
> The battery jars were filled with approximately 800 ml of aerated river water at the acclimation temperature, and the bass were placed in the jar. The temperature within the jar was raised to the test temperature within 5 to 9 seconds by adding 800 ml of aerated river water heated to a temperature equal to the acclimation temperature plus twice the temperature difference between the acclimation and the test temperature. The bass were held at the test temperature from 0 (placed in acclimation temperature bath as soon as the warm water was added) to 6 minutes in 2-minute intervals. At the end of the selected interval the jars were placed in a bath at acclimation temperature and held for 48 hours.

> Mixing of the water was accomplished by rapidly pouring the warm water in a circular motion since preliminary tests indicated that mechanical stirring might cause some mortality.
>
> One group of experiments was with fish averaging 7 to 8 mm and ranging from 5 to 13 mm, while the second group averaged 25 to 31 mm with most between 20 mm and the arbitrarily selected 38 mm upper limit. The relationship between mortality and temperature increase is similar for the two groups.
>
> In absolute terms, the most meaningful experiments were those with acclimation temperatures of 60°, 62°, 69° and 70°F. In these experiments little mortality occurred, with few exceptions, irregardless of the temperature increase until the temperature approached 90°F. At that point mortality generally increased sharply.
>
> Some results suggest that mortality increased as the length of exposure to maximum temperature increased from 0 to 6 minutes. The 70F° acclimation temperature experiment provides the clearest evidence of this effect, and survivals at 6 minutes in the 69F° experiment also suggest it."

At normal operation the temperatures in the discharge canal at Indian Point would exceed 90°F beginning about mid June. Thus, the temperature effect alone could result in substantial mortality of entrained bass, particularly in late June and July.

c. Pressure Change

It is quite possible that pressure changes may be a more important factor than temperature. The average depth from which organisms will be withdrawn is at about 14 feet at a total pressure of slightly less than 1.5 atmospheres (1 from the atmosphere itself and 0.43 from the weight of the water column). Upon passage through the condensers these organisms will experience a rapid pressure reduction to about 0.45 atmosphere at the same time that their body temperature is sharply increased by about 15°F.

The rapid drop in pressure and reduced solubility of dissolved gases would favor the formation of gas bubbles (mostly nitrogen) in the fishes tissue just as it does in the surrounding water (see applicant's discussion on dissolved oxygen loss). The formation of such bubbles within tissues of early larvae could result in serious physical damage which would either kill the fish directly or prohibit normal subsequent development.

Similar effects could occur with older larvae but with the added complication of an almost instantaneous three-fold increase in the volume of gas present in the gas bladder (a hydrostatic organ which forms during the second week of larval development). The potential for tissue damage is apparent, and damage to the gas bladder itself on almost certain consequence. In the relation it is noted that Doroshev found that striped bass larvae with an abnormal gas bladder differed markedly from normal individuals "both in appearance and in their greatly reduced vitality."[3]

The combination of temperature shock, the formation of gas bubbles within tissues, and the probability of damage from expansion of gas within the gas bladder will all contribute to mortality of entrained fish larvae. Furthermore, much of the mortality may be delayed from a few hours to several days.

d. Contribution of Hudson River Spawning Areas

The most intensive analysis of the migration of striped bass in and around the Hudson River is based on tagging - recapture data resulting from volunteer tagging by a Long Island, N. Y., sportsman's group during 1959-1963. The tagging and recapture locations were centered around the southern end of Long Island. In an analysis of the data, Clark found that most of the fish recaptured in rivers during the spawning season were in the Hudson, and that the size composition of these Hudson recaptures indicated that most were contributing to the spawning activity.[4] He concluded that the heavy concentration of spring recaptures in the Hudson River suggest that the Hudson is "by far the most important spawning stream for the striped bass tagged during the study." His analysis revealed three regions which seemed most closely dependent upon the Hudson stock for recruitment. The following description of these three contingents are largely taken from Clark's discussion:

(1) Hudson Estuary Contingent:

This group is comprised of striped bass that confine their seasonal movements almost wholly to the Hudson estuary system, wintering and spawning in the Hudson and moving downstream into the bays around the mouth of the river to feed in summer. This contingent was first identified as part of the "Hudson race" by Raney et al.,[5] who concluded that the bass found in these bays in summer spend winter and spring in the Hudson and exhibit a characteristic fall upstream migration into the Hudson. This conclusion is supported by the recapture data of stripers tagged in New York Bay from 1959-63. However, as Clark point out, fish of southern contingents also appear in the Hudson estuary particularly in fall. This fact is demonstrated by recaptures of bass tagged from the lower New Jersey coast and southward.

The eastward limit of the Hudson Estuary Contingent, as deduced from summer returns of fish tagged in New York Bay, was approximately Jones Beach. This apparent limit was also supported by tag returns from southwestern Long Island Sound since all but one of the Hudson River spring recaptures were from fish tagged from Jones Inlet west to Rockaway Inlet. The Long Island shore from the Hudson Narrows to Jones Beach appears to be an area of intermingling of the Hudson Estuary Contingent with other contingents found in this area during summer and fall. Mixing of the various races appears to occur mostly along open beaches, rather than in protected waters such as Jamaica Bay.

(2) Hudson-West Sound Contingent:

This contingent occurs in Long Island Sound from summer to fall and moves into the Hudson River to spend the winter. This group remains there in the spring for spawning and then returns to the Sound in summer, apparently by way of the Harlem River and East River or around Manhattan Island and up the East River to the Sound, but not via an oceanic pathway around Long Island. This pattern has been deduced from the results of summer and fall tagging in the West Sound, which yielded extensive recaptures in the Hudson River in spring.

(3) Hudson-Atlantic Contingent:

There is some evidence of a Hudson contingent consisting of fish that spend winter and summer elsewhere but move into the river in spring for spawning and then depart. This group, tentatively designated the Hudson-Atlantic Contingent, was reported by Merriman[6] and Raney[7] from spring recaptures in the Hudson estuary of fish tagged in North Jersey in the spring (by R. A. Nesbit). Similarly, Clark found that the 1959-63 taggings along the northern New Jersey coast yielded six spring recaptures in New York Bay and two in the Hudson River, adding some support to the credibility of a Hudson-Atlantic Contingent.

Records of striped bass taggings in the Hudson River have been summarized by Alperin.[8] He concluded that these data provided no evidence that the river stock reaches the south shore of Long Island to any appreciable extent, except in the vicinity of New York City.

However, most of the tagged fish were small, with many in their second year. This factor is important because young striped bass tend to be non-migratory. For example, Vladykov and Wallace[9,10] Merriman[6] Raney[7] Mansueti[11] and Massmann and Pacheco[12] have discussed the non-migratory behavior of small striped bass and their tendency to remain in or near restricted river systems. The latter two investigators reported that up to 90% of recaptures were within the river system in which they were tagged. Thus, it is not surprising that none of the 82 returns (16.2%) from the 504 bass tagged in the Hudson during the period from 1940 - 1956 came from beyond New York Harbor and adjacent Jamaica Bay.

This same factor limits the applicability of the data analyzed by Raney et al. which resulted from recaptures of angler-tagged striped bass principally in the 9 - 15" range.[13] These data show that, of the recoveries of bass tagged at the Narrows and in the Upper and Lower New York Bays, about 98% (130 of 133) came from the Hudson and none of the tagged fish which were released within the Hudson were recaptured elsewhere.

The contribution of Hudson stock to the Atlantic coast of Long Island is not completely understood. Two relatively recent and comprehensive studies of the composition and migration of striped bass which frequent this area were reported by Alperin[8] and Schaefer.[14] In both studies, the bass were captured by haul seine and most were tagged and released after appropriate size data and scale samples (used for age determination) were taken. One of the important objectives of each of these studies was to determine the origins of bass occurring on the outer coast of Long Island. Such information is particularly needed to assess the extent of the contribution of the Hudson stock to the commercial and sport fisheries. The size, age, and migration data which resulted from these studies permit evaluation of certain questions related to the annual variations in contributions from the Chesapeake Bay and the Hudson River to populations on the Atlantic coast of Long Island.

To properly demonstrate the origins of the striped bass from tagging data, pre-migratory fish would have to be tagged near the location of their origin. Subsequent recaptures of these fish then could be used to infer origin of fish in the area where they were recaptured.

A second technique which could effectively be employed would be to compare meristic characteristics of the coastal population to the meristic characteristics of the various races of striped bass which can be separated by such characteristics. However, since genetically distinct races of striped bass are associated with spawning areas and a homing tendency can be deduced from tag returns during spawning seasons, it can be inferred that bass within a given population will return to the streams of their origin to spawn. Thus, recapture locations of reproductively active adults during the spawning season are considered to be indicative of the origin of those fish. In contrast, recaptures at other seasons or of non-reproductively active individuals cannot be used to infer origin. With these reservations in mind, tagging data from these two studies can be used to indicate the origins of tagged stripers.

Sampling in the first of these two studies was concentrated in Great South Bay during the period from 1956 to 1961. In discussing the results of this study, Alperin concluded the following:[8]

> "The origins of the striped bass that frequent Great South Bay are not readily discernible 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 per cent) 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 ligher rates of recovery in the Hudson River resulted from the small samples tagged in 1956 and 1959. Of the six returns for fish tagged in 1956, all in New York waters, one (16.6 per cent) was taken in the lower Hudson River in 1958. For the fish tagged in 1959, recoveries from the Hudson River in 1958. For the fish tagged in 1959, recoveries from the Hudson River totalled four (18.1 per cent) of the 22 from State waters. Also none of the striped bass tagged in 1959 were recovered south of New Jersey although some did reach New England.
>
> "These data, 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, 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."

Alperin further concluded that, "It is unlikely that the striped bass of Great South Bay, in years of abundance, are of Hudson River origin. Rather they appear to be part of the coastwide migratory population that originates to the southward, either in the Chesapeake or Delaware Bay area. There are no meristic data to support this assumption, but tag returns do not exclude this probability."[8]

In comparing the results of tag returns from striped bass tagged in surf waters with the results obtained by Alperin, Schaefer commented,[14]

> "The result of the tagging conducted in the present study, however, roughly parallel those presented by Alperin for striped bass tagged in Great South Bay between 1956 and 1961. He reported that 16.6 per cent and 18.1 per cent, respectively, of the recoveries for fish tagged during 1956 and 1959 came from the Hudson River, but that only 2.0 per cent of those for fish tagged during 1960 and 1961 came from that location. These observations prompted him to hypothesize that 'the fish marked in 1956 and 1959 were of more local nature and may have originated in the Hudson River, while those bass marked in 1960 and 1961, 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'. Although it may seem contradictory that both Raney et al. and Alperin suggested that striped bass of Hudson River stock seldom go farther east along the south shore of Long Island than Jones Beach, it should be noted that this conclusion is based solely on recovery data from fish tagged in the Hudson River which were mostly speciments of sublegal (less than 16 inches in fork length) size. It has been demonstrated by several investigators that small striped bass, especially those less than 2 years old, are, for the most part, non-migratory. With this in mind, the hypothesis of Alperin concerning the origins of the Great South Bay population seems quite plausible. Applying similar reasoning to the recovery observations of the present study, it is suggested that a rather sizeable portion of the fish tagged at Westhampton Beach between 1954 and 1956, and possibly some of those tagged at Great South Beach between 1961 and 1963, however, most striped bass tagged between 1961 and 1963 at Great South Beach were probably of Chesapeake Bay or Delaware Bay stock."

"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. It should further be noted that from the best information available, the annual production in Chesapeake Bay is primarily governed by environmental conditions over which man has little control. Indeed, Mansueti and Hollis[15] concluded that 'under most conditions, the effects of environment determine the success or failure of a hatch, and man's fishing at the present intensity seems to have little effect on the long-range production of striped bass in Chesapeake Bay.'"

Assuming that winter recaptures near important spawning areas indicate that the recaptured fish would have spawned in that area, analysis of data which Alperin presented indicated a relatively important contribution of the Hudson to the populations of striped bass in Great South Bay. Since the Hudson is apparently the northernmost estuary which supports consistent annual reproduction, the winter and spring recaptures north of the Hudson cannot be used to indicate the origin of the tagged population. Likewise, the summer and fall recapture data can also be eliminated from consideration as providing information related to origin.

When approached from this viewpoint, the recaptures of bass tagged in 1956 and 1959,[8] which could possibly be used to infer the origin of the Great South Bay population, reflects the probably predominance of the Hudson stock during this period. This conclusion agrees with that of Alperin[8] and is necessitated by the fact that 80% (= 4 fish) of the potentially spawning fishes were recaptured in the Hudson. In addition, all of the recaptures in the spawning season came from the Hudson.

Recaptures of bass tagged during 1960 and 1961 can be similarly treated. Winter and spring returns from Chesapeake Bay and its tributaries accounted for seven recaptures, while returns from the Hudson numbered 4 for this same period. When allowances are made for the much more intense winter and spring fishery in the Chesapeake, the Hudson stock again emerges as important for recruitment to Great South Bay.

This conclusion is further supported by the length-frequency distribution of bass tagged in the Bay during Alperin's study.[8] The modal fork length for six out of the seven tagging periods ranged from about 10" to 14". These fish account for about 75% of the bass which were present in Great South Bay during these six study intervals and 62% of all of the bass tagged. Stripers of this size in the spring would apparently just be beginning their third year of life.[11] These bass were already quite abundant during May of 1960[8] and, although they may have migrated from the Chesapeake during March and April of 1960, it seems equally likely that these fish were more local in origin, possibly originating within the Hudson.

During its analysis the staff has examined the evidence presented in the literature which has resulted in the prevailing opinion that the bulk of the striped bass fishery in the Mid-Atlantic and New England States is supported by recruitment from spawning and nursery areas in the Chesapeake Bay area. This hypothesis was originally developed by Merriman[6] to explain the source of the striped bass which contributed to the Connecticut fishery prior to 1938. Although subsequent data does not support his analysis on many points, it is believed by many that the major production of the coastal striped bass is from the

Chesapeake. For example, Raney,[7] Tiller,[16] Mansueti,[11] and Koo[17] have described the occurrence of extensive recruitment to northern areas from Chesapeake Bay spawnings. Thus, it has become a common belief tht the Chesapeake supplies most of the coastal stock along the Middle and North Atlantic coasts. Tagging studies in the Chesapeake Bay area have failed to confirm this belief.

Studies of tagged striped bass recaptured within the Chesapeake Bay drainage basin show that only a very small proportion of the bass less than four years old migrate out of the Bay.[9,10,11,12,15,18,19] This information is in direct conflict with the hypothesis that the Chesapeake produces the migratory stock which populates the Atlantic Coast. The conflict results from the fact that two year old fish composed the largest proportion of the Coastal populations studied by Merriman[6] and Alperin,[8] and were also consistently present in Shaefer's samples.[14] This obvious conflict has been recognized by several investigators but has not been resolved.[17]

Another factor which conflicts with the hypothesis of a Chesapeake origin of the Atlantic migratory stock is related to size. Merriman found that members of dominant year classes were smaller on the average than less abundant year classes, presumably because of crowding effects.[6] However, since most of his data were gathered there has been about a tenfold increase in the Chesapeake population[17] without a significant reduction in growth.[11] Thus, it seems unlikely that the smaller size of the bass in the dominant year classes is related to their density. It is worth noting that the growth rate of the Hudson bass is known to be slower than that exhibited in more southern areas[20,21] and is consistent with Merriman's data.

The hypothesis that the Hudson spawning and nursery areas provide important recruitment to the Mid-Atlantic States is consistent with the available data. Because of size limits, striped bass enter the Mid-Atlantic fishery at four to six years of age. Furthermore, because of the 16" minimum size, the spring landings of striped bass in the Hudson reflect the abundance of adult fish available for spawning. Comparison of Hudson landings with Atlantic landings five years later (these point moving averages) shows the probable importance of the Hudson as the source of the Mid-Atlantic stock (Figure XII-2).

Regression analysis of these data show that 93% of the variation in the three year mean of the Atlantic Landings during the period from 1930 to 1966 can be accounted for by variations in the three year average of the Hudson landings five years earlier (number of pairs = 26; $R = 0.97$;** $R^2 = 0.93$). However, from a biological standpoint the three point moving average would provide the best estimate. A regression analysis based upon pairs of such means would tend to reduce the variability and overestimate the degree of correlation. However, even with the less biologically realistic comparisons which

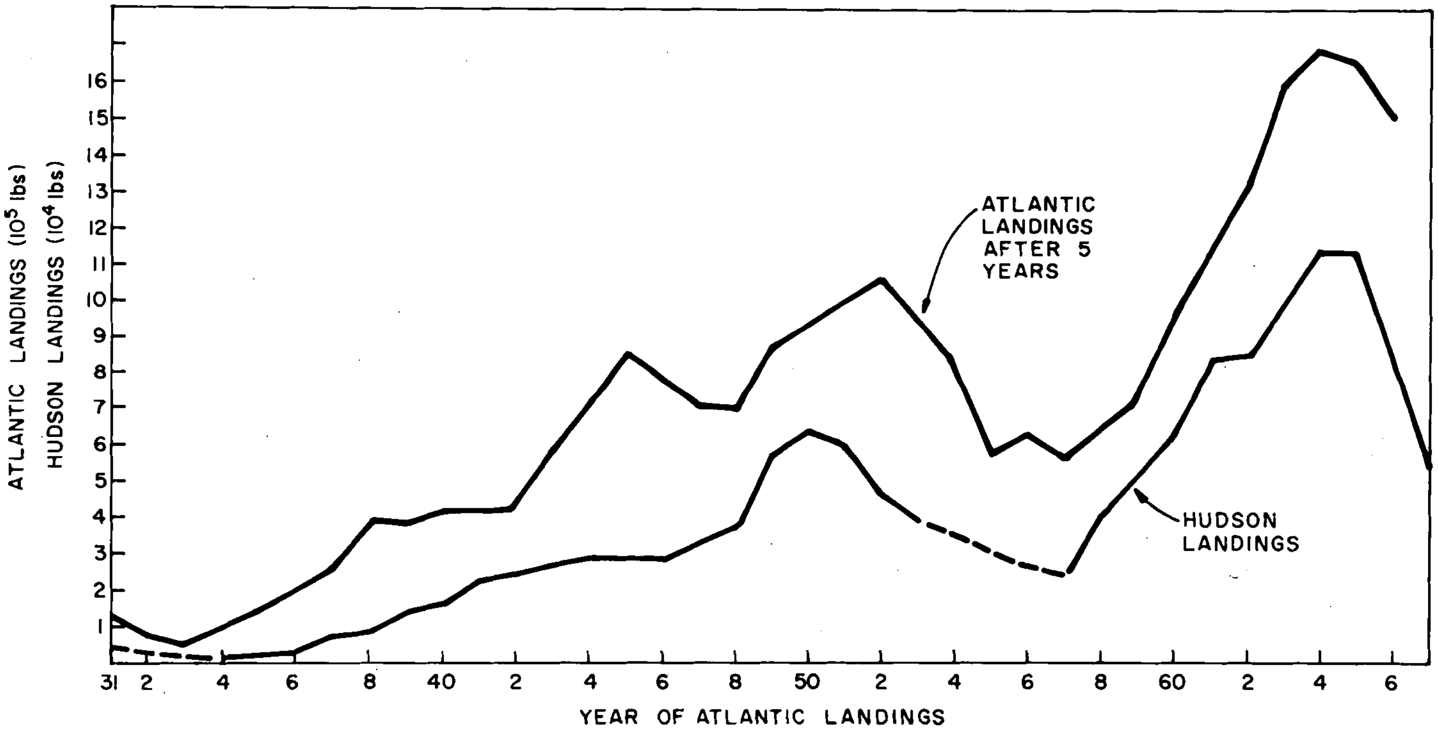

Fig. XII-2. Striped bass landings by commercial fisheries in the Hudson River and the mid-Atlantic region.

were not smoothed, the linear regression is still highly significant (number of pairs = 26; R = 0.89;** R^2 = 0.79).

J. COMMENTS ON DISSOLVED OXYGEN

The applicant's consultants have made an intensive effort to determine the dissolved oxygen (DO) loss in the cooling water system and to use this value to estimate the resultant changes in the ambient DO concentration in the lower Hudson River. Their approach was to compute the loss in DO during condenser passage using one mathematical model and subsequently use these values in another model which would account for longitudinal transport by advection and dispersion and for other factors which affect the DO concentrations in the river.

The model used to predict the DO loss across the condenser system was verified with data collected at Indian Point Unit No. 1 at an ambient temperature of about 44°F and a DO of about 10.5 ppm. There was fairly good agreement between the model output and the data. The methodology was then applied to other conditions of temperature, salinity, and freshwater flow, so that the resulting output could be used to predict the change in concentrations in the river for various operating conditions.

The measured decrease in DO during transit through Unit No. 1 was about 2% (range: 0 to 2.8%). Although these values are statistically significant, they are biologically unimportant (i.e., they are normal ambient levels). All the computed values for the in-Plant loss were of the same order, with the greatest fractional in-Plant reduction about 4%.

This study represents a significant effort to provide the staff with meaningful data with which to evaluate the DO problem. Unfortunately, a few problems limit the applicability of the present effort. There is an exponential relationship between temperature increases and increases in oxygen consumption in most organisms.

The predicted 3% oxygen loss computed for summer conditions would result from degassing the condenser water; thus its prediction does not include any metabolic components. Likewise, the data were verified at a time characterized by low population levels of many of the important planktonic forms. Thus, their metabolic contribution to the DO reduction was probably not similar to that in the time periods (late summer) when DO problems could be anticipated. In addition, no effort was made to analyze a case where the intake DO was abnormally low (3 to 4 ppm); the potential for an impact in this case is high. No accommodation was made for increased DO production or removal by plankton entrained in the plume. The staff is also uncertain about the applicability of the one-dimensional transport model in view of the arguments made in conjunction with the thermal plume analysis, especially when the water subjected to the DO reduction will be contained within the plume.

These observations make any staff conclusion concerning the relative applicability of the results by the applicant's consultants' unwarranted at this time. In addition, the clear resolution of the magnitude of the oxygen loss which occurs across Unit No. 1 during periods of low ambient DO is not included in the analysis. The point is further strengthened by the prediction that DO losses of 0.4 to 0.47 ppm for winter conditions is not necessarily inconsistent with the 0.5 ppm data that the Raytheon Company reported for similar conditons, although a direct comparison was not made.

The staff's concern that Plant operation during certain periods may result in important reduction in DO is supported by field data gathered near the discharges of the Lovett and Indian Point Unit No. 1 Generating Stations. Temperature and DO data presented in both Appendix E of the Bowline Report and in the NYU 1969-70 Annual Report show occasional 10 to 40% reductions in oxygen concentrations in the vicinity of the thermal discharges. These reductions are probably caused by increased community metabolism rather than by physical processes during condenser passage.

K. TOXIC AGENTS

1. Synergistic Effects

Several comments concerned the possibility of synergistic relationships that could intensify any effects resulting from simultaneous exposure of organisms to several toxic agents. The staff concurs that such synergistic relationships probably do exist between some of the chemicals which will be released during Plant operation.

However, because of the small total amount of chemicals that will be released, such synergism is not likely to be important for most compounds, except perhaps within the discharge canal where any effect would most likely be masked by chlorination and temperature effects.

2. Chlorination

The applicant's comments related to the staff discussion of possible toxic effects of chlorine were given careful consideration. However, the staff has found no reason to alter its opinion on the subject. The discharge concentration of residual chlorine from Unit No. 1 has at times exceeded 0.5 ppm. Furthermore, the decomposition rate of the biologically active forms is not known. As a consequence, it is not possible to predict the concentrations of free or combined residual chlorine which will occur in the plume. Similarly, the use of measured Unit No. 1 discharge concentrations to predict similar levels for combined operation, as the applicant did in its comments, is inappropriate. This conclusion results from the fact that the magnitude of the residual chlorine concentration at the point of discharge depends both on the rate of decomposition and on the retention time in the canal. Since the addition of Unit No. 2 will cause a nearly four-fold reduction in the retention time, the discharge concentration of residual chlorine are likely to be higher than the applicant's estimates during chlorination of Unit No. 2.

The staff agrees with the applicant on the importance of exposure time to the magnitude of any toxic effect. However, even very short exposure times at levels below 1 ppm can result in mortality of sensitive species in life stages such as early developmental stages of larval fish. Unfortunately, laboratory bioassays are not often performed with sensitive organisms because of the difficulty in handling them. As a result, most available toxicity data apply to hardy species and in most instances are not broadly applicable.

An additional point in the applicant's comments on chlorination needs to be briefly mentioned. The mortality of organisms which have been exposed to chlorine may not occur immediately but is, rather, often delayed up to several days. As a result, the data from the bioassay tests conducted for the applicant are very inconclusive insofar as related to predicting ultimate survival of the test organisms at the lower concentrations. Similar arguments apply to observations of chlorine-shocked organisms in the discharge canal.

L. ALTERNATE METHODS TO COOLING THERMAL DISCHARGES

The Department of Interior, the Environmental Protection Agency, the New York State Office of Attorney General, and interested persons have offered several comments stating that an alternate closed-cycle cooling system should be required in place of the once-through cooling system because of the significant impacts of Plant operation on the aquatic biota in the Hudson River. This Final Statement has described in extensive detail the short-term and long-term environmental impacts anticipated during the lifetime of the Plant. The staff assessment points out that during the short-term (up to about 5 years), a sizeable damage to the aquatic biota will occur but it is not expected to be irreversible. During this time, however, the power output of the Plant is essential in meeting the needs of the applicant's customers in the New York metropolitan area, particularly during the summer time, and thus the benefits outweigh the estimated environmental costs, incurred during this short-term period. However, operation of the Plant with the once-through cooling system has the potential for a long-term environmental impact on the aquatic biota inhabiting the Hudson River which would result in permanent damage to and severe reduction in the fish population, particularly striped bass, in the Hudson River, Long Island Sound, the adjacent New Jersey Coast and the New York Bight. As such the environmental impacts as detailed in this Statement over the long-term are considered by the staff to be an unacceptable assault on the Hudson River fishery resource and the environment which would lead to an irreversible loss of productivity of the river.

Although the applicant has made valid attempts to solve the problems of fish damage from operation of Unit No. 1 and has modified the design of the once-through cooling system to avoid ecological problems from operation of Unit No. 2, it does not appear that one can predict that the efforts planned by the applicant promise complete success. Therefore, the biological damage estimated by the staff over the long-term is of sufficient magnitude to justify considering an alternative cooling system design as the best corrective measure for continuing Plant operation. Upon consideration of the welfare of the present generation and protection of the environment for future generations, the staff has concluded that the applicant be granted an operating license to operate the Plant with the once-through cooling system up to January 1, 1978 provided due caution through an affirmative plan-of-action is taken by the applicant to reduce to a practical minimum any damage to the aquatic biota and provided that the New York State water quality standards are met as revealed by the ecological monitoring program during this interim period and thereafter operate the Plant with an alternate closed-cycle cooling system.

The applicant will be required to carry out an evaluation study for the purposes of selecting a particular type of closed-cycle cooling system and submit the study to the Commission by July 1, 1973. The applicant has already carried out a detailed benefit-cost analysis of alternate cooling systems in its Supplement No. 3 to the Environmental Report. The staff in Chapter XI of this Statement has also discussed different cooling systems, pointing out their advantages and disadvantages. The applicant has also mentioned in Item 164 of its May 30, 1972 comments that "brackish water cooling towers are commercially available but there has, as yet, been little operating experience with them." It is expected that the applicant in its evaluation study will determine whether such towers are feasible for Indian Point. It is also expected that the applicant in its evaluation study provide for appropriate measures to minimize the environmental impact of chemical blowdown, noise, fog and mist, and other adverse impacts of the preferred closed-cycle cooling system. The applicant will be required to monitor and conduct study programs as described in Section V.D. to assess the environmental damage before and after installation of the closed-cycle cooling system, and through its plan of action to assure that interim operation of the Plant with the once-through cooling system will be carried out to protect the environment as much as possible.

M. MULTIPLE PLANTS ON THE HUDSON RIVER

The Department of the Interior, Environmental Protection Agency, New York State Department of Environmental Conservation, the Attorney General of New York State, and interested persons have commented that the Commission should assess the cumulative effects of all the power plants on the Hudson River.

The staff has evaluated the environmental impacts of the once-through cooling system of Indian Point Unit No. 2 superimposed upon the cumulative effects of the existing plants on the river, namely, Danskammer, Lovett, and Indian Point Unit No. 1. The impacts of Unit No. 2 were assessed utilizing the fishery data, temperature measurements for thermal modeling, data on biological damage from chemical dischharges, mechanical effects, and other discharges obtained in field studies during operation of the existing plants on the river. Thus, the ambient environment has been taken into account in the staff's assessment of Unit No. 2

From the analysis, the staff has concluded that in view of the potential long-term impact from operation of Indian Point Unit No. 2, the applicant will be required to install an alternative cooling system to decrease the heat input and the amount of water withdrawn from the Hudson River and thereby reduce the incremental effect of Plant operation on the aquatic biota.

The applicant will also be required to conduct a comprehensive monitoring and study program, as outlined in this Statement and to be included in the Technical Specifications, to determine the incremental effects of Plant operation with the once-through cooling system on the environment. During any field studies, it will be almost impossible to distinguish between the effects caused by one plant as against another, particularly when the plants are located within a short distance of each other. During this time, new plants will be put into operation, superimposing their effects on the total environment. Thus the monitoring program and studies to be conducted on the river over a number of years will reflect the cumulative effects of operation of the multiple plants located on the river. These are listed in Table III-1 and are shown in Figure XII-3.

Although this Final Statement includes the incremental effects of operation of Indian Point Units Nos. 1 and 2, other impact statements will be prepared for Units Nos. 1 and 3. The Commission's scope of responsibility and authority is limited to studying the impact of the proposed action before the Commission, namely, the impact of granting a license to the applicant to operate Unit No. 2. As such, the staff agrees with the applicant in its June 27, 1972 comments on pages 7-14 and believes that the incremental effects of operation of Unit No. 2 are of a sufficient magnitude to justify the use of an alternate cooling system for protection of the environment. The Commission has no jurisdiction over the operation of fossil plants on the river and thus has limited its assessment to the incremental impacts of Indian Point Units Nos. 1 and 2.

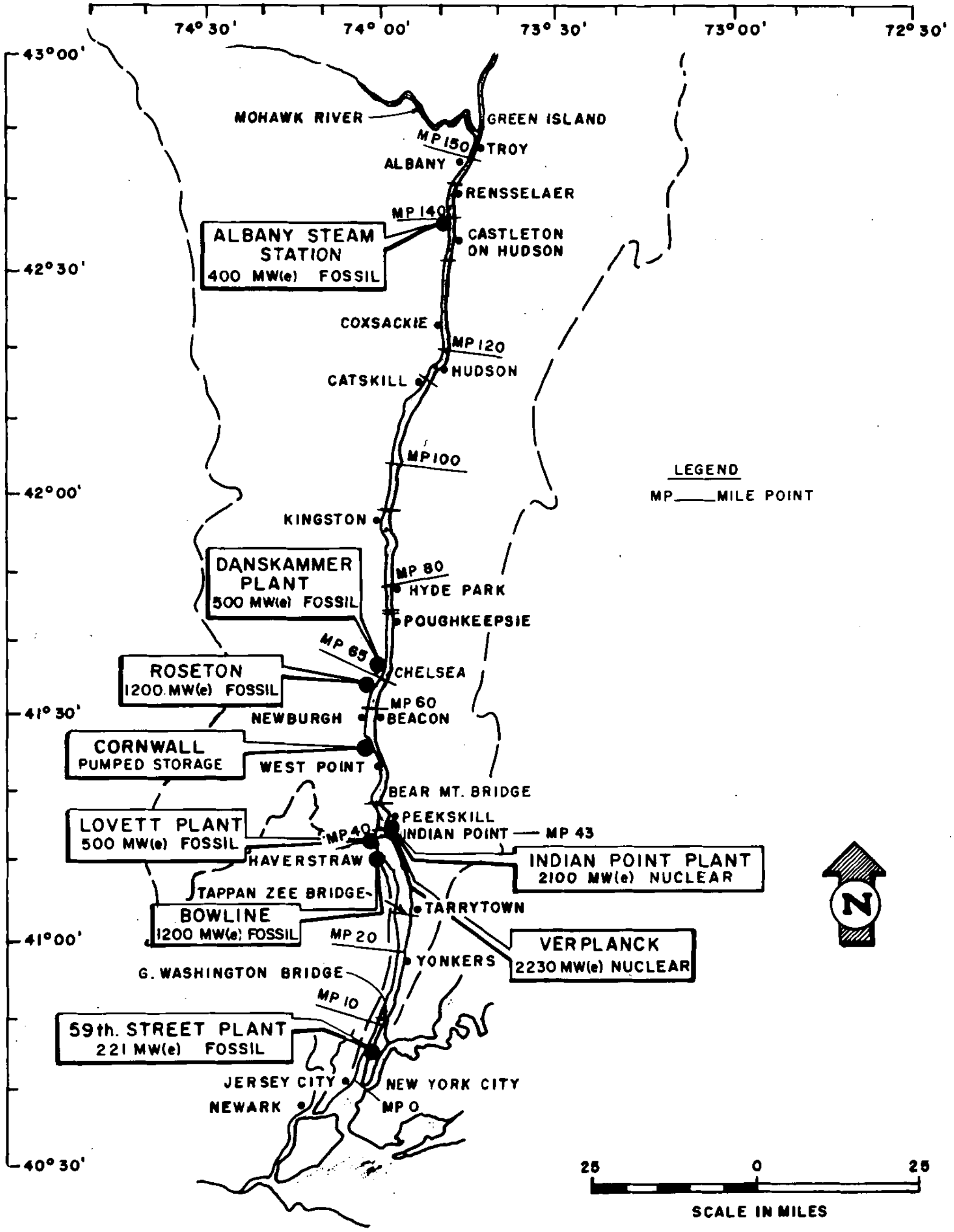

Fig. XII-3
Hudson River Steam Electric Power Generating Stations
(Existing and Planned)
Adapted from Ref. 1

N. LOCATION OF PRINCIPAL CHANGES IN THIS STATEMENT IN RESPONSE TO COMMENTS

(The applicant has made extensive comments on May 30, 1972, which include the following topics)

Contact State Historical Officials (ACHP)	II.D
Historical Significance of Site (NYHT)	V.A.4
Visual Impact of Site (NYHT, SHPC, NYS, DEC)	V.A.4, XI.B.2.
Soil Conservation Through Landscaping (DOA)	IV.B.3
Employment of Local Employees (DOA)	IV.B.2, XI.B.1.i
Nuclear Versus Oil or Gas Fuel (DOA)	XI.A.
Production and Effects of SO_2 and Cl_2 Gases (DOA)	III.E.4 V.C.
Ozone Production (EPA)	III.E.4
Noise Pollution and Controls (DOA)	V.A.3
Ecological Monitoring Program (DOA, DOI, EPA, NYS DEC NYSAG HRFA)	V.D.3 XII.L
Sampling Frequency (DOI)	V.D.3
Consultation with Bureau of Sport Fisheries and Wildlife (DOI)	V.D.3
Hudson River Policy and Technical Committees (DOC, NYSDEC)	VIII.B.2 XII.G
Maximum, Minimum Flow Through Once-Through Condenser (Corp. Eng, NYSDEC)	III.E.1c VII.B.3.b XII.C.1
Section 10 and 13 Permits (Corp. Eng.)	I.B, III.E.1.b

Construction Permits (Corp. Eng., NYSDEC)	I.B, XII.H
Transmission Lines (NYSDEC)	III.C., V.A.6
American Shad as Spawning Fish (DOC)	VII.B.4
Radiological Monitoring Program (DOC)	V.D.3, V.E.5 XII.D.
Meteorological Assumptions for Radioactive Releases (DOC, EPA)	XII.D. XII.E.
Releases of Acids and Bases (EPA)	III.E.3
Sanitary Wastes and Disposal (EPA)	III.E.4
Disposal of Wastes from Fish Kills (EPA, DOI)	III.E.4
Land Use (DOI)	V.A.1
Plant Decommissioning (DOI)	V.G. and VIII.B.1
Recreation (DOI)	V.A.1, XI.B.;
Intake-Discharge Structure Design (NYS DEC)	III.D., III.E.1
Maximum Ambient River Temperature (NYS DEC)	III.E.1.g XII.B
Maximum Surface Temperature (NYS DEC)	III.E.1.g
Jet Interference of Thermal Discharge (NYS DEC)	III.E.1.g
Thermal Discharges and Models (EPA, NYS DEC)	III.E.1 XII.C.
Compliance With Water Quality Standards (EPA, NYS DEC, NYSAG)	III.E.1, III.E.3 XII.C.
Hydraulics and Flow Conditions (NYS DEC)	II.E.1 XII.B.

Initial and Modified Radwaste System (DOC, EPA, NYS DEC)	III.E.2 XII.D
Utilization of Radwaste System (EPA)	XII.D.
Decontamination Factors (EPA)	XII.D.
No Weather Modification from Plume (DOI)	V.B.5
No Hydrological Interaction (DOC)	V.B.
Earthquake Intensity (DOC, NYS DEC)	II.E.3
Tornado Frequency (DOC, NYS DEC)	II.E.4
Radiological Impacts on Man and Biota (EPA, DOC, NYS DEC)	V.D.1, V.E. XII.D.
Direct Radiation Exposure (EPA)	V-E.
Dose from Fish Ingestion (EPA)	V.E.3.b,XII.D
Radioactive Releases from Coal (DOI)	XI.A.1a,
Radiation Protection Standards (CTERH)	XII.D
Plant Accidents (EPA, DOI)	XII.E.
Transportation Accidents (EPA, DOT)	XII.F.
Radiological Safety ICCPE)	VI.A., XII.E
Restricted Operating Levels (EPA, DOT)	XII.F.
Radiological Safety (CCPE)	VI.A., XII.E.
Restricted Operating Levels (EPA, DOT)	III.E. I.S. V.D.1f.
Ecological Impacts on Aquatic Biota (DOI, EPA, NYS DEC, SNPC, HRFA, EDF, Bingham, Dow, Ryan, Ottinger, Burns, NYS AG)	V.D., App. V-1 V-2 V-3
Entrainment and Impingement	V.D.1e, V.D.1f, V.D.2.C. XII.I, App. V-1, V-2, V-3.

Fish Kills and Size Impinged	V.D.1f
Spawning Areas of Fish	V.D App V-1, V-2. V-3.
Thermal Effects (Burns)	V-D.1d, App V-1.
Chlorine and Chemical Effects (EPA, DOI, NYS DEC)	V.D.1.c XII. K.2. App. V-1
Dissolved Oxygen (Burns)	V.D.1.b., appen. V-1 XII.J.
Synergestic Effects of Chemicals (EPA, DOI)	V.D.2.e. XII, K.1)
Short-Term and Long-Term Damage (EPA, DOI, NYS DEC)	V.D., VII.B.5, VIII, IX, XI.C.
Environmental Protection Measures (DOI, EPA, SNPC, Bingham)	V.D.1.f., V.D.3., VII, XI.B.2., XII.L.
Fish Hatchery (SHPC)	XI.A.2.a.
Plan of action to Reduce Damage (NYS AG, HRFA)	XII.L.
Alternatives and Cost-Benefit Analysis (EPA)	XI.
Closed-Cycle Cooling System (EPA, DOI, HRFA, EDF, SHPC, NYSAG, Bingham, Dow, Ryan, Ottinger, Burns)	XI.A.2 XI.B. XII.L
Modified Intake Structure (EPA)	V.D.1.f., XI.B.2.
Taxes and Community Benefits (DOI)	XI.B.1.
Need for Power (FPC, HRFA, EDF, Burns, NYSDEC, NYSAG)	V.III.A., X, XI.B.1
Replacement of Fossil Plants (NYSDEC)	XI.A.1.
Alternate Power Sources (DOI)	X.B., XI.A.1.
Cumulative Effects of Multiple Plants (EPA, DOI, NYSDEC, NYSAG, HRFA, EDF, SHPC, Bingham, Dow, Ryan, Ottinger, Burns)	III.D. VIII.B.2. XII.M.

Compliance with Air Quality Standards (NYSDEC)	III.E.4
Use of Hudson River for Cooling (NYSDEC)	VIII.B.2.
Open-Cycle Cooling System (NYSDEC)	XI.B.

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APPENDIX II-1

AQUATIC ORGANISMS THAT OCCUR IN THE HUDSON RIVER NEAR INDIAN POINT

Table A-II-1. Aquatic plants which have been identified in collections from the Hudson River near Indian Point

- Chrysophyta (yellow-green algae)
  - *Acnanthes*
  - *Asterionella formosa*
  - *Asterionella gracillima*
  - *Asterionella japonica*
  - *Bacillaria paradoxa*
  - *Bacteriastrum*
  - *Campylodiscus*
  - *Cocconeis*
  - *Coscinodiscus denarius*
  - *Coscinodiscus* sp.
  - *Cyclotella glomerata*
  - *Cyclotella kutzingiana*
  - *Cymbella*
  - *Diatoma anceps*
  - *Diploneis*
  - *Ditylium brightwellii*
  - *Eunotia*
  - *Fragilaria capucina*
  - *Fragilaria crotonensis*
  - *Gomphonema*
  - *Melosira ambigua*
  - *Melosira borreri*
  - *Melosira crenulata (italica)*
  - *Melosira granulata*
  - *Melosira italica*
  - *Melosira varians*
  - *Meridion*
  - *Navicula*
  - *Navicula acicularis*
  - *Nitzschia iridula*
  - *Nitzschia longissima*
  - *Nitzschia paradoxa*
  - *Nitzschia sigma*
  - *Nitzschia sigmoidea*
  - *Pinnularia*
  - *Pleurosigma (Gyrosigma)*
  - *Rhizosolenia*
  - *Skeletonema*
  - *Stephanodiscus dubins*
  - *Surirella brightwellii*
  - *Synedra ulva*
  - *Tabellaria*
- Chlorophyta (green algae)
  - *Actinastrum*
  - *Characium*
  - *Cladophora*
  - *Closterium*
  - *Coelastrum*
  - *Eudorina*
  - *Mougeotia*
  - *Oedogonium*
  - *Pediastrum boryanum*
  - *Pediastrum duplex*
  - *Pediastrum simplex*
  - *Phormidium (Sphaerotilus)*
  - *Scenedesmus dimorphus*
  - *Scenedesmus quadricauda*
  - *Spirogyra*
  - *Tetraspora*
  - *Thallassiothrix longissima*
  - *Thallassiothrix nitzschiodes*
  - *Ulothrix*
- Cyanophyta (blue-green algae)
  - *Anabaena*
  - *Aphanizomenon*
  - *Chaetoceros*
  - *Gomphosphaeria*
  - *Lyngbya*
  - *Microcystis*
  - *Microspora*
  - *Oscillatoria tenuis*
  - *Rivularia*
- Vascular plants
  - *Chara* sp.
  - *Eleocharis* sp. (spike rush)
  - *Elodea* sp.
  - *Myriophyllum* sp.
  - *Najas flexilis*
  - *Nitella* sp.
  - *Pontederia cordata* (pickerel weed)
  - *Potomogeton crispus*
  - *Potomogeton pectinatus*
  - *Potomogeton perfoliatus*
  - *Potomogeton* sp.
  - *Spartina* sp.
  - *Trapa natans* (water chestnut)
  - *Vallisneria americana*

Table A-II-2. Aquatic animals which have been identified in the Hudson River near Indian Point

- Protozoa
  - Ciliata
    - *Coleps*
    - *Colpidium*
    - *Colpoda*
    - *Epistylis*
    - *Euplotes*
    - *Frontonia*
    - *Glaucoma*
    - *Hypotricha*
    - *Lionotus*
    - *Oxytricha*
    - *Paramecium*
    - *Prorodon discolor*
    - *Stentor*
    - *Stylonychia*
    - *Tetrahymena*
    - *Tentinnidium*
    - *Urostyla*
    - *Vorticella*
    - *Zoothamnium*
  - Flagellata
    - *Astasiid*
    - *Bodo*
    - *Ceratium hirundinella*
    - *Euglena*
    - *Mastigamoeba* sp.
    - *Ochromonas* sp.
    - *Phacus*
    - *Polytomella* sp.
    - *Synura*
  - Sarcodina
    - *Amoeba proteus*
    - *Arcella* sp.
    - *Cyclidium* sp.
    - *Difflugia* sp.
    - Foraminifera

- Coelenterata
    - *Blackfordia manhattensis*
    - *Campanularia calceolifera*
    - *Cordylophora lacustris*
    - *Gonionemus*
    - *Hydra oligactis*
    - *Nemopsis bachei*
    - *Podocoryne*
    - *Sagartia leucolena*
  - Ctenophora
    - *Mnemiopsis leidyi*

- Platyhelminthes
  - Turbellaria
    - *Planaria*
    - *Planocera* sp.
    - Rhabdocoela
  - Nemertinea (Rhynchocoela)
    - *Amphiporous* sp.
  - Rotifera
    - *Asplanchna*
    - *Brachionus calyciflorus*
    - *Brachionus quadridentata*
    - *Filinia* sp.
    - *Hydratina* sp.
    - *Kellicottia longispina*
    - *Keratella cochlearis*
    - *Keratella quadrata*
    - *Notholca*
    - *Philodina* sp.
    - *Platyias* sp.
    - *Rotoria* sp.
    - *Seison*
    - *Trichocerca* sp.
  - Gastrotricha
  - Nematoda
  - Ectoprocta
    - *Ectoprocta crustulenta*
    - *Hyalinella*
  - Tardigrada

- Annelida
  - Hirudinea
    - *Piscicola punctata*
    - *Piscicola milneri*
  - Oligochaeta
    - *Aeolosoma* sp.
    - *Tubifex tubifex*
  - Polychaeta
    - *Hypaniola grayi*
    - *Nectochaete*
    - *Nereis succinea*
    - *Prionospio* sp.
    - *Spio setosa*
- Mollusca
  - Gastropoda
    - *Amnicola limosa*
    - *Bithinia tentaculata*
    - *Lymnaea*
    - *Physa* sp.
  - Pelecypoda
    - *Congeria leucophaeta* (mussel)
    - *Crassostrea virginica*
    - *Elliptio complana*
    - *Macoma balthica*
    - *Mya arenaria*
    - *Pisidium*
    - *Sphaerium* sp.
- Arthropoda
  - Crustacea
    - Cladocera
      - *Bosmina longirostris*
      - *Daphnia pulex*
      - *Diaphanosoma*
      - *Ephippium* sp.
      - *Leptodora kindti*
      - *Sida crystallina*
    - Copepoda
      - *Acartia discaudata*
      - *Acartia tonsa*
      - *Calanoid* sp.
      - *Canthocamptidae* sp.
      - *Canthocamptus microstaphylinus*
      - *Canuella elongata*
      - *Cyclops bicuspidatus*

Table A-II-2 (continued)

    - *Cyclops vernalis*
    - *Diaptomus ashlandi*
    - *Diaptomus pallidus*
    - *Ectinosoma curticorne*
    - *Epischura* sp.
    - *Eurytemora copepodid V.*
    - *Eurytemora hirundoides*
    - *Eurytemora lacustris*
    - *Harpactocoid* sp.
    - *Laophonte* sp.
    - *Microarthridion littorale*
  - Amphipoda
    - *Corophium volutator*
    - *Gammarus fasciatus*
    - *Leptocherius pinguis*
    - *Monoculoides edwardsi*
    - *Pontocrates norvegicus*
  - Isopoda
    - *Ancinus depressus*
    - *Cyathura carinata*
    - *Cyathura polita*
    - *Edotea montosa*
    - *Edotea triloba*
    - *Livoneca ovalis* (fantail sowbug)
  - Mysidacea
    - *Neomysis americana*
    - *Neomysis mercedis*
  - Ostracoda
    - *Cypris* sp.
  - Decapoda
    - *Callinectes sapidus* (blue crab)
    - *Crangon septemspinosa* (brown crab)
    - *Orconectes limosus*
    - *Palaemonetes intermedius* ("shrimp")
    - *Palaemonetes paludosus* ("shrimp")
    - *Rithropanopeus harrisii* (mud crab)
  - Cirrepedia (barnacles)
    - *Balanus improvisus*
- Insecta
  - Diptera
    - *Pentaneura monalis*
    - *Chaoborus albipes* (larvae)

- Chordata
  - Cyclostomata
    - Petromyzontidae
      - *Petromyzon marinus* (sea lamprey)
  - Osteichthyes
    - Acipenseridae
      - *Acipenser brevirostrum* (shortnose sturgeon)
      - *Acipenser oxyrhynchus* (Atlantic sturgeon)
    - Anguillidae
      - *Anguilla rostrata* (American eel)
    - Atherinidae
      - *Menidia beryllina* (tidewater silverside)
      - *Menidia menidia* (Atlantic silverside)
    - Belonidae
      - *Strongylura marina* (Atlantic needlefish)
    - Carangidae
      - *Caranx hippos* (crevalle jack)
    - Catostomidae
      - *Catostomus commersoni* (white sucker)
    - Centrarchidae
      - *Lepomis auritus* (redbreast sunfish)
      - *Lepomis gibbosus* (pumpkinseed)
      - *Lepomis macrochirus* (bluegill)
      - *Micropterus dolomieu* (smallmouth bass)
      - *Micropterus salmoides* (largemouth bass)
      - *Pomoxis nigromaculatus* (black crappie)
    - Clupeidae
      - *Alosa aestivalis* (blueback herring)
      - *Alosa pseudoharengus* (alewife)
      - *Alosa sapidissima* (American shad)
      - *Brevoortia tyrannus* (Atlantic menhaden)
      - *Dorosoma cepedianum* (gizzard shad)
    - Cyprinidae
      - *Carassius auratus* (goldfish)
      - *Cyprinus carpio* (carp)
      - *Notemigonus crysoleucas* (golden shiner)
      - *Notropis atherinoides* (emerald shiner)
      - *Notropis cornutus* (common shiner)
      - *Notropis hudsonius* (spottail shiner)
      - *Semotilus corporalis* (fallfish)
    - Cyprinodontidae
      - *Fundulus diaphanus* (banded killifish)
      - *Fundulus heteroclitus* (mummichog)
    - Engraulidae
      - *Anchoa mitchilli* (bay anchovy)
    - Esocidae
      - *Esox niger* (chain pickerel)
      - *Esox vermiculatus* (grass pickerel)
    - Gadidae
      - *Merluccius* (silver hake)
      - *Microgadus tomcod* (Atlantic tomcod)
      - *Urophycis chuss* (squirrel hake)
    - Gasterosteidae
      - *Apeltes quadracus* (fourspine stickleback)
      - *Gasterosteus aculeatus* (threespine stickleback)
    - Ictaluridae
      - *Ictalurus catus* (white catfish)
      - *Ictalurus melas* (black bullhead)
      - *Ictalurus nebulosus* (brown bullhead)
    - Mugilidae
      - *Mugil cephalus* (striped mullet)
      - *Mugil curema* (white mullet)
    - Osmeridae
      - *Osmerus mordax* (rainbow smelt)
    - Percidae
      - *Etheostoma nigrum* (Johnny darter)
      - *Etheostoma olmstedi* (tessellated darter)
      - *Perca flavescens* (yellow perch)
    - Pleuronectidae
      - *Pseudopleuronectes americanus* (winter flounder)
    - Pomatomidae
      - *Pomatomus saltatrix* (bluefish)
    - Salmonidae
      - *Salma trutta* (brown trout)
    - Sciaenidae
      - *Cynoscion regalis* (weakfish)

Table A-II-2 (continued)

- Serranidae
  - *Morone americana* (white perch)
  - *Morone saxatilis* (striped bass)
- Soleidae
  - *Trinectes maculatus* (hogchoker)
- Sparidae
  - *Lagodon rhomboides* (pinfish)
  - *Stenotomus chrysops* (scup)
- Syngnathidae
  - *Syngnathus fuscus* (northern pipefish)

Table A-II-3. List of free-swimming larvae of major forms at Indian Point which are subject to withdrawal with cooling water

- Mollusca
  - veliger larvae (gastropod and pelecypod)
- Crustacea
  - Copepoda
    - nauplii
    - metanauplii
  - Decapoda
    - zooea larvae
    - megalops
  - Cirrepedia (*Balanus* – barnacles)
    - nauplii
    - cypris
- Osteichthyes (fishes)
  - *Anguilla rostrata* (American eel)
  - *Menidia menidia* (Atlantic silverside)
  - *Alosa aestivalis* (blueback herring)
  - *Alosa pseudoharengus* (alewife)
  - *Anchoa mitchilli* (bay anchovy)
  - *Microgadus tomcod* (Atlantic tomcod)
  - *Osmerus mordax* (rainbow smelt)
  - *Morone americanus* (white perch)
  - *Morone saxatilis* (striped bass)

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APPENDIX II-2

LIFE HISTORY INFORMATION OF IMPORTANT FISH SPECIES IN THE HUDSON RIVER NEAR INDIAN POINT

From an ecological standpoint the most important fish species that occur near Indian Point are the estuarine and marine forms which migrate through the area to spawn and those which require the estuarine environment for a nursery area. Fresh water and marine fishes which occur in the area from time to time through random wandering are less important to the area and will not be discussed in detail.

Shortnose Sturgeon *(Acipenser brevirostris)*

This, the smallest species of sturgeon, is classified as an endangered species.[1] Apparently it never grows to more than about 3 feet.

The early life history is unknown. Few small specimens have been recorded; probably the smallest fish is one of 7.3 inches (about 185 mm), from North Carolina. The smallest specimens taken in the Hudson River were two females; both a little less than 18 inches; one weighed 15 ounces and the other 19 ounces. The sizes of five specimens from the Delaware River observed by Ryder ranged between 18 and 23 inches. Age determinations based on otolith readings[2] have shown that *A. brevirostris* is a very slow-growing species. Specimens of *brevirostris* from the Hudson River that measured 17 to 35 inches (about 430 to 890 mm), total length, were 4 to 15 years old.

Males may mature when they are only about 20 inches total length, and most of them do so by the time they pass 21 inches; most of the females mature at about 24 inches. The ripe eggs are dark brown. The number of eggs is not known. Spawning takes place in rivers early in the spring. For Hudson River fish, the spawning season evidently includes late April.

On account of its small size, *A. Brevirostris* has attracted little attention except when taken in nets in fresh, brackish, or salt water. It is found most often in tidal rivers. But the capture of specimens in the Gulf of Maine shows that some uncertainly go out into the open sea and wander for some distance from the parent stream.

Studies of stomach contents from Hudson River specimens showed that *A. brevirostris* feeds upon the bottom, eating small animals and plants intermingled with mud. The organisms consumed were sludgeworms, chironomid larvae, small crustaceans, etc.[3] Judging from the stomach contents of fish taken from the area between Rhinebach and Nyack, they seem to feed mostly on the bottom at a depth of 12 to 30 feet.[4] Snails, clams, crustaceans, and other bottom organisms are the main diet.

The breeding range of *A. brevirostris* is not clearly defined, but it is known to include the Hudson River, where the spawning areas appear to be very restricted.[2] The Delaware River may still maintain a small local population, and it seems likely that the Saint John River, in New Brunswick, has a spawning population, judging by the near-spawning condition of a male and female taken at Gagetown. If, through increased pollution or habitat changes, the population is no longer able to persist in these northern rivers; the species may become dangerously reduced.[2]

Atlantic Sturgeon (*Acipenser oxyrhynchus*)

The Atlantic sturgeon is an anadromous fish distributed on the Atlantic coast from the Saint Lawrence River, Canada, to northern Florida. This sturgeon is found in both fresh and brackish waters of the Hudson. Adults enter the river in spring to deposit their eggs in fresh or brackish water, possibly preferring brackish.[5] They then spend the remainder of the summer in the river before returning to the sea in the fall.

Sturgeon are bottom feeders and are usually found over sand or mud. Their diet consists mainly of worms, insect larvae, crustaceans, molluscs, and small fish.[6]

Female Atlantic sturgeons produce from 1 to 2-1/2 million eggs for each year's spawning. The eggs are heavy and strongly adhesive, sticking to each other and to the river bed, where they lie in large masses.[2,6] The eggs, 2.5 mm in diameter, hatch in about 6 days. At hatching, the larvae are about 11 mm long, but they gain a length of about 4 inches (10 cm) in a month's time.[2,6] Sturgeon young live on their yolk sac until about 20 mm long, then begin to feed on planktonic crustaceans. At a length of about 9 inches (23 cm) they become bottom feeders, rooting in the sand or mud with their snouts for amphipod and isopod crustaceans.[6]

Their juvenile distribution is not well known, because unlike striped bass and other species, the young are not taken by seines along the river's edge. Young sturgeon may remain in rivers until they reach 30 to 36 inches (76 to 91 cm) in length.[5] In March of 1968, 500 Atlantic sturgeon were captured in Haverstraw Bay with the 40-foot otter trawl. Of these, a sample of 71 fish ranged from 10 to 34 inches (26 to 87 cm).[3]

The Atlantic sturgeon is an anadromous species, invariably spawning in fresh or brackish water but making its growth in salt water. The adults migrate from the sea to fresh water in advance of the spawning season. The spawning migration begins at the end of April and in May in the Hudson River.

The eggs when laid are light to dark brown. The outside membrane of ripe eggs readily imbibes water and becomes attached to weeds, stones, and so forth, and it is believed that the eggs are scattered over a wide area. There is no evidence of prenatal care, such as preparation of a nest area.[2,5]

Sturgeon are bottom fish and are seldom seen except when taken in nets or when jumping. It is of interest that this relatively sluggish species is capable of making powerful jumps.[2]

Very little appears to be known about the behavior of the sturgeon in salt water. These fish can adapt to a sudden change from salt to fresh water, or vice versa. Some tagged specimens were forced to abruptly change salinity habitats at least twice during the same season, apparently without harmful results, because they were recaptured again alive.[2]

The large sturgeon feeds on molluscs and other bottom organisms. The fish roots in the sand or mud with its snout, as it noses up the worms and molluscs on which it feeds and which it sucks into its mouth with considerable amounts of mud.[2,6] The sturgeon also eats small fishes, particularly launce (*Ammodytes*).[2] The mature sturgeon, like the salmon, eats little or nothing while it travels up the river to spawn.

The digestive tracts of 26 young *A. oxyrhynchus* weighing 1 to 7 pounds from the Hudson River contained bottom mud along with plant and animal matter, including sludgeworms (*Limnodrilus*), chironomid larvae, isopods, amphipods, and small bivalve molluscs (*Pisidium*).[2]

The food of *A. Oxyrhynchus* varies with the type of habitat, as in the Saint Lawrence River, Quebec. Polychaete worms (*Nereis virens*) were found (265 on the average; the maximum number in a single stomach was 1,221) in 27 half-grown sturgeon taken in salt water. In addition, the sturgeon fed on marine gastropods, shrimps (*Crago*), amphipods, and isopods, in that order. In fresh water, the bulk of the food consisted of aquatic insects, amphipods, and oligochaete worms; in 88% of 178 sturgeon examined, larvae of the burrowing mayfly (*Hexagenia*) were present.[2]

Bluefish (*Pomatomus saltatrix*)

The bluefish occurs on the Atlantic coast seasonally from the Florida Keys to southern New England.[3] Throughout this range, it is particularly abundant in southern Florida, in North Carolina and Virginia, and from New Jersey to southern Massachusetts.

In the north, bluefish spawn in July and August between the 15-fathom (27-m) isobath and the edge of the shelf from northern North Carolina to Long Island.

After spawning, young bluefish lead a pelagic life for one month or longer, depending on the distance they must travel to the coast from the spawning areas and upon water temperature and other unknown environmental variables. In the New York area, the young arrive in two waves. The first reaches the coast from late June to early July, when most juveniles range from 3 to 5 inches (7.5 to 12.5 cm) in length. These juveniles are probably recruits from the spring spawning south of Cape Hatteras, having been carried north by the Gulf Stream system. The second wave, which reaches Middle Atlantic coasts in mid-August, when the young range from 1 to 4 inches (3 to 10 cm), are probably recruits from the northern spawnings in summer. Those of the first wave change from a diet largely of planktonic forms (crustaceans and fish eggs) to one of small fish when they are 2.4 to 3.5 inches (6 to 9 cm) long. This is about the time they become abundant along the coast and move into the Hudson estuary. They grow very fast during the course of their first summer, those of the first wave reaching around 10 inches or more before the end of the summer. They leave the estuaries in the early part of autumn and disappear into the sea for winter. According to Greeley,[7] bluefish were moderately common in the Hudson in August and September in 1937, with considerable numbers of young fish inhabiting the lower areas of the river. However, recent surveys have not indicated so great an abundance in the area.

Menhaden *(Brevoortia tyrannus)*

The menhaden is a very abundant and economically important oceanic member of the herring family.[3] Its range extends from Nova Scotia to Florida. Adults undertake extensive migrations, moving northward along the coast in spring and southward in fall. During the summer, they tend to be found in inshore areas, while in winter they move to deeper water. They spawn at sea over a wide geographical range throughout much of the year.[8] The larvae move inshore to enter the estuaries along the coast and usually congregate near the upstream limits of the tidal zone. These areas are rich in plankton organisms such as diatoms and holophytic flagellates which provide the food necessary for the survival of the young. As they increase in size, they tend to move farther downstream, and as fall approaches, they congregate near the mouth of the river before moving out to sea.[8]

In 1936, Greeley reported that young menhaden were common in the Hudson and were numerous at the mouth of the Mamroneck River in mid-July.[7] In recent surveys the menhaden have not been abundant. However, this species may once again become abundant as pollution abatement measures reduce the pollution level of the lower Hudson.[3]

Menhaden feed on small organisms strained from the water by their numerous long, slender, close-set gill rakers, which form an effective strainer. While feeding, the fish generally swim near the surface and often "break water"; they whirl around, sound a short distance, come out of the whirl, and swim up and straight ahead at a considerable speed for a rather short distance. During this time the mouth is wide open and the gill covers are lifted, thus making it possible for a fish to filter a great amount of water with minimum effort. The food that is ingested depends in large measure upon the organisms that are present where the fish is feeding. Even a considerable amount of mud and general debris is often swallowed. Included in the stomach contents examined by various investigators were numerous small crustaceans, especially copepods; small annelid worms; rotifers; and unicellular plants, particularly diatoms and peridinians. The plant organisms, as a rule, constitute the chief food.[9]

Most predatory animals associated with the sea feed on Atlantic menhaden - an easy prey because of their habit of schooling. Their fiercest enemy probably is the bluefish *(Pomatomus)*, which it is said, kills many more than it eats. Among the other fish that feed on them extensively are the cod, pollock, hakes, weakfish, swordfish, tuna, dolphin, amberjacks, and sharks. Whales and porpoises, as well as birds, also devour many of them.[9]

Large commercial fisheries exist for this species. Two products are obtained, oil and fish meal. The fish meal is used for poultry and livestock feed. These fish, though exceedingly valuable, are not used very extensively as food by man, mainly because of their bony nature and oiliness. However, some find the flesh delicious, and many people living along the coast, especially the fishermen, eat them in season as a common article of diet. Considerable quantities are often "corned" (salted) for home use during winter, and they are said to be delicious when smoked. They were canned to a limited extent for export during the last war, and a small quantity is still canned for home consumption.[9]

American Shad (*Alosa sapidissima*)

The American shad is an anadromous fish of the herring family, Clupeidae. Its range includes offshore, coastal, and river waters from Newfoundland to the Saint John's River, Florida. Shad are most abundant from Connecticut south to North Carolina. They spend their adult lives in the ocean, except in spring, when they ascend rivers along the coast to spawn. Hudson fish, like others that spawn in rivers north of the Chesapeake Bay, are said to return to the sea and migrate north to Gulf of Maine waters.[5] In winter they are presumed to remain in the deeper offshore waters of the Middle Atlantic coast, moving inshore again as the spawning season approaches.[10]

Shad begin their spawning run into the Hudson in late March and early April, and the run continues until the end of June. Although much of the river below the Troy Dam is used for spawning, the major breeding area appears to be just below the town of Catskill.[11] The average number of eggs produced by a single fish varies between 25,000 and 30,000, with larger fish producing more eggs than small ones.[12] The eggs are deposited free in the water and sink, to be carried along near the bottom by the current. They were reported[12] to hatch in 52 hours at an average temperature of 57.2°F, and in less than 36 hours at an average of 74°F. However, a longer incubation period has been reported.[12] Eggs held under artificial conditions hatched in 12 to 15 days at 53.6°F (12°C) and in 6 to 8 days at 62.6°F (17°C). The yolk is absorbed in 4 to 5 days at 62.5°F.[12]

Newly hatched larval shad average 0.40 inches in length and are transported by water currents.[12] They were most abundant near river mile 110 during the 1940-1942 surveys (New York State Conservation Department, 1943).

The young, as they grow, tend to disperse from the upstream spawning grounds down into the lower brackish parts of the river. The larvae appear to feed on plankton; the principal diet of juveniles consists of small crustaceans and insect larvae.[13] Those found in the lower estuarine parts of the river are reported to grow faster than those further upstream.[14] In the autumn, the young migrate to the sea to stay until they mature and join the annual spring migrations into the river for spawning.

Working with young specimens from the Shubenacadie River, a tributary to the Bay of Fundy, and its estuary, Leim found that the first food taken by larvae 11 mm long consisted of midge larvae (Chironomidae), while the somewhat larger larvae had fed principally on mature and immature copepods.[15] In fact, these organisms constituted the chief food of the young up to the time of transformation, with the relative abundance of these forms in a particular locality determining which food predominated. These data show also that young adults taken in the same vicinity continued to subsist principally on these same organisms. Other foods ingested consisted of ostracods, insects, and fish.[12]

Little or no food has been found in the stomachs of shad caught while in fresh water en route to their spawning grounds, indicating that these fish, like salmon, do not ordinarily feed then. However, there are some records showing that adults occasionally do take food while in fresh water, at least late during the spawning season. They will often take a live minnow or an artificial fly when working upstream on their spawning run.[12]

From an examination of about 350 stomachs of both mature and immature fish caught in the salt water of Scotsman Bay (Bay of Fundy), Leim found that, while copepods constituted the chief food of the smaller ones, as in fresh water, these crustaceans were unimportant in fish 400 mm and more in length.[15] Mysids, which were sparingly eaten by small fish, were the chief food of adult fish. In general, about 90% of the specimens of all sizes from that area had eaten copepods and mysids, with ostracods, amphipods, isopods, decapod larvae, insects, molluscs, algae, fish eggs, and fish making up the remainder. After examining many stomachs of specimens taken in the Bay of Fundy, Willey also concluded that the chief foods consisted of copepods and mysids, with a few shrimp and larval stages of barnacles.[12] Stomach samples from Hudson River fish support his conclusions.[13]

The shad is still an important contributor to the Hudson River commercial fishery. The catch was 238,000 pounds in 1965 and 245,000 pounds in 1968. The peak catch during the past 50 years was 3,800,000 pounds in 1944. Sport fishing for shad in the Hudson is presently unimportant.[3]

Although there is no sport fishing for shad in the Hudson, more than 100,000 sport fishermen fished for shad in other Atlantic coastal rivers, estuaries, and bays in 1965 and took an estimated 4,700,000 pounds of them. From Maine to North Carolina, commercial fishermen took 6,372,000 pounds of shad in 1965. The part of this catch that depends upon Hudson stock is not certain. However, it is known, from tagging experiments in the river, that Hudson shad migrate as far north as Maine and as far south as North Carolina, and thus contribute to coastal fisheries far from New York.[11] Tagging shad from pound nets on the New Jersey and New York coasts in 1956 indicated that Hudson River stock made up 76% of the catches of these nets; therefore these catches were dependent on the size of the Hudson River shad population.[16]

Bay Anchovy *(Anchoa mitchilli)*

The bay anchovy is a schooling species found in coastal salt and brackish waters, ranging from Mexico to Maine. This species has a long spawning season from late spring to September in the New York area and is a major component of the fish fauna at Indian Point.

A total length of 4 inches (100 mm) is seldom exceeded, with a usual length of about 3 inches (75 mm). The largest specimens have been taken in New York, where this species evidently grows larger than in the southern part of its range.[17]

The anchovy numerically is the most abundant fish caught by trawls within the study area near Indian Point. This species constituted 43% of the bottom trawl and 68% of the surface trawl catches. However, it made up less than a percent of the beach seine populations, occurring only in small numbers in 11 catches from August through October.[18]

The highest concentrations of the anchovy were observed during the months of August through October and were confined primarily to Haverstraw Bay.[18] There appears to be a general dispersal of the anchovy population from lower Haverstraw Bay in July throughout the entire Bay during August. The anchovy was caught in every surface and bottom trawl sample taken in September by Raytheon Co. investigators in 1969.[35] There is an abrupt decrease and general disappearance of the anchovy from the area during November and December. This species occurred at only 3 of the 14 bottom trawl stations sampled during December, and the 3 stations were located in the immediate vicinity of the Indian Point and Lovett Power Plants.[17]

The eggs are buoyant when spawned but gradually become demersal. They hatch in about 24 hours at room temperature.[17] The newly hatched fish, 1.8 to 2.0 mm long, are rather slender, are perfectly transparent, and have no pigment spots. The yolk sacs are absorbed within about two days, and the large mouths, which are terminal at this stage, then seem to be functional. Larvae of this species occur at Indian Point.

Young-of-the-year fish, immatures, and adults are abundant from late spring to early autumn in the lower Hudson River. The early young of the season may become sexually mature during their first summer, for specimens 45 to 60 mm long that remained quite transparent, taken late in July and during the first half of August, contained well-developed roe.[18]

The food apparently consists mostly of *Mysis* and copepods, the latter being the sole food of the young. Other items taken are small fish, gastropods, and isopods.[17]

Eels (*Anguilla rostrata*)

The American eel is a catadromous species found in abundance in the Hudson River. The species occurs from the Gulf of Saint Lawrence as far south as Brazil. The eel spends most of its life in freshwater creeks and ponds, rivers, and estuaries but migrates to the Sargasso Sea southwest of Bermuda to spawn. Newly hatched larvae, with the help of ocean currents, migrate from the ocean spawning grounds to the coastal rivers. The females travel far upstream into freshwater environments, but the males remain in the estuarine environment near the mouth of the river. As a mature adult, several years later, the eel retraces its route back to the oceanic spawning grounds, where it breeds and then dies. As eels migrate upstream in the vicinity of Indian Point, they are relatively common both in the surface and bottom samples but less so at mid depth.[18]

A small commercial fishery for eels is carried on in the Hudson River. The catch was 5,300 pounds in 1965 and only 2,500 pounds in 1968. Sport fishing catches are undoubtedly much higher than this, but no estimates are available for the Hudson.[3]

This species has been found to be a major component of the fish fauna in certain New Jersey streams[19] and may play a similar role for the tributaries of the Hudson.

Tomcod *(Microgadus tomcod)*

This species was previously described in relation to the Hudson by Clark and Smith.[3] The tomcod is a marine species that commonly spawns in the Hudson. It is a member of the family Gadidae, which contains some commercially important species. Tomcod spawn in shallow estuarine waters and around stream mouths. The demersal eggs are about 1.5 mm in diameter, heavy, and adhesive. They hatch in 24 to 30 days, depending on the temperature of the water. Spawning occurs from January through April in brackish water, and larvae are common at Indian Point in early spring. The adults move into the estuary from October to December and return to the lower estuary or the Atlantic after spawning. The juvenile fish spend their first summer in the waters where they were spawned and grow to a length of 2-1/2 to 3 inches by the following autumn.

Tomcod feed on a variety of organisms including small crustaceans, especially shrimp and amphipods, worms, small molluscs, squids, and small fish. They are most commonly found on the bottom.

White Perch (*Morone americana*)

This species is found in fresh, brackish, and coastal salt water between South Carolina and Nova Scotia.[20] Spawning of demersal and adhesive eggs (7.5 mm in diameter) occurs in fresh and brackish water from April to June, depending on geographic location, and at water temperatures between 45° and 60°F.[21] The eggs hatch in about 3 days at 58°F. Young and adults remain in fresh or brackish waters. They frequent shoal areas, except in winter, when they congregate in the deeper parts of bays and rivers, where they remain sluggish until spring. During spring, summer, and autumn, localized wandering occurs.[20] This species feeds on small crustaceans and small fish.[13,20]

The white perch is a major resident species at Indian Point. It is one of the most abundant species in the lower Hudson and is found throughout the year in all life stages at Indian Point.[18]

This species grows to about 15 inches and weighs from 2 to 3 pounds. It is of limited commercial importance but is commonly fished for along the shore at many localities.[18]

American Smelt *(Osmerus mordax)*

American smelt from salt water average 7 to 9 inches long when fully grown, and about 12 to 13 inches at the maximum. They ordinarily run between 1 and 4 ounces, with very large individuals weighing up to 6 ounces. The following discussion has been abstracted from a discussion by Bigelow and Schroeder.[22]

Females weighing no more than 2 ounces may produce as many as 40,000 to 50,000 eggs; one which was 9.12 inches long (taken in Crystal Lake, Michigan) contained 43,125 eggs. The eggs, which range in diameter from 0.6 mm to about 1.2 mm in different waters and according to different authorities, sink to the bottom, where they adhere to each other in clusters or cling to any object upon which they settle. In European waters, the eggs hatch in 8 to 27 days, depending on the temperature of the water. In Massachusetts they have been reported as hatching in 13 days.

The larvae are about 5 to 6 mm long when they hatch and are perfectly transparent at first. Once hatched they rise close to the surface and drift downstream. On the average, they grow to 17 or 18 mm during their first month, 27 to 34 mm during the second month, and about 40 mm after 3-1/2 months. By the time the larvae have grown to 8 mm, the yolk sac is mostly absorbed; at 15 mm all the fins are more or less developed; and by 45 mm the formation of scales has begun.

In their second spring, when 1 year old, the fry average about 3.4 inches long. From scale studies it appears that they average as follows: at 2 years about 5.7 inches and about 0.6 ounces; at 3 years, 6.7 inches and about 1.1 ounces; at 4 years, 8.7 inches and about 2 ounces. The largest measured was about 9 inches. Four or more year classes are often represented in the commercial catches.

The marine fish normally spawn in fresh water, and as a rule they do not travel far upstream; they may go only a few hundred yards above the head of the tide. Others spawn in the tidal zone or even in brackish water behind barrier beaches. They generally spawn on pebbly bottom where there is a current, often in water only a few inches deep. Most often the spawners are 2 years old or older. Spawning takes place in late winter or early spring, depending on the temperature of the water. According to data from hatchery operations, the chief production of eggs takes place in temperatures of 50° to 57°F in Massachusetts and of about 45° to 50°F in Grand River, Quebec, representative of the northern part of their range. The spawning period lasts 10 to 14 days and is completed ordinarily by mid-May. The spent fish - except those that die, as many do - move downstream to brackish or salt water immediately after spawning, so that all of them have left fresh water by the middle of May.

The smelt mature in brackish or salt water if they are not landlocked. During the marine phase of their life they are confined to so narrow a coastal belt that none has ever been reported more than 6 miles or so out from the land and seldom below 2 or 3 fathoms; the deepest record for them is 9 or 10 fathoms at the mouth of Port-au-Port Bay on the west coast of Newfoundland. Many of them spend their entire growth period in estuarine areas, including the tidal reaches of rivers.

Their habitat in the summer along any particular section of the coast appears to depend chiefly on the temperature of the water. From Massachusetts southward, most of them (though not all) desert the harbors and similar situations during the warmest season, moving, it seems, only far enough out and deep enough to find slightly cooler water. Along the coasts of Maine and the Maritime Provinces of Canada, however, where water temperatures are lower, they are found in the harbors, bays, and estuaries all summer.

With the onset of autumn, those that have moved out to sea reenter the harbors and estuaries, so that by mid-October or early November practically the entire population is concentrated there. The smaller ones tend to reappear the earliest, but reports are contradictory in this respect. By December, some have even worked up into stream mouths to the head of tide. But the fish that will breed that season, most of which are 2 years old or older, do not actually enter fresh water until late winter or early spring, when the water off the mouth of the stream has warmed to at least 39° to 42°F (4° to 5.5°C).

The movement of the maturing fish into fresh water commences late in February along the southern coast of New England and southward, sometime in March along northern Massachusetts, seldom until April along the eastern part of the Maine coast, and not until the latter half of May along the southern shores of the Gulf of Saint Lawrence.

This species, though confined to shallow water, is not a bottom fish but tends to hold position at some intermediate level. The small ones, and probably the large ones also, gather and travel in schools that are composed for the most part of fish of about the same size, the product of one year's hatch. In the smaller harbors, they tend to move in and out with the tide, especially if the tidal flow is strong.

This species is carnivorous and predaceous. In salt and brackish water, shrimps (decapod and mysid) probably are their chief support on the Massachusetts coast; similarly, the stomach contents of those in the Gulf of Saint Lawrence have consisted chiefly of copepods, amphipods, and mysids, with algal debris probably taken incidentally. In some localities, small fish rank next. They have been found packed full of young Atlantic herring on the coast of Maine, and a wide variety of fishes has been recorded as occurring in their stomachs at Woods Hole. They also take small shellfish, small squid, annelid worms, and small crabs. But they cease to feed during the spawning season, as many other fishes do.

American smelt have been a favorite subject for artificial propagation. Many million fry were hatched in past years at the Cold Spring Harbor Hatchery, New York, as well as the Palmer Hatchery, Massachusetts. The results have been widely heralded, for great catch increases were reported for streams where fry were released. The most notable example is that 32 million eggs were collected in 1885 from a New York stream where there had been no smelts for at least some years previous. A similar example, though less spectacular, was reported for Massachusetts.

The American smelt is a favorite among the market fish, delicious when fresh-caught or even after being iced properly, and great numbers, especially from the Gulf of Saint Lawrence, are marketed. The average landings reported for the 4-year period 1951-1954 were 5,323,000 pounds for the Canadian Atlantic coast and 150,700 pounds for the United States coast, a total of 5,473,700 pounds; this represents 55 million individuals if these ran, say, 10 to the pound, all marketed for human consumption. Years ago they served as cod bait in the Gulf of Saint Lawrence, and large quantities were used as manure along the Gulf of Saint Lawrence shores of New Brunswick.

Alewife *(Alosa pseudoharengus)*

The alewife is an important forage species found along the coast from Nova Scotia to the Carolinas. During April and May, the fish travel upstream into many tributary creeks and ponds to spawn at temperatures of 50° to 60°F, sometimes in rapidly flowing water but usually in sluggish water, often only a few inches deep. After spawning, the adult fish return to the sea, remaining in the coastal waters in the general vicinity of their natal estuaries.[12]

The average female deposits about 100,000 adhesive eggs in the annual spawning. After the demersal eggs hatch, the young alewives at about 5 mm long are carried along with the current. They grow to about 15 mm in a month's time, when they are common at Indian Point. When they are about 1 to 1-1/2 inches long, they are found in the shallows of the Hudson upper estuary, as well as in the freshwater parts of the river, and apparently feed on small crustaceans and insect larvae.[18] Raytheon data indicate that these fish prefer to remain near the bottom.[30]

Although some of the young may remain in the river for more than a single season, most move out to sea before or at the end of their first season. They remain in salt water until they reach sexual maturity (at about 3 or 4 years old), at which time they return to the rivers to spawn.[12]

Blueback Herring *(Alosa aestivalis)*

The blueback herring closely resembles the alewife, and the two are often confused. The blueback has a more southerly range, extending from Nova Scotia to northern Florida, being more abundant south of New England. Bluebacks spawn later in the season than alewives, usually when water temperatures reach 70° to 75°F.[3] They do not seem to run far above tidewater in the Hudson, preferring deeper water, with most spawning probably occurring in the open river above Indian Point.[18] Bluebacks return to the sea soon after spawning, to reside in the inshore coastal waters until winter, when they apparently move offshore.[12]

The eggs of the blueback are demersal and adhesive and hatch in about 50 hours at 72°F. The larvae are common at Indian Point. Within a month the young reach a length of 1 to 2 inches. They spend the summer in fresh and brackish water nursery areas.[3] During a sampling program conducted in the summer of 1966, young blueback herring were found to be the second most abundant species along the shores of the Hudson.[23] In the late summer and fall, they move out of the river to the sea.

Young bluebacks in the Hudson feed mainly on small crustaceans and insect larvae;[13] as adults, they feed mainly on copepods and amphipods.[12] Raytheon data indicate that the blueback herring has a stronger preference for surface water than its relative the alewife.[18]

Striped Bass *(Morone saxatilis)*

The striped bass is an anadromous species of the family Serranidae. This family includes freshwater, estuarine, and marine forms. Although the species was originally an Atlantic form, it has been successfully introduced on the Pacific coast and is a common food and game fish in that area. On the Atlantic coast, these fish are found from Florida to Nova Scotia but are most abundant in protected waters between North Carolina and Massachusetts. Large fish often reach 35 or more pounds and are generally found along the open coast but within 5 miles of shore.[3] Most stripers are found associated with bays, sounds, and tidal rivers. However, according to Clark,[24] they are also abundant along the Atlantic seaboard from the Delaware Bay to Cape Cod.

Clark[24] described the movements of striped bass in the area from the Chesapeake Bay to New England. Evidence from his studies, as well as previous studies, indicates that the species is not homogeneous but is instead composed of a number of separate groups which are more or less isolated from other groups. In southern waters, the fish remain in protected water throughout their life span, and as a consequence the various populations have little interchange and are most intensely isolated from each other. In contrast, striped bass from the Chesapeake Bay north to New England commonly leave their nursery areas after 3 or more years and migrate in groups along the open coast. Summer movements are generally north, while winter movements are generally south. In the northern part of their range, the striped bass become dormant in the winter.

Striped bass tagged in the Hudson have been caught in fisheries as far away as Massachusetts. However, most of the Hudson striped bass contribute to the commercial and sport fisheries in Connecticut, New York, and New Jersey.[3] Stripers that originate within the Hudson appear to be subdivided into three major groups: those which remain within the Hudson River, those which are in the southwestern portion of Long Island Sound, and those which are typically located along the New York - New Jersey coast.[24] In New York, Connecticut, and New Jersey, where the striped bass fishery is most dependent on the supply from the Hudson, the 1965 commercial catch amounted to 1,500,000 pounds, and the sport catch has been estimated as over 19,000,000 pounds caught by some 200,000 anglers.[3]

The best available evidence indicates that bass from New Jersey to Connecticut spawn in the Hudson. Clark[24] concluded that the "Hudson River is by far the most important spawning stream" in the New York area.

Details of the spawning and distribution of the species in the Hudson were described by Clark and Smith,[3] McCann and Carlson,[25] Jensen,[21] Schaefer,[26] Raney,[27] and Rathjen and Miller.[28] Their conclusions are summarized in the following description. The species spawns from Kingston to Bear Mountain, with the greatest concentrations of eggs in the vicinity of West Point, although the exact location varies from year to year. The variability is the result of the fact that the greatest area of spawning is a few miles upstream from the salt water front, which varies in location from year to year. The nonadhesive demersal eggs are semibuoyant and require sufficient vertical water flow in order to remain suspended. Eggs are encountered most often in fresh or only slightly brackish water (salinity below 1 part per thousand). They average 0.134 inches in diameter and hatch in 2 or 3 days at 60° to 64°F.[29] After hatching, the larvae, which are about 0.13 inches long, continue to drift downstream. At this stage in development, the larvae are still unable to move effectively against the currents and will settle to the bottom in quiet water despite swimming efforts to approach the surface. These larvae are reported to be concentrated above the Haverstraw Bay area, with the greatest abundance between Peekskill and Newburgh. Once the larvae reach a length of 0.5 inches, they appear capable of sustained swimming. The larvae make extensive vertical diurnal migrations, being found in surface water at night and nearer the bottom during the day.[21,30] After they reach a length of about 1 in., they are found in greatest abundance in Haverstraw Bay.

As related to the Indian Point site, the striped bass generally spawn upstream from the area. Both eggs and larvae drift downstream past Indian Point. However, the majority of the spawn that drifts through the Indian Point area is composed of larvae rather than eggs. A large proportion of the yearly spawn passes Indian Point as eggs, larvae, or early juvenile stages. The young fish apparently stop along shoal areas, where they remain.

This species, like white perch, shows a definite preference for the bottom waters in shoal areas. Only small numbers were collected in the bottom trawls at the channel stations north of Stony Point, whereas large numbers were caught on shoals in Haverstraw Bay and in Peekskill Bay.[30]

After spawning, the adults generally return to sea. Larvae and young of the year remain in freshwaters and estuaries. Striped bass in the Hudson may remain in the estuary for 2 or 3 years before migrating to the sea. During winter, adults and young are found in the lower regions.

As larvae and young of the year, striped bass feed primarily on microcrustaceans. As they grow, their diet changes from smaller to larger forms. *Gammarus* apparently makes up a major proportion of their diet, but most other microcrustaceans are also taken, and there is evidence that a variety of food is needed for normal growth.[31] Small fish also become an important food item as the fish grow larger.

Note

A great deal of information on the migrations and growth of various life stages of striped bass from and within the Hudson is available in references 21, 23, 24, 25, 26, 27, 28, 30, 32, 33, 34, 35, 36, and 37.

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APPENDICES FOR SECTION III

APPENDIX III-1

WATER VELOCITY CALCULATIONS THROUGH THE INTAKE STRUCTURES OF INDIAN POINT UNIT NO. 1 AND UNIT NO. 2

UNIT NO. 1 Design flow = 280,000 gpm* or 623 cfs*

4 openings each 11 ft 2 in. wide x 20 ft 6 in. high

FIXED FINE MESH SCREENS - 4 x 11 ft 2 in. x 20 ft 6 in. = 917 ft^2

Assume 0.080 in. diameter wire in 3/8 in. square mesh screen

$$\frac{(0.375 - 0.080)^2}{(0.375)^2} = 0.62 \text{ fraction of area available for flow}$$

Velocity through fine mesh screen, Unit No. 1

$$\frac{\text{Flow}}{\text{Area}} = \frac{623}{917 \times 0.062} = 1.09 \text{ fps}$$

UNIT NO. 2 Design Flow = 840,000 gpm or 1872 cfs

6 openings each 14 ft 10 in. wide x 26 ft 0 in. high

INTAKE OPENINGS, 6 x 14 ft 10 in. x 26 ft 0 in. = 2320 ft^2

Velocity through main openings, Unit No. 2

$$\frac{\text{Flow}}{\text{Area}} = \frac{1872}{2320} = 0.81 \text{ fps}$$

TRASH BARS - 1/2 in. thick x 3 in. wide @ 3.5 in. on center apart

$$\frac{3}{3.5} = 0.857 \text{ fraction of area available for flow}$$

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*Note - 1 cubic foot per second (cfs) is equal to about 450 gallons per minute (gpm).

Mean low water = 26 ft depth

Cross sectional area of water intake = 6 x 14 ft 10 in. x 26 = 2320 ft^2

Velocity through trash bars, Unit No. 2

$$\frac{1872}{2320 \times 0.857} = 0.94 \text{ fps}$$

FIXED FINE MESH SCREENS

Assume intake aperture dimensions with 2 in. wide frame, i.e., screened area = 14 ft 10 in. wide x mean water depth less 2 in. or 25 ft x 10 in. = 2300 ft^2. Screen is 0.080 in. diameter wire, 3/8 in. square mesh, 0.62 fraction of area available for flow.

Velocity through the fixed screen, Unit No. 2

$$\frac{1872}{2300 \times 0.62} = 1.32 \text{ fps}^*$$

TRAVELING SCREENS - 12 ft 0 in. wide

Each panel = 2 ft 0 in. x 12 ft 0 in. = 24 ft^2 area

Assume 2 in. wide frame around each panel or open area = 1 ft 8 in. x 11 ft. 8 in. = 19.44 ft^2

$$\frac{19.44}{24.0} = 0.81 \text{ fraction of area available for flow.}$$

Screen is 0.080 in diameter wire, 3/8 in. square mesh, 0.62 fraction of area.

Velocity through traveling screen, Unit No. 2

$$\frac{1872}{6 \times 12 \times 26 \times 0.81 \times 0.62} = 2.02 \text{ fps}^*$$

Thus, for Indian Point Unit No. 2, the calculated water velocity increases from 0.8 fps at the intake openings of the intake structure to 2.02 fps through the traveling screens. This latter flow is more than 85% greater than the flow through the traveling screens of Indian Point Unit No. 1.

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*At mean low water depth = 26 ft.

APPENDIX III-2

SOURCE TERM DETERMINATION TECHNICAL BACKGROUND

INDIAN POINT UNIT NO. 2 - 100% POWER LEVEL

The following parameters were used in the calculation of Indian Point Unit No. 2 estimated radioactive releases.

Percent fuel leak - 0.25%
Power level - 2,758 MW(t) - initial system; 3,216 MW(t) - modified system
Primary to secondary leakage - 20 gallons per day (gpd)
Steam generator blowdown - 10 gallons per minute (gpm)
Containment purge - 12 times per year
Decay time - Waste Gas Processing Systems - 45 days

1. Gases

a. Containment Purge Releases

Assumed 12 purges annually. It was assumed that the activity in the containment would be reduced to 10X the occupational MPC by drawing air through a prefilter, HEPA filter and charcoal adsorber before being discharged to the Plant vent.

b. Blowdown Tank Vent Releases

It has been estimated that 0.62 Ci/yr of I-131 will be released in the initial system via the blowdown vent. This estimate assumes: a 20 gpd primary to secondary leak; a 10 gpm blowdown rate; 1/3 of the steam flashes in the tank; and a 10^{-1} iodine partition factor. The radioactivity in curies released is approximately 1/20 of the curie input. We have also estimated an annual release of 35 Ci/yr in liquid effluent without treatment. The proposed intertie between Units Nos. 1 and 2 and the blowdown purification system in the modified system should reduce this to less than 1.7 Ci/yr.

c. Waste Gas System

Strip main coolant 4 times per year. Combined fill - hold - release time yields 45 effective days of holdup.

2. Liquids

a. Chemical and Volume Control System (CVCS)

Release 4 primary coolant volumes per year (per Supplement No. 15, page Q11.1-19 of FFDSAR). Use 10^5 Decontamination Factor (D.F.) for Evaporator-Demineralizer except 10^3 for iodine, and 1 for H^3 and 10-hour holdup.

b. Waste Disposal System

130,000 gallons per year - evaporator D.F. = 10^4 except 10^3 Iodine - 10 - hour holdup.

c. Steam Generator Blowdown

20 gpd leakage from primary system and 10 gpm released untreated to the discharge canal.

APPENDIX III-3

SUMMARY OF RADIOACTIVE WASTE DISCHARGES TO THE ENVIRONMENT FROM PRESSURIZED WATER REACTORS 1965-1970

This is a summary of discharges of radioactive wastes from pressurized water reactors operating in the United States from 1965 to 1970, except for the Saxton Nuclear Experimental Reactor, which has a net electrical capacity of only 3.25 MW(e).

It should be noted that 10 CFR 20 provides alternatives for determining permissible limits to the activity of radioactive liquid effluents. One of the limits specifically mentioned is 1×10^{-7} μCi/cc, which is sufficiently restrictive that it can be used for mixtures of fission and corrosion products in liquid waste from light water nuclear power reactors without any identification of the radioisotopic composition of the mixture. Other alternatives require knowledge of the identity and concentration of the radionuclides present and establishing that certain isotopes are not present. Typical compositions of radioactivity in water from light water power reactors are such that much higher limits are expected to be available to the applicant if it wishes to support them by adequate radiochemical analyses.

The corresponding proposed 10 CFR 50 guideline (June 9, 1971) is 0.2×10^{-7} μCi/cc, a value one-fifth as large as the 10 CFR 20 limit; 10 CFR 50 makes no provision for analysis for specific radionuclides. Therefore the percent of limit values can be calculated from the tables of radioactive discharges in Chapter III (for 10 CFR 20 limits) which may be converted to the percent of the 10 CFR 50 guideline by multiplying these values by 5, except for the instances where the applicant analyzed the discharge for specific radionuclides. In those cases, the 10 CFR 50 guideline of a maximum discharge of 5 curies per reactor can be used for comparative purposes.

The values for 1965-1968 are from Reference 1, for 1969 from Reference 2, and for 1970 from References 3 and 4.

TABLE A-III-1

RADIOACTIVE WASTE RELEASES TO THE ENVIRONMENT FROM PRESSURIZED WATER REACTORS

Annual Liquid Wastes, Gross Beta-Gamma Less Tritium, in Curies

Facility	Rated Power MW(e)	Curies Released in Liquid Wastes 1965	1966	1967	1968	1969	1970
Connecticut Yankee	600			0.216	3.9	12	22
Ginna	420					0.02	9.4
Indian Point Unit No. 1	285	26.3	43.7	28.0	34.6	28[a]	7.8
San Onofre	450			0.32	1.6	8	3.8
Shippingport	90	0.14	0.06	0.07	0.08		
Yankee	185	0.029	0.036	0.055	0.008	0.019	0.034

(a) 28 Ci for Indian Point No. 1 represent 1.5% of the limit expressed in 10 CFR 20 where individual isotopes are analyzed. (Rogers, L. and Gamertsfelder, C. C., "U. S. Regulations for the Control of Releases of Radioactivity to the Environment in Effluents from Nuclear Facilities," IAEA Symposium on Environmental Aspects of Nuclear Power Stations, New York, N.Y., August 10-14, 1970.)

TABLE A-III-2

RADIOACTIVE WASTE RELEASES TO THE ENVIRONMENT FROM PRESSURIZED WATER REACTORS

Tritium in Liquids, in Curies

Facility	1965	1966	1967	1968	1969	1970
Connecticut Yankee			221	1,740	5,200	7,400
Indian Point Unit No. 1		125	297	787	1,100	410
San Onofre				2,350	3,500	4,800
Shippingport*	3.04	27.3	34.8	35.2		
Yankee	1,300	1,920	1,690	1,170	1,700	1,500

* Modified to 150 MW(e) in 1965.

TABLE A-III-3

RADIOACTIVE WASTE RELEASES TO THE ENVIRONMENT FROM PRESSURIZED WATER REACTORS

Noble and Activation Gases, in Curies[a]

	Rated Power MW(e)	Maximum Permissible Release[b,c]	1965[b]	1966[b]	1967[b]	1968[b]	1969[c]	1970[d]
Connecticut Yankee	600	18,900			0.021 (29.8)	3.74 (73.4)	190 (75.0)	700 (71.3)
Indian Point Unit No. 1	285	5,360,000	33.1 (46.4)	34.6 (50.3)	23.4 (68.3)	59.7 (64.9)	600 (72.1)	1750 (14.1)
San Onofre	450	567,000			4.02 (21.3)	4.83 (33.6)	260 (69.2)	1610 (81.0)
Shippingport	90[b]	40[b]	0.032 (42.0)	0.030 (67.0)	0.002 (60.8)	0.001 (46.8)	(39.1)	(49.1)
Yankee[e]	185	6,600	1.7 (64.7)	2.4 (85.9)	2.3 (85.7)	0.68 (81.5)	4 (75.3)	17.2 (78.8)

[a] In parentheses, beneath the radioactivity discharge values, are power plant capacity factors (%) taken from Table 8 of "Operating History, U. S. Nuclear Power Reactors," Division of Reactor Development and Technology, 1970, Atomic Energy Commission.

[b] Data from Reference 1.

[c] Data from Reference 2.

[d] Data from Reference 3, except as noted.

[e] See, in particular, Reference 4.

TABLE A-III-4

RADIOACTIVE WASTE RELEASES TO THE ENVIRONMENT FROM PRESSURIZED WATER REACTORS

Halogens and Particulates in Gaseous Effluents

Facility	Rated Power MW(e)	Curies Released in Gases			
		1967	1968	1969	1970
Connecticut Yankee	600			<0.0001	0.00046
Ginna	420			<0.0001	None Detected
Indian Point Unit No. 1	285	*	*	0.025	0.075
San Onofre	450	0.001	*	<0.0001	None Detected
Shippingport**	90	*	*		
Yankee	185	*	*	<0.001	None Detected

* Negligible

** Modified to 150 MW(e) in 1965.

REFERENCES FOR APPENDIX A-III-3

1. Logsdon, J. E. and Chissler, R. I., "Radioactive Waste Discharges to the Environment from Nuclear Power Facilities," U.S. Department of Health, Education, and Welfare, Report PB-190717 (BRH/DER 70-2), March 1970.

2. *Environmental Effects of Producing Electric Power*, Hearings Before the Joint Committee on Atomic Energy, Congress of the United States, 91st Congress, Second Session, February 27-30 and February 24-26, 1970, Appendix 10, pp. 2316-2317.

3. Kahn, B., Shleien, B., and Weaver, C., in *U.S. Papers for the Fourth United Nations International Conference on the Peaceful Uses of ATomic Energy*, Vol. 2, Sessions 3.3-28 to 2.3-45, A/Conf-49/P-087, Geneva, Switzerland, September 6-16, 1971.

4. Kahn, B. et al., "Radiological Surveillance Studies at a Pressurized Water Nuclear Power Reactor," Environmental Protection Agency, Cincinnati, Ohio, August 1971.

APPENDIX V-1

BASIC INFORMATION FOR ASSESSING BIOLOGICAL IMPACT*

A. EFFECTS OF TEMPERATURE INCREASES IN THE ENVIRONMENT

Temperature is a particularly important factor governing the occurrence and behavior of organisms. It not only affects the distribution of a single species but may also modify the species composition of a community or an ecosystem. Generally, tropical and subtropical species are more stenothermal (tolerate only a narrow range of temperatures) than those of higher latitudes, and marine forms are more stenothermal than freshwater or estuarine ones.[1] In this connection, Naylor[2] noted that estuarine species were more tolerant of heated effluents than marine forms and concluded that some cold-water stenothermal species may be eliminated by heated discharges while eurythermal (tolerate a wide range of temperatures) species may be increased.

Planktonic forms are most susceptible to temperature fluctuations resulting from power plant operations since they are dependent upon water currents for much of their movement. Larger, motile organisms are usually able to find and remain in areas near their preferred temperature unless trapped in shallow or enclosed areas or forced to migrate through thermally altered zones. Many organisms have restricted ranges of temperature within which they can reproduce successfully.[1] Larval development also requires narrow ranges of temperature.[3] For these reasons, many species may exist in excessively heated areas only by continued recruitment from the outside. In such areas, fish may be absent during warm summer months and present in cold winter months. In some locations, populations of widely heat-tolerant species may replace stenothermal species.

1. Decomposers

The temperature of the Hudson, even during the summer, is below the optimum for most bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant. Increasing the water temperature within the growth range of the bacteria causes a more rapid die-off when the food supply is limited.[4] Consequently the few degrees increase in temperature due to the discharge of heat by the Plant would be expected to favor increased bacterial growth during most of the year, only if the standing

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*Manuscript by C. P. Goodyear, Oak Ridge National Laboratory, Oak Ridge, Tennessee crop of bacteria is less than the carrying capacity of their food supply. Because of metabolic considerations, increases in temperature which favor population growth may be counteracted by a reduction in the carrying capacity of the area. However, if, in addition to the increased temperature, there is an associated increase in available organic material, increased standing crops of bacteria might be experienced. Bacterial counts in the influent and effluent water of a power plant on the Patuxent River estuary when there was a rapid heat change (but no chlorination) were found to remain constant.[5]

2. Producers

Inherent in the question of availability of different algal groups as food for invertebrates is the succession of these algae with increasing temperature. As Patrick[6] noted in her review of the effects of temperature on freshwater algae, each species in nature has its own range of temperature tolerance and its range of optimum growth, photosynthesis, and reproduction. Diatoms are represented by the largest number of species with relatively low temperature tolerances; namely, to temperatures below 86°F. The tolerances of the green algae cover a wide temperature span. The blue-green algae have more species that are tolerant of very high temperatures. There are some species in all groups, however, that tolerate the unusual extreme for their group. Under normal seasonal conditions, there is a succession of species on the same substrate. This succession is largely the result of changes in water temperature and light intensity through the optima for the various species. As the temperature increases or decreases, one species replaces another as the dominant organisms. In nature, there are also many other pressures upon a species, including interspecies competition and predation, so that the temperature of maximum development in a stream may not be exactly the same as the optimum range for growth in the laboratory. Figure A-V-1 indicates the most commonly observed type of population shift. This figure is generally accepted, although, as Coutant[8] points out, it is a generalized pattern, which is not always followed by algal populations in the field.

Reports of field studies of the biota associated with discharge canals of power plants, where the water temperature is still essentially as high as it was when it left the condensers, have noted dominance of the periphyton community by heat-tolerant blue-green algae when water temperatures exceed about 86°F. Reports

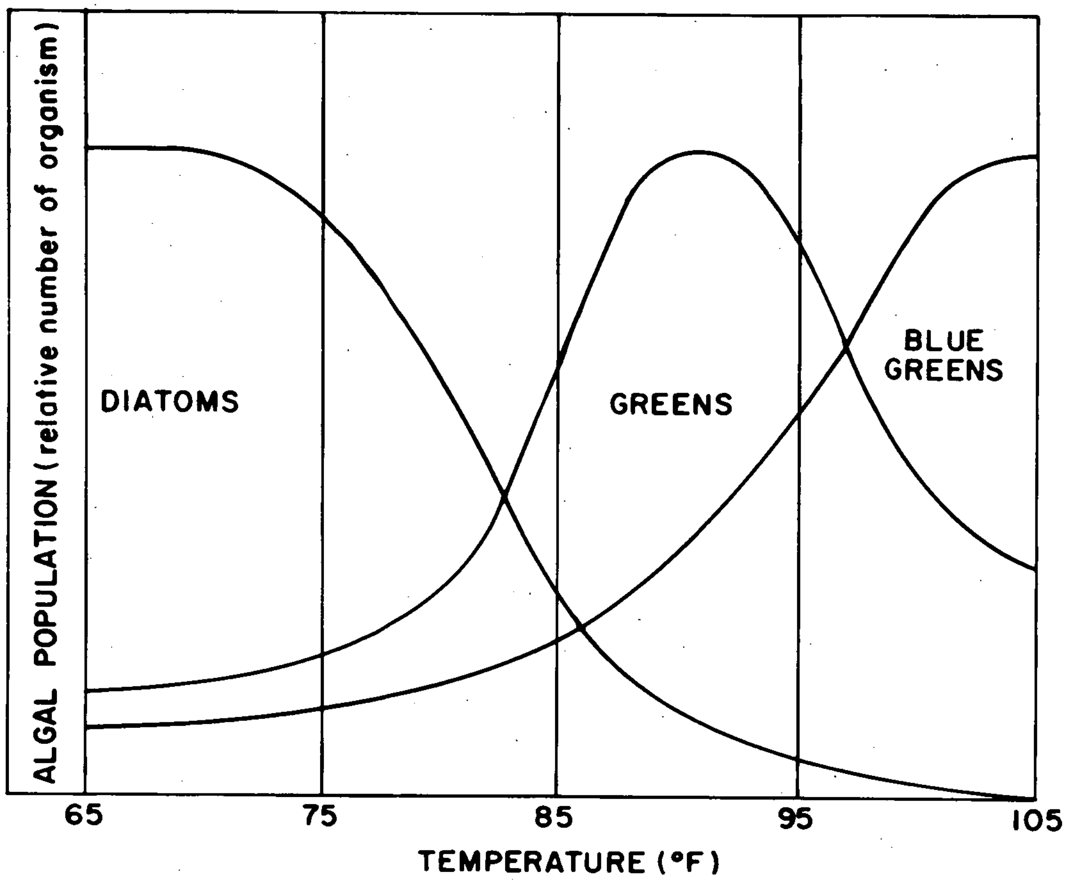

Fig. A-V-1
Population Changes Among Algal Groups with Change in Temperature.

by Trembley[9] indicate that the periphyton growth on glass slides was dominated more completely by blue-green algal species in the discharge canal of the Martin's Creek Power Plant on the Delaware River when the temperature exceeded 94.1°F. There were fewer species on the slides than when the water was cooler, but those remaining were represented by a larger number of individuals. This condition is generally recognized as an indication of an abnormal community structure. It is difficult to determine, however, how much of the alteration of community structure was due to chlorination of the cooling water.[8]

Forester[10] discussed the apparent early arrival of spring seasonal successions in periphyton of the discharge canal of the Yankee Atomic Power Plant on the Connecticut River. Buck[11] reported a noticeable shift from diatoms to blue-green algae in plankton in the area of thermal effluent. These planktonic forms were presumably derived from the periphyton populations of the mile-long canal, although a detailed report of this study has not yet been published. Similar changes in the species composition of plankton in cooling water were reported by Beer and Pipes,[12] who described a shift from diatom dominance in the inlet to dominance by unicellular green algae in the effluent canal of the Dresden Station on the Illinois River.

In a September survey, *Oscillatoria* (a blue-green filamentous alga) covered all bottom materials in shallow water of the discharge canal and the river bed close to the confluence of the discharge from the John Sevier Steam Plant (Tennessee Valley Authority) with the Holston River, Tennessee.[8] No large-scale replacement of cold-water marine algae by warm-water-tolerant forms, however, was found by North[13] at the Morro Bay discharge canal. The entire algal flora was simply depleted at the warmer temperature.

The lethal temperature of the algae varies with the species.[6] For most of the algal species studied to date, the lethal temperature is in the range from 91.5°F to 113°F, with the majority being near 111°F. Diatoms that require cooler temperature (stenotherms) are generally most sensitive to temperature change and can withstand an 18F° temperature change. Diatoms suited to warmer temperatures can tolerate temperature changes of from 27F° to 36F°.[6]

At Indian Point, the diatom *Melosira* is dominant throughout most of the year, although their dominance declines during the summer period of high temperatures and salinity. Many other species are also consistently present.[14] However, there is a seasonal change in composition characterized by diatom dominance much of the year, with green and blue-green algae becoming more abundant in late summer and early fall.[15] The pattern of dominant algal forms (Fig. A-V-2) conforms to the typical pattern previously described (Fig. A-V-1), although the shifts in abundance of the green and blue-green algae seem to be occurring at lower temperatures than would be predicted. For further discussion, see Section V.D.2.a(2).

3. Consumers

The physiology of aquatic organisms is affected by temperature. Changes in temperature may cause increases in metabolism, changes in food conversion abilities, changes in reproductive capacity, changes in behavior, or even thermal death. Fry *et al.*[16] described the thermal responses of fish and divided the total range of temperature experience of an organism into several zones. They discerned an upper and a lower zone of thermal resistance and a central zone of thermal tolerance, bounded respectively above and below by an upper and a lower lethal temperature. The lethal temperature is defined as that temperature which, when a fish is brought rapidly to it from a different temperature, will kill a stated fraction of the population (generally 50%) within an indefinitely prolonged exposure. In the zones of thermal resistance an organism can survive for a definite period of time that becomes shorter as the temperature approaches the lethal temperature.

Previous thermal history affects the lethal temperature, this history being referred to as acclimation temperature. In general, a history of cold temperatures results in a low lethal temperature, while a history of warm temperatures produces an elevated lethal temperature.

There is accumulating evidence that many cold-blooded (poikilothermic) species are capable of considerable adjustment of their metabolic activities to a wide range of temperatures. This adjustment to warmer temperatures is evidenced by increased upper and lower lethal temperatures. The range of adjustment may be considerable, as, for example, in the goldfish, which has an upper lethal temperature that varies from approximately 78.8°F to 104°F. This hardy species may be one of the universal cases in this respect.[8]

Elevation of lethal temperature is not directly proportional to elevation of acclimation temperature, but rather some fraction of it. The result is that the acclimation temperature and the upper lethal temperature tend to converge upon the ultimate upper lethal temperature, at which both the acclimation and the lethal temperature are the same.

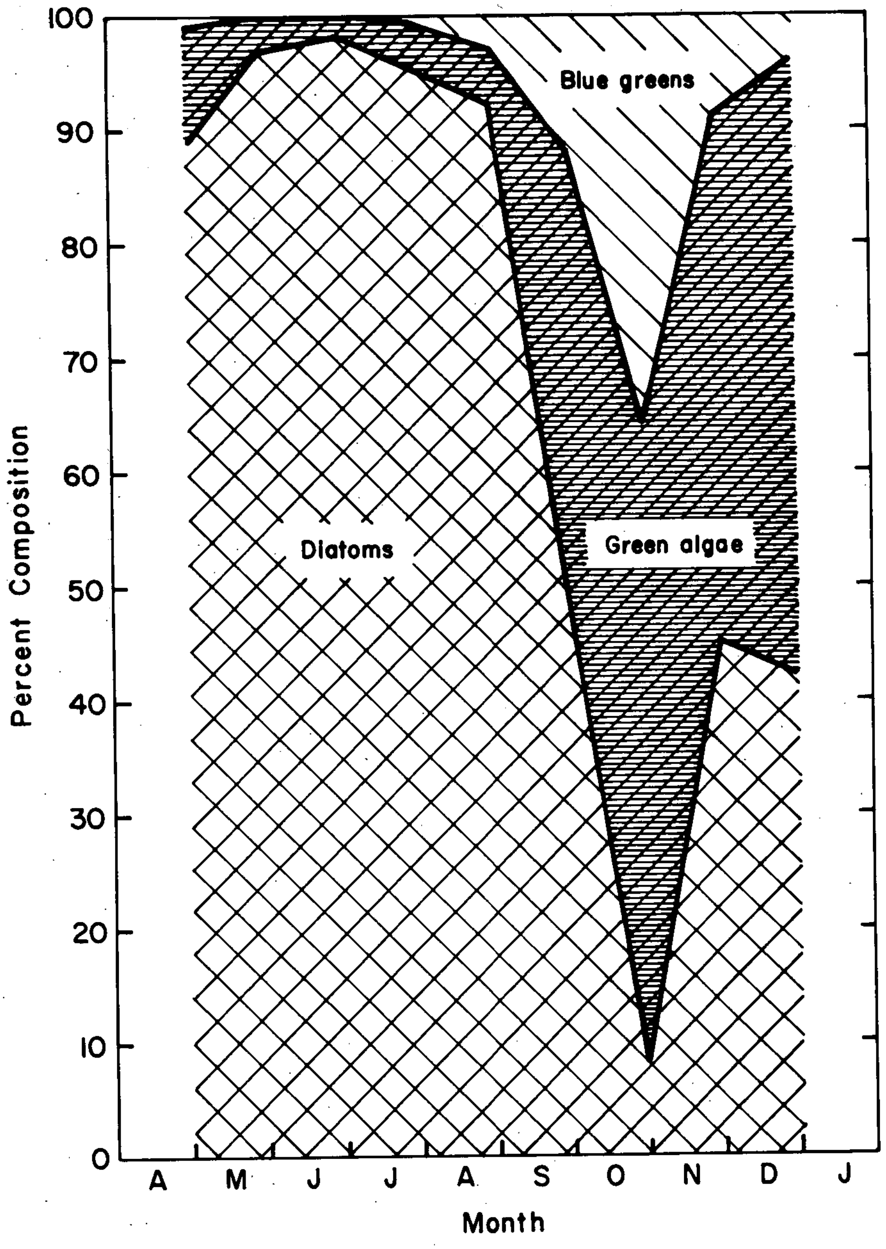

Fig. A-V-2
Relative Proportions of Diatoms, Green, and Blue-Green Algae in the Standing Crop at Indian Point, 1970. (East Channel Station)

The time necessary for thermal acclimation varies among species, as has been shown by several workers.[8] Adjustment to higher temperatures is generally fairly rapid; data of Alabaster and Downing[17] indicate an elevation of about 1.8F° per day for the roach; Sprague[18] found that acclimation temperatures could be raised 4.5F° to 9F° per day for several crustaceans. Once acquired, tolerance to high temperatures may persist for considerable periods after return of a fish to a lower temperature. Heat exposure during acclimation need not be continuous. An intermittent exposure to a different temperature for sufficient hours per day can produce the same acclimation temperature as a continuous exposure. According to several authors,[8] acclimation to low temperature usually tends to shift the lower thermal limits downward, and acclimation to high temperatures tends to shift the lower limits upward. Since intermittent brief exposure to high temperatures can result in markedly increased resistance to heat which is not readily lost during subsequent exposure to low temperatures, possible increased susceptibility to reduced temperatures may result in areas where organisms regularly encounter thermal plumes.

By testing species in the laboratory, Brett[19] noted that a slow rate of decrease in environmental temperature is of greater importance for maintaining life than a slow rate of increase. Thus, lethal cold can be more important than lethal heat as a factor affecting survival of some species exposed to thermal plumes. Deaths resulting from the inability of fish to rapidly acclimate to lowering temperatures have been reported.[20,21]

Upon exposure to altered temperatures, the duration of the exposure, the size of the fish, and its thermal history are important in determining its survival. Eggs and larvae are exacting in their temperature requirements, while subjuveniles and juveniles appear to be more eurythermal, and adults tend to be broadly stenothermal.[3]

Based upon the few data on upper lethal temperatures reported in the literature, larvae of temperate marine fishes have lower upper lethal limits than the adults do.[1,3] The experimentally derived median upper temperature for temperate species is 78.8°F for larvae and 86°F for the adults.[3] Although the upper limits for larvae and adults differ, the absolute ranges of temperatures tolerated are approximately identical.[3]

The eggs of some species may be especially sensitive to fluctuations of temperature. For instance, one of the most important effects noted in the study on eggs of the American smelt (*Osmerus mordax*) in Maine was the large increases in mortality during fluctuations in daily water temperature of as much as 12.6F°, as observed by Rothschild.[22] In contrast, striped bass eggs (*Morone saxatilis*) were found to survive in water whose temperature varied from 55° to 75°F daily.[23]

The thermal tolerances of invertebrate herbivores that are generally most active in grazing algal populations are poorly known. Coutant[24] observed a reduction in the normal complement of Delaware River invertebrates when the daily maximum temperature was near 89.6°F. Chironomids larvae, which are generally important as periphyton harvesters, persisted in the zone where algae were accumulating. Other studies have noted depletions of invertebrates in warmed water.[8]

The effects of thermal discharges on benthic communities have been reviewed by Stewart.[25] In general, the number and distribution of bottom organisms decrease as water temperatures increase, with a tolerance limit close to 90°F for a "balanced" population structure. Studies of particular species of macroinvertebrates have shown that lethal temperatures vary considerably with the type of organism. In some cases a particular species may be stenothermal for one developmental stage and eurythermal for another. Thus, a large number of species are able to tolerate higher temperatures than those at which they can reproduce. In a study on the York River, in Virginia, Warinner and Brehmer[26] found that the community composition and abundance of marine benthic invertebrates in the river were affected by thermal discharges over a distance of 1,000 to 1,300 feet from the discharge outfall, and they concluded that during the months of high normal river temmperatures there was clear evidence of biological stress.

At power plants where benthic communities are destroyed in summer, the reverse is often the case in winter.[25] Massengill[27] reported not only colonization, but also a 10% to 40% increase in standing crop in the discharge canal at the Connecticut Yankee Atomic Power Plant, as compared to other stations on the Connecticut River.

Results of thermal tolerance studies[1,3,28,29] conducted on species of aquatic organisms that occur in the Hudson near Indian Point are reported in Table V-5. The actual predictive utility of these figures is limited, since acclimation temperatures have not often been reported. In most cases, however, these data should be regarded as optimistic estimates of upper lethal limits of the populations as a whole, because, as McCauley[30] has stressed, lethal temperatures quoted in the literature usually have been determined for individuals of the more hardy stages of postembryonic development.

In predicting responses to increased temperature, it is important to note that a temperature need not kill the organisms directly to produce effects on a population. For instance, brook trout were found to be comparatively slow in catching minnows at 63°F and virtually incapable of catching them at 69.8°F. This resulted in the trout virtually starving to death.[8] Many other types of sublethal effects on populations are known to occur.

Rates of metabolism and activity of organisms increase with increasing temperatures over most of the tolerated temperature range and then often drop suddenly near the upper lethal temperature. Such rates vary with different species, processes, and levels or ranges of temperature and may be modified by salinity and oxygen factors. It is often considered that the effects of elevated temperatures on a biological system increase the rate of biochemical reactions within the system by 100% to 600% for each 18F° increase,[31] although this rate does not necessarily hold for extreme temperatures. By applying this concept it is apparent that even a slight temperature increase may have far-reaching effects, because a number of metabolic functions will be accelerated with a temperature increase even though the organism may not be killed outright. Fortunately, the actual metabolic increases upon exposure to elevated temperatures are often less than would be anticipated from strictly thermodynamic considerations where metabolic rate would typically vary directly with temperature.[8] If their oxidative processes are independent of temperature (thermally insensitive), then the rate of oxygen utilization would be relatively constant over a wide temperature range. Studies involving many species of invertebrates indicate that over certain parts of a temperature range in which they can be held for prolonged periods, animals tend to be metabolically independent. This kind of response is intermediate between the two extremes. In general, this thermal range of metabolic insensitivity coincides with the temperature regime of the animal's habitat. For such species, slight changes in their thermal environment would have little effect as long as such changes remained within the zone of metabolic insensitivity. However, changes which exceeded this zone could have an adverse effect.

The temperature requirements for reproduction in many species are confined to narrower ranges than for other physiological functions.[3,31] Most aquatic animals have restricted temperatures for breeding. Photo-period effects and rising temperatures in the spring induce development of the gonads, and actual spawning takes place when a certain temperature level is reached. This value varies for different species, and in some species the whole process may be reversed.[1]

A temperature stimulus of some kind is often required for inducing sexual activity in aquatic animals. This threshold is often quite critical and may occur with a temperature rise of only 1.8° or 3.6F°.[19] Brandhorst[32] believed that spawning activity in herring was induced by the suddenness of the temperature change rather than by the magnitude of the change *per se*. Generally, low temperatures during pre-spawning periods delay spawning, and higher temperatures hasten it.[3,19]

Fish attracted to discharge canals and in residence there for several months may be induced by higher temperatures to spawn earlier than might otherwise be expected.[8] Premature spawning can be speculated to have many repercussions in the receiving water, ranging from loss of progeny due to lack of proper food to species changes brought about by the dominant large warm-water fry. The problem is not unique to discharge canals but occurs in cooling ponds and mixed water bodies wherever the water temperature is elevated.[8]

Few of the theoretically predicted changes in reproductive schedules have been studied at power plants, and observations are generally limited to evidence that premature spawning can and does occur. For instance, white suckers (*Catostomus commersonni*) spawned prematurely in the discharge canal of the Martin's Creek Power Plant on the Delaware River.[33] Spawning activities were observed earlier there than elsewhere (times not given). Young-of-the-year were active in the spring in the canal and apparently left the warmer water as the temperature rose in summer. Very small fry of several other species (rearing determined them to be principally minnow species) were found in the canal prior to normal spawning times. They probably were spawned in the canal, instead of having passed through the condensers, although it was not certain.[8]

The attraction of fish to warm areas associated with thermal discharges may cause additional problems. For instance, fish attracted to warm discharge canals of power plants, and forced by their own temperature selection behavior to remain there, subject themselves to speeded metabolic rates compared to their seasonal norm in other parts of their environment.

At the Connecticut Yankee Atomic Power Company's plant on the Connecticut River, Merriman *et al.*[34] have identified "skinny fish" in the winter accumulations of brown bullheads (*Ictalurus nebulosus*) and white catfish (*I. catus*) in the discharge canal. The weight-length ratio, or "condition factor," exhibited significant declines throughout the winter months. Fish tagged early in the winter of 1968-1969 and recaptured four months later has lost an average of 20% of their weight, some having lost 60%. Comparisons of tagged and untagged fish in weekly collections indicated that this marked weight loss was not the result of the tagging but was indicative of the resident canal population as a whole. Populations in the cooler river water outside the canal also showed some condition loss, but at a much slower rate. The poorer condition was also identifiable in these two species of fish caught in the canal in the summer. Channel catfish (*I. punctatus*), on the other hand, showed no such decline in condition at any season.

Significance of the weight losses for ultimate survival of the populations in the Connecticut River has yet to be established, but the persistence of the effect beyond the winter was demonstrated through tagging and recovery studies.[11] Early fall returns from fish tagged in the canal the previous winter revealed that these fish had not made up their past winter's weight loss over the summer.

As a corollary to feeding rate and quantity of food consumed, the effect of temperature upon the growth of fish is an important factor in considering the effects of heated effluents but is one which has been studied essentially using freshwater fished in the laboratory. The general relation between growth rate of fish and temperature has been discussed by several authors.[19,35] In general, reduction in growth rate can be expected with increasing temperature above optimum for the species, especially if the availability of food does not increase. This situation is the result of reduced food conversion efficiency, which in some cases may be intensified by behavioral changes such as reduced effectiveness as a predator or reduced appetite.

B. ENTRAINMENT

The importance of entrainment is related to the relative quantity of organisms withdrawn, the level of mortality incurred, the ecological role of the entrained organisms, and the reproductive strategy of the species involved. The importance of these factors will be different for different species. Consequently, detailed considerations of the effects of entrainment must be done separately for each species.

Mortality of entrained organisms is caused by mechanical damage, thermal shock, and chemicals discharged into the water. Mortality caused by other factors associated with Plant operations would, of course, be additive.

1. Decomposers

As previously indicated in Section II.F, bacteria are generally tolerant of exposure to changes in temperature that far exceed the predicted temperature rise of Indian Point Units Nos. 1 and 2 cooling water and are also unlikely to be physically damaged as a result of entrainment. The only extensive bacterial mortality which might be encountered would be at times when the sodium hypochlorite is being added to the circulating water to control fouling in the condensers.

2. Producers

Entrainment effects on algal populations have been determined by examining the ability of the algae to produce organic matter. Using this method in studies on the York River, Virginia, Warinner and Brehmer[26] showed that the responses of phytoplankton to entrainment depended on the ambient stream temperature as well as on the change of temperature imposed by the condensers. At low winter temperatures (32° to 50°F), temperature rises increased production. During the summer (temperatures 59° to 70°F), slight additional temperature rises increased production, but larger rises (greater than 10F°) depressed it. The greater the temperature rise in summer, the greater was the depression of the affected plankton's ability to photosynthesize.

Similar results were shown by Morgan and Stross[36] for the Chalk Point Power Plant on the Patuxent estuary off Chesapeake Bay. In this study, temperature rises of about 14.5F° stimulated photosynthesis when natural water temperatures were 60°F or cooler and inhibited photosynthesis when temperatures were 68° or warmer. Passage through the condensers at times, however, contributed additional damage (perhaps mechanical or chemical) that nullified stimulation by temperature rise at cool temperatures and increased inhibition at warmer ambient levels. Return of phytoplankton to the cool temperatures of the mixed estuary at the end of the discharge canal did not allow recovery of photosynthetic ability. In relating the observed changes in productivity to the entire estuary, the authors noted that real reductions in productivity might occur only if the rate of photosynthesis is not nutrient limited. They concluded that, since Stottlemyer[37] found that nutrient limitation was only a sporadic occurrence, reduction in photosynthesis by another factor (the power plant) must, therefore, reduce the amount of material available for passage through the food chain.

In contrast, another study showed rates of photosynthesis that were similar for power plant intake and effluent water when incubated at the prevailing temperature for each source, although some differences were significant.[3] Algae in heated water had a higher rate of photosynthesis than algae incubated at ambient temperatures. The highest rates of photosynthesis occurred at temperatures between 80.6° and 91.4°F. The highest rate observed was for effluent water incubated at 86.9°F. No consistent reduction of photosynthesis was observed in the vicinity of the discharge canal during field studies.

3. Consumers

Entrainment analysis of the coolant system should include an estimate of zooplankton mortality and the potential for a rapid recovery downstream of the power plant. Such an analysis was carried out in May 1964 at the Paradise Generating Station at Green River, Kentucky.[38] Biologists of the Tennessee Valley Authority found that the volume of zooplankton was drastically reduced during passage through the single-pass coolant system of the plant. However, organisms that bypassed the plant were found to reproduce at an accelerated pace in water that was warmed by mixing with a thermal discharge, 16 F° above an ambient of 82°F (Fig. A-V-3). Coutant[8] observed that decreases in zooplankton volume could not be attributable to thermal shock effects alone. Other factors might include mechanical destruction in the condenser or piping system and predation upon carcasses and weakened individuals at or near the plant discharge. The Green River reports shed no light on these processes.[8]

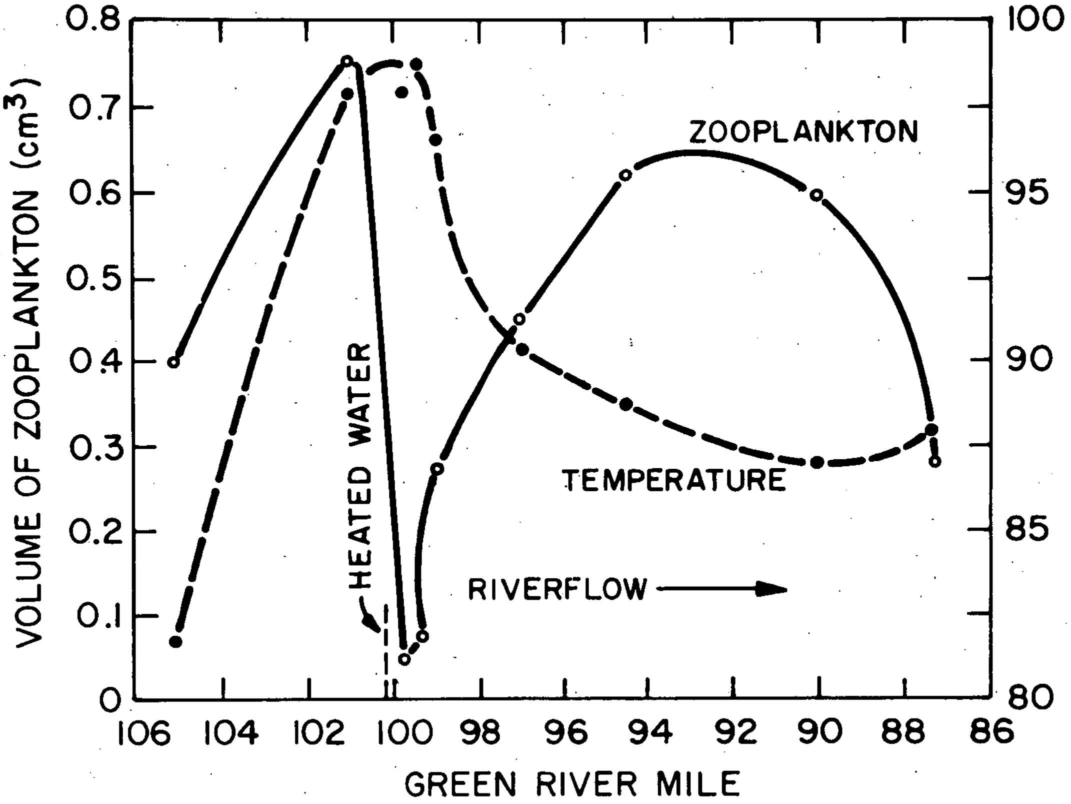

Fig. A-V-3
Zooplankton and Water Temperatures in the Green River, Ky., Near the Paradise Steam Plant, May 26 - 27, 1964.

Heinle[39] conducted an extensive series of laboratory and field experiments to determine the effect of condenser passage on zooplankton in the brackish Patuxent estuary in the vicinity of the Chalk Point power station of Potomac Electric Power Company. Instead of examining survival alone, the reproductive success was observed in subsequent laboratory culture of populations that had experienced the thermal, mechanical, and chemical shocks of condenser passage. Entrained populations of some copepods were generally not as fit for reproduction as control groups, even when the exposure temperatures were below the laboratory-determined lethal temperatures. Part of this effect was attributed to chlorination of cooling water as a normal operating routine at the plant. While effects of condenser passage were identified by this research, the methodology and the lack of control over such variables as chlorination yielded results of uncertain predictive utility. Within the estuary, population densities of the zooplankton organisms remained high despite high rates of natural predation and the additional losses attributable to the power plant. Certainly, the reproductive potential of the entire population exceeded the effects of the condenser passage.

Normandeau[40] identified clear effects of condenser passage on summer zooplankton and phytoplankton at the Merrimack Generating Station. Samples taken above the inlet and in the discharge canal indicated a reduction in population density of nearly all zooplankton and diatoms after passing through the power plant. These effects were definitely related to absolute temperature, being discernible principally when the condenser cooling water was elevated in July to temperatures above 100°F. The increase in temperature by itself was not the apparent causative factor; rather, mortality was evidenced when the maximum temperature attained exceeded the tolerance limits of the species. The zooplankton population depressions were also evident in the mixing zone in the Merrimack River downstream of the plant, although cooling water was a small percentage of the total river flow at this point.[40]

On the other hand, other studies indicate little or no damage following entrainment. Adams[41] reported that the discharge canal of the Humboldt Bay Nuclear Plant on the California coast was a favorable site for natural setting of native oysters (*Ostrea lurida*), cockles (*Cardium corbis*), littleneck clams (*Protothaca staminae*), butter clams (*Saxidomus giganteus*), gaper clams (*Tresus nuttalli*), and about half a dozen other bivalves. The net flow in the canal was always outward because of domination by the cooling water flow, and complete evacuation of the canal, as revealed by dye studies, took place in less than 3 hours. Therefore, some of the free-swimming stages of these bivalves had to pass alive through the condenser system of the power plant in order to colonize the canal. Similar successful passage must have occurred at the Chalk Point Power Station on the Patuxent estuary to account for high densities of invertebrates found in the discharge canal.[42,43]

Profitt found that after the passage of minnows through condensers of a power plant, several hundred were seen dead and dying along the banks of the effluent canal.[44] In another study, preliminary observations obtained at the Connecticut Yankee Atomic Power Plant on the Connecticut River indicated that larval river herring (*Alosa* spp.) were able to successfully pass through condensers in July in which the temperature was raised to 93°F. All larvae were judged to be in good condition following the rapid thermal shock and collection by plankton net in the plant's discharge canal.[45] However, more detailed studies[46] at this site found that no larval or juvenile fish of the 9 species which were entrained in the condenser cooling-water system of the plant survived when the temperature of the canal water exceeded 86°F. Among these species were several that are found at Indian Point, including alewives, blueback herring, white perch, and American eels.

In contrast to these findings, Kerr[29] found that juvenile striped bass and Chinook salmon that passed through the condenser system of a power plant had generally high survival. Unfortunately the ambient water temperature was not reported. Kerr acknowledged the fact that the small striped bass would "readily go into a state of shock" during the experiments, and as Coutant[8] pointed out, the data from Kerr's study have little predictive value for application to other power plants.

In connection with Kerr's observation that the juvenile striped bass would go into a state of shock, it is important to recognize that considerable mortality may result from such shock which would not cause death from physiological causes and would consequently not be observed in laboratory studies. Thermal death, with an end point such as (for fish) cessation of beating of the opercula as is often used in laboratory studies, may not be the most pertitent ecological effect of acute thermal shock to organisms exposed to elevated temperatures. Heat death of cold-blooded organisms has been observed to follow a common pattern which includes, in sequence, loss of equilibrium, coma, and physiological death. These observations have been made with several species of fish and with amphibians and reptiles. They probably hold, in essence, for lower forms as well. The early stages of heat death, while not "death" in themselves, may lead to death through immobilization in the area of adverse temperature (which may prolong exposure until death results) or through stimualtion of predatory activity upon the heat-injured organisms. Both results have been observed in the field and in laboratory experiments.[8]

A concept of a critical exposure to heat, which causes equilibrium loss, similar to that proposed by Cowels and Bogert,[47] would seem to be of paramount significance in understanding the relations of aquatic populations to thermal shock in condenser cooling water of a power station, as was noted by Mihursky and Kennedy.[28] It is increasingly recognized that the demise of animal populations is not absolutely dependent upon the physiological death limits of individuals, but involves broad ecological considerations such as breeding densities and predator-prey relationships. Equilibrium loss in the natural environment is a critical occurrence for the survival of an organism because it greatly increases the organism's susceptibility to predation.

The effect of equilibrium loss in providing stimulatory cues to predators may be a particularly important feature in fish and other animals shocked by condenser cooling water. Mossman[48] cites several points of evidence that suggest release of predator attack by any behavior associated with weakness. Coutant[8] has specifically studied the effects of acute thermal shock and found that the vulnerability of thermally shocked juvenile salmonids to predation by larger fish increased. When both shocked and control fish were offered simultaneously under laboratory conditions, the shocked fish were found to be selectively preyed upon by larger fish. Relative vulnerability of shocked fish to predation increased with duration of sublethal exposure to lethal temperatures. Effects were also shown well below doses causing equilibrium losses.

Confirmation of the potential importance of predation on shocked organisms in the field situations of thermal discharges can be found in the many references to predators being attracted to points of thermal discharges. Although preference for a particular temperature range may be the predominant attractant for some organisms, it hardly would apply to concentrations of fish-eating gulls.[49] Neill[50] reported intensive feeding by fish on entrained zooplankton in the outfall area of a power plant on Lake Monona. Young-of-the-year bluegills congregated at the periphery of the discharge plume and fed on zooplankton. Several large long-nose gar, their stomachs distended by an abundance of zooplankton, were taken in and near the discharge. Bigmouth buffalo, yellow bass, bluegills, black crappeis, and brook silversides caught near the outfalls were suspected of feeding heavily on zooplankton, although confirming data were not coolected. Abundant zooplankton was entrained by this plant in cooling water taken from 100 meters offshore and 5.2 meters below the water surface. The temperature rise of 18F° may have killed or debilitated the zooplankton sufficiently that predation upon them was easier than it was in the unheated water of the lake.

Obviously, it is impossible to make absolute statements concerning the mortality of organisms which will be drawn through any given plant. The possibility is high that some fraction of the organisms entrained will be killed or damaged by the entrainment. Unfortunately, such data have not been compiled for Indian Point Unit No. 1 during critical periods of the year, although preliminary observations indicate that at least some of the organisms entrained survive.

C. DISSOLVED OXYGEN

The following analysis is derived in part from a recent review by Coutant.[8] It is known that the solubility of dissolved oxygen is less in warm water than in cool water. At Indian Point, coolant water is expected to increase by 15F° during passage through the condenser tubes under normal full-flow conditions.[51,52] At times this flow may be reduced and the maximum increase in temperature under these conditions could be as high as 25F°. Increases in temperature could therefore result in a loss of oxygen and may subsequently influence aquatic organisms. For example, the concentration of oxygen in water in equilibrium with air at 82.4°F is 7.9 ppm, whereas at 111.2°F the saturation concentration is 6.1 ppm. Another factor theoretically tending to lower dissolved oxygen concentrations in the water passing through a condenser is the partial vacuum existing at the discharge end of the condenser. This partial vacuum results from the fact that the discharge end of the condenser lies above the hydraulic gradient. This situation is common to all steam plants. Vacuum pumps are often installed in the cooling circuit to remove any accumulated air in order to reduce the effect of oxygen on corrosion of condenser tubing. The applicant discussed its model for changes in dissolved oxygen at the Indian Point Plant in evidence submitted at the ASLB hearings of April 5, 1972, and included it in its comments of May 30, 1972, in Appendix XII-23 of this Statement.

These theoretical considerations have been examined in a number of studies at operating power stations throughout the world. Alabaster and Downing,[17] after examining the literature and conducting their own studies in Britain, acknowledge that the oxygen content of water used for direct cooling may change slightly in its passage through electrical generating stations.

This appeared to be partly due to the turbulent flow in the effluent outfall causing water unsaturated with oxygen to pick up this gas, while supersaturated water lost it.

Dissolved oxygen analyses of samples taken by Alabaster and Downing[17] showed that most unheated water was not saturated, that there was either a slight rise or little change in concentration in the heated water discharged from the condensers, and that, as a result, the effluent was supersaturated with respect to oxygen (and other gases). These authors made the further (very pertinent) observation that the changes were generally small compared with those occurring in most natural waters through plant photosynthesis and respiration and through the oxidation of organic effluents.

Adams has reported similar analyses at California power stations.[41] Measurements of dissolved oxygen at intake and outfall points showed that dissolved-oxygen concentrations were not decreased in passing through the cooling water system. Rather, the water merely became supersaturated with oxygen. As the temperature of the effluent dropped in the mixing zone, saturation values dropped correspondingly, with little loss of dissolved oxygen.

Once the cooling water has entered the main body of water, rates of oxygen demand by organic materials (both living and decomposing) will be increased because of the higher temperature. In waters that are heavily loaded with decomposing organic matter, this additional demand can exceed the rate of reoxygenation through the water surface (from the air), and dissolved oxygen levels could fall below those normally expected.[53]

D. FACTORS RELATED TO THE EFFECTS OF CHEMICAL DISCHARGES

1. Sodium Phosphate

The toxicity of phosphate has been discussed by McKee and Wolf;[54] *Daphnia magna* was the most sensitive organism discussed and was affected by levels above 50 ppm. Most other organisms were much less sensitive.

Phosphates are known to be involved in the eutrophication process at times when phosphate levels limit primary production. In the Hudson, Howells and Weaver[14] found that low phosphate levels occurred at the time of maximum phytoplankton abundance. They concluded that phosphate may be limiting at times, but that it was unlikely that a significant shortage of phosphates would occur at any time in the Hudson.[14] Since the discharge concentrations will generally be only a fraction above ambient conditions, phosphate releases should not alter ambient phytoplankton production.

2. Sodium Hydroxide, Lithium Hydroxide, Sulfuric Acid

The toxicity of these compounds is related to their ability to alter pH. Because of the buffering capacity of the dilution water, discharges of these substances are not expected to alter the pH appreciably, as indicated by pH measurements made during releases of these chemicals from Indian Point Unit No. 1.[17] As a consequence, no effects on the aquatic biota are expected as a result of discharges of these chemicals.

3. Boric Acid

The minimum lethal dose for minnows exposed to boric acid for 6 hours at 68°F was found to be 18,000 to 19,500 ppm.[54] Wallen found that 18,000 ppm was needed to kill 50% of test mosquito fish in 24 hours and that 5,600 ppm caused 50% mortality in 96 hours.[56] Boric acid can be toxic to freshwater fish without lowering the pH to 5.0.[56] Thus, pH is not a reliable index of toxicity of boric acid. However, concentrations of up to 2,000 ppm have been found nontoxic to fish,[24] and over 1,000 ppm are required for 50% inhibition of the utilization of oxygen by synthetic sewage. On the other hand, many terrestrial plants are sensitive to concentrations of boron in the range of 1 ppm.[54]

4. Hydrazine

Hydrazine is a fuming oily liquid with a penetrating odor and is a violent poison. Hydrazine hydrate, NH_2NH_2O, a fuming refractive liquid with a faint characteristic odor, is miscible with water and is presumably in the form of N_2H_4 when used in water treatment.

At 0.7 ppm, hydrazine hydrate caused fingerling trout to lose equilibrium in less than 24 hours. On the other hand, hydrazine hydrate had no effect on sea lampreys exposed for 24 hours at a concentration of 5 ppm.[54] Corti reports that rainbow trout exposed to 146 ppm of hydrazine at pH 8.35 and 56.3°F demonstrated an adverse reaction after 14 to 18 minutes and succumbed completely in 22 to 35 minutes.[54]

5. Soda Ash (Sodium Carbonate)

The threshold concentration of sodium carbonate for immobilization of *Daphnia magna* in Lake Erie water at 77°F was reported to be between 424 and 300 ppm. The minimum lethal concentration for *Daphnia* was shown to be 300 ppm, and at 800 ppm all were killed. The threshold of toxicity toward *Daphnia* depends on the dissolved oxygen content of the test water. At 73.4°F for a 100-hour exposure the threshold toxicity level was 552 ppm at a dissolved oxygen concentration of 6.5 ppm, but only 267 ppm when the dissolved oxygen dropped to 1.53 ppm. The toxicity of this compound to fish was reported to range from 60 to 1,200 ppm.[54]

6. Potassium Chromate

The toxicity of potassium chromate toward aquatic life varies with the species, temperature, pH, and other compounds that are present. Extensive literature exists on the toxicity of chromates.[57] In general, fish are more tolerant of chromium salts, but many invertebrates and aquatic algae are very sensitive. Toxic effects have been observed on *Daphnia magna* at values less than 0.01 ppm and on many microcrustaceans and algae at concentrations less than 1 ppm. Toxicity to fish begins around 5 ppm.

7. Sodium Hypochlorite - Residual Chlorine

Merksen[58] found that at a pH of 7.0, 0.08 ppm of residual chlorine killed half of his test rainbow trout in 7 days. Zillich[59] found chlorinated sewage effluent to be toxic to fathead minnows at residual chlorine concentrations of 0.04 to 0.05 ppm. Basch[57] found that 50% of a population of rainbow trout could tolerate 0.23 ppm for only 96 hr. Arthur and Eaton[60] found that half of a population of the invertebrate *Gammarus pseudolimnaeus* survived 96 hours at a concentration of 0.22 ppm and that reproduction was reduced when chronic concentrations (for 15 weeks) were maintained at 0.0034 ppm. They also found that the highest concentration that produced no effect on the life cycle of the fathead minnow was 0.016 ppm. Sprague and Drury[61] showed an avoidance response by rainbow trout to free chlorine levels of 0.001 ppm.

Generally, concentrations of free chlorine tend to decay rapidly; however, if ammonia is present, chloramines will be formed which are more persistent in the natural environment. Since ammonia levels in the Hudson have been measured up to 0.5 ppm,[62] chloramine concentration in the discharge water may be relatively high.

Much progress was made in the 1940's in the use of chlorine for the sterilization of water supplies. Griffin[63] gave an annotated guide to over a hundred papers published between 1939 and 1952. Fair[64] gave a lucid exposition of the behavior of chlorine as it was then understood. The subject has been summarized recently by Lewis.[65]

Certain terms have come into use to describe chlorine in water. They are often used carelessly in industrial practice. The distinctions given are those of Lewis.[65]

(a) Free chlorine (short for free available chlorine): that part of the chlorine injected into the water that remains as molecular chlorine, hypochlorous acid, and hypochlorite ion.

(b) Combined chlorine (short for combined available chlorine): that part of the chlorine injected into the water that remains combined with ammonia or other nitrogenous compounds.

(c) Active chlorine (alternative for total available chlorine or chlorine residual): the total free and/or combined chlorine that remains. The terms "active" and "available" refer by implication to activity and availability for sterilization. The amount of "active chlorine" present is recognized as being equivalent to the amount of iodine that will be released from potassium iodide at acid pH.

(d) Chlorine demand: by implication, the exact amount of chlorine required to oxidize completely all compounds that reduce free chlorine in the water. These compounds include both organic and inorganic substances. In practice, the term is used when referring to the difference between the dose and the active chlorine left (chlorine residual) after a particular period of contact, for one particular dose rate.

1. Reactions During Chlorination

When sodium hypochlorite is dissolved in water it dissociates into a sodium ion and a hypochlorite ion:

$$NaClO = Na^{+} + ClO^{-} \quad , \quad \text{and} \quad H^{+} + ClO^{-} = HClO \; .$$

At pH 7.0 the equilibrium is approximately 75% $HClO$, 25% ClO^{-}, and at pH 8.0 this is reversed to approximately 25% $HClO$, 75% ClO^{-} (at a water temperature of 68°F).

There are apparent differences in disinfecting properties of chlorine gas and hypochlorite solutions, which Fair *et al.*[64] considered to be caused by failure of the experimenter to adjust the pH, or other experimental errors. Injection of chlorine gas will lower the initial pH, whereas addition of hypochlorite solution will raise the pH.

When ammonia or organic amines are present in the water they react with hypochlorous acid to give chloramines. The first step is the formation of monochloramine:

$$NH_3 + HClO = NH_2Cl + H_2O \ .$$

The rate of reaction between ammonia and hypochlorous acid is dependent on pH and is at a maximum at pH 8.3. Fair *et al.*[64] found that for a mixture of 0.8 ppm* chlorine and 0.32 ppm ammonia nitrogen, at 25°C, 99% of the chlorine reacted in 1 minute at pH 8.3, in 210 minutes at pH 5.0, and in 50 minutes at pH 11.0. They found that the rate of reaction varied with temperature (Q_{10} values ranging from 2.0 to 2.5 according to pH).

The next step is the formation of dichloramine from monochloramine and hypochlorous acid:

$$NH_2Cl + HClO = NHCl_2 + H_2O \ ,$$

the dichloramine being in equilibrium with monochloramine:

$$2NH_2Cl + H^+ = NH_4{}^+ + NHCl_2 \ .$$

This equilibrium depends upon both pH and the ratio of chlorine to ammonia. Fair *et al.*[64] found that with a chlorine-to-ammonia-nitrogen ratio of 5:1, the relative percentages of the two chloramines were: at pH 5.0, 16% monochloramine and 84% dichloramine; and at pH 8.0, 85% monochloramine and 15% dichloramine. The third step in the chloramine formation is quoted as:

$$NHCl_2 + HClO = NCl_3 + H_2O \ ,$$

but, little is known about the reactions at this stage.[65] As more chlorine is added in excess of that required for the above reactions, the chloramines break down, with an overall reaction:

$$3Cl_2 + 2NH_3 = N_2 + 6Cl^- + 6H^+ \ ,$$

giving a chlorine-to-ammonia-nitrogen ratio of 7.6:1.

Theoretically, with a chlorine-to-ammonia-nitrogen ratio of 7.6:1, the reaction should be complete, so that no residual chlorine remains. This is known as the breakpoint. With a higher percentage of chlorine, the excess should remain as free chlorine, and with

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* ppm = parts per million.

a lower percentage of chlorine, the chlorine should consist of a mixture of mono- and dichloramine.

In practice, when waters containing organic amines, as well as ammonia, are chlorinated, such a clearcut breakpoint is not obtained. Pulham[66] gave some "illustrative" breakpoint curves for these conditions. These curves show that where organic amines are present it is possible for chloramines and free chlorine to coexist. This is shown diagrammatically in Fig. A-V-4. Presumably, where free chlorine coexists with combined chlorine, all mono- and dichloramine (inorganic) must have been oxidized, and the remaining combined chlorine must be organic chloramine.

Ingols[67] studied reactions between chlorine and sulfur-containing amino acids (at concentrations of 10^{-4} M amino acid). It was found that HClO would oxidize sulfhydryl groups to sulfonic groups and then deaminate the amino acid via the formation of chloramines. With slightly more monochloramine, an organic chloramine formed that was stable for some hours. With monochloramine the sulfhydryl groups were oxidized to give disulfide linkages.

2. Reactions During Periods of Salt Intrusion

When saline water is present at Indian Point, another reaction will be involved. Since the low flow conditions which favor the buildup of chlorinated residues are accompanied by saline water at Indian Point, these reactions are important.

In 1955 Johannesson[68] pointed out that seawater may contain up to 68 ppm bromide and that the reaction:

$$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$$

goes to completion. The dissociation products, HClO and ClO^-, will, however, release bromine from the bromide ion in the form of hypobromous acid and hypobromite ion:[65]

$$ClO^- + Br^- \rightarrow BrO^- + Cl^-$$

$$BrO^- + H^+ = HBrO \ .$$

Addition of chlorine water to a solution of bromide and ammonium salts, buffered to pH 8.3 with bicarbonate, resulted in a mixture of monobromamine and some monochloramine, but addition of a sodium hypochlorite solution gave mostly monochloramine. This relationship results because the hypochlorite in solution will react with both the bromide and ammonia according to the equations:

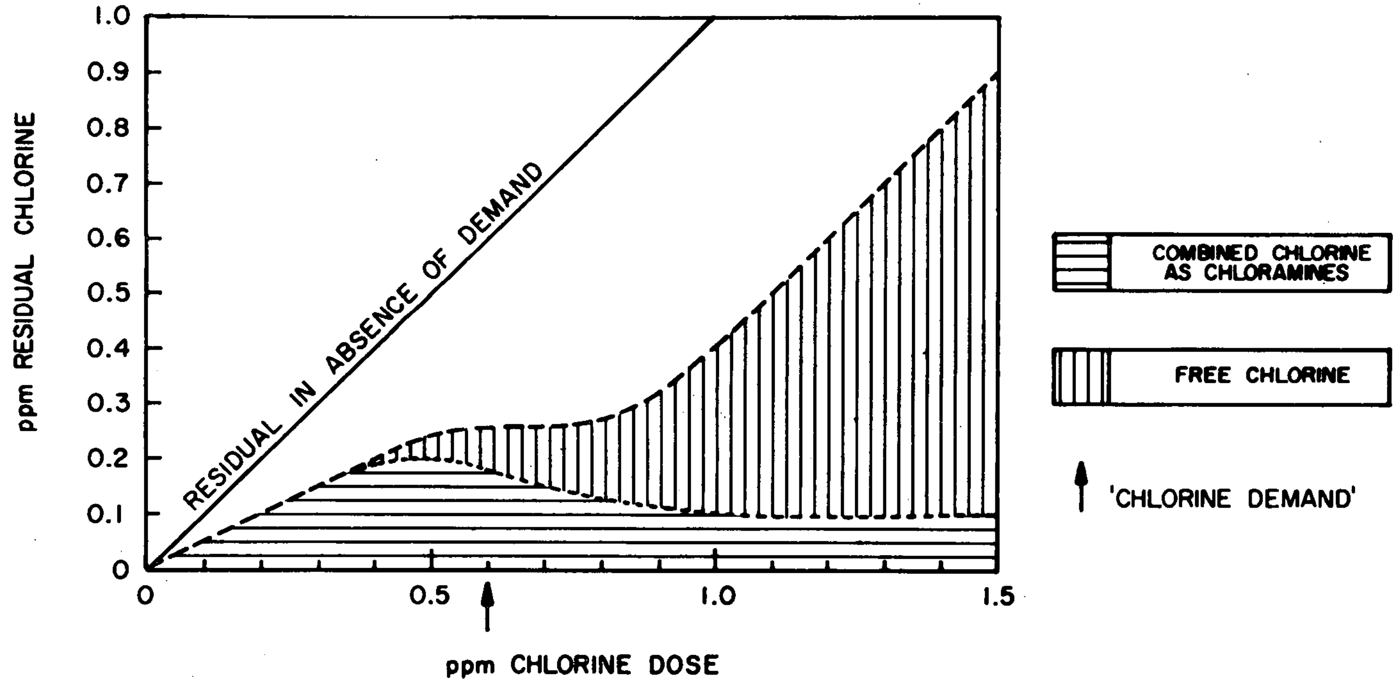

Fig. A-V-4

Typical Pattern of Chlorine Reaction With Natural Water. Actual Scale Values Are Dependent Upon Local Conditions.

$$ClO^- + Br^- \rightarrow BrO^- + Cl^- \text{ ,} \qquad \text{(A)}$$

$$ClO^- + NH_3 \rightarrow NH_2Cl + OH^- \text{ .} \qquad \text{(B)}$$

Reaction A is only rapid at pH values below 8.0 (at pH values between 8.0 and 10.0 the reaction takes some minutes to reach completion). Reaction B is rapid at pH 8.3 (99% complete in 1 minute at 25°C), but slower at higher and lower pH values. If chlorine gas is injected into seawater, local acidity can be produced, depressing the pH below the normal range of 8.0 to 8.3. In these circumstances reaction A will be favored. However, when sodium hypochlorite is added, the pH is not depressed, and reaction B is favored.[65,68]

Johannesson[69] also stated that he had found dibromamine was formed:

$$NH_2Br + BrO^- \rightarrow NHBr_2 + OH^- \text{ .}$$

This existed only in equilibrium with monochloramine, the balance depending on the ammonia-to-bromine ratio (i.e. monochloramine and dichloramine). In the presence of excess bromine the mono- and dibromamine break down, and the same form of breakpoint curve is obtained as for chlorine and ammonia. But Johannesson[69] was not convinced that nitrogen tribromide took part in the breakpoint reactions, although its analogue, nitrogen trichloride, had been proposed as a stage in the breakdown of chloramines.

Monobromamine apparently has greater oxidizing properties than monochloramine, and, as a result, tests that distinguish between free and combined chlorine fail to distinguish between free and combined bromine. Johannesson[69] explained that this was on account of the presence of significant proportions of a monobromammonium ion:

	pH 7.5	p 8.5
Ratio of monobromammonium ion to base monobromamine	1:10	$1:10^2$
Ratio of monochlorammonium ion to base monochloramine	$1:10^7$	$1:10^8$

These reactions are essentially similar to those described for chlorine, with the exception that monobromamine is a larger oxidizing agent than monochloramine.

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At Indian Point the normal chlorination process will be to inject sodium hypochlorite into the circulating water flow. During periods of salt water intrusion, some of the chlorine can be expected to react with the bromide as described above. The net result, presumably, will be that there will always be some combined chlorine and some combined bromine in any chlorinated saline water passing through the Indian Point Station. The actual composition of the residual must vary with mixing, amount and types of organics present in the water, and rates of reaction (particularly the dissociation of hypochlorous acid, the release of bromine, and the formation of chloramine), which will depend on temperature, pH, and length of contact.[65]

3. Analyzing for Chlorine Residuals

Several evaluations have been made of the numerous analytical methods used for determining residual chlorine in water (Table A-V-1). Nicolson[70] who evaluated 9 colorimetric and 3 titrimetric methods, found that the barbituric acid method was the best laboratory colorimetric procedure if combined chlorine residual was absent. In the presence of combined chlorine, the N,N-diethyl-p-phenylenediamine (DPD) method was more satisfactory. Lishka,[71] who analyzed the results from 72 participating laboratories using several different analytical methods, reported that the ferrous-DPD method had the best accuracy and precision, followed closely by the methyl orange, SNORT (Stabilized Neutral Orthotolidine), and amperometric methods. None of the methods has outstanding reliability even when care is taken (see Table A-V-1). Reliability is undoubtedly even less in truly routine analyses.

The standard methods for the examination of water and wastewater[72] include the ferrous-DPD, the orthotolidine-arsenite, the leuco crystal violet, the methyl orange, and the SNORT methods, all of which determine both free and combined chlorine residuals. However, the determination of combined residual is dependent upon monochloramine and dichloramine and the extent of their influence depends upon the types of organic compounds present.

The role of bromine as related to these determinations is not clear at present. Most of the tests for residual chlorine would include the residual bromine but would not tell the relative proportion of the two elements. It is evident that the chemistry of chlorine in seawater is quite complex and that further work is required to investigate this chemistry and to produce useful analytical techniques.[65]

APPENDIX V-1

TABLE A-V-I

PRECISION AND ACCURACY DATA FOR RESIDUAL CHLORINE METHODS BASED UPON DETERMINATIONS BY SEVERAL LABORATORIES(72)

Method	Residual Chlorine Concentration		Number of Laboratories	Relative Standard Deviation %	Relative Error %
	Free µg/l	Total µg/l			
Iodometric		840	32	27.0	23.6
		640	30	32.4	18.5
		1,830	32	23.6	16.7
Amperometric	800		23	42.3	25.0
		640	24	24.8	8.5
		1,830	24	12.5	8.8
Orthotolidine	800		15	64.6	42.5
		640	17	37.3	20.2
		1,830	23	35.0	49.6
Orthotolidine-arsenite	800		20	52.4	42.3
		640	21	28.0	14.2
		1,830	23	35.0	49.6
Stabilized neutral orthotolidine	800		15	34.7	12.8
		640	16	8.0	2.0
		1,830	17	26.1	12.4
Ferrous DPD	800		19	39.8	19.8
		640	19	19.2	8.1
		1,830	19	9.4	4.3
Leuco crystal violet	800		17	32.7	7.1
		640	17	34.4	0.9
		1,830	18	32.4	18.6
Methyl orange	800		26	43.0	22.0
		640	26	30.1	14.2
		1,830	26	19.9	7.2

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APPENDIX V-2

ENTRAINMENT

Entrainment at the Indian Point Station is influenced by seasonal variations of the estuarine hydraulics near the site. Under average conditions, the freshwater flow of the Hudson River ranges from a maximum of over 30,000 cfs in the spring to a minimum of 6,500 cfs during the late summer. The maximum water requirements of Indian Point Units Nos. 1 and 2 of 2,650 cfs correspond to a range of less than 9% to about 40% of the available freshwater flow. During drought conditions, such as those in August 1964 when the freshwater flow rate dropped to about 3,050 cfs, the water requirements might be as high as 87% of the freshwater flow. Under average conditions, the annual water requirement will be about 13% of the freshwater flow.

This proportionally high usage of Hudson River water appears to have a potential for exposing a large part of the planktonic community to thermal, physical, and chemical damage by entrainment with the circulating cooling water. The ecological effects of such entrainment are the result of both biological and non-biological factors. The biological factors (Section V.D.1) indicate that two aspects of entrainment may be particularly important: the concentration of entrained organisms at various points in the river and the fraction of organisms originating above the site which pass through the two Units before they leave the area in the downstream direction.

In this appendix, the staff estimates the fraction of entrained organisms that migrate by the condenser inlet in a more or less passive state, i.e., possess only small motive power of their own and largely follow the direction of the fluid velocity.

A. TECHNIQUE FOR ENTRAINMENT CALCULATIONS

Although many organisms evidently do possess some motive power, the following discussion is simplified by being limited to passive organisms only. For the same reason, the organisms are assumed to be uniformly distributed across the width of the river at all times and to have the same specific density as water. In addition, calculations are based on average values over a tidal period. The results must be considered then as tentative approximations, subject to the above limitations, which will be further discussed at the end of this appendix. These approximations require further field investigations.

The organisms, while being transported downstream along the river, are repeatedly exposed to the possibility of entrainment because of tidal oscillations. If n is the number of times that an organism is exposed to the intake, and if P_e is the probability of entrainment per exposure, then the total capture probability, P_T, can be approximately calculated by

$$P_T = 1 - (1-P_e)^n \qquad (1)$$

The probability that an organism moving past the station intake will be withdrawn, assuming uniform distribution, is

$$P_e = Q_C/Q_T \ . \qquad (2)$$

where

Q_C = condenser cooling water intake flow, cfs
Q_T = total flow averaged over a complete tidal period, cfs

If the organisms discharged from the condenser are mixed with the fresh ones, then the probability of an organism being withdrawn on each exposure reduces to

$$P_e = \frac{Q_C}{Q_T}\,(1-\nu), \qquad (3)$$

where ν is the fraction resulting from re-exposure of the same water volume from direct recirculation.

The number of exposures of one organism to the Station intake can be estimated as twice the ratio between the tidal excursion length and the net downstream movement per cycle period. When based on a common cross sectional area, the number of exposures will be equal to

$$n = Q_T/Q_{TR} \qquad (4)$$

where Q_{TR}, termed "transport flow," is defined as the effective net downstream transport flow that determines the net movement downstream toward the ocean of a specific passive organism under consideration. This term will be discussed later.

Substitution of Equations (3) and (4) into Equation (1) gives:

$$P_T = 1 - \left[1 - \frac{Q_C}{Q_T} \quad (1-\nu) \right] Q_T/Q_{TR} \qquad (5)$$

For $Q_T >> Q_{TR}$, Equation (5) simplified to:

$$P_T \approx \frac{Q_C}{Q_{TR}} \ (1 - \nu) \left[1 - 1/2 \ (1 - \nu) \ \frac{Q_C}{Q_{TR}} \right] \qquad (6)$$

Equation (6) shows that the total probability of being withdrawn is proportional to the ratio of cooling water flow to transport flow. It is almost independent of the tidal characteristics, although these important characteristics do provide the energy for mixing and dilution that must exist for this model to be correct.

When both Units are operating at full capacity, the cooling water flow will be approximately 2,650 cfs. The tidal flow past the site 80% of the time[1] is about 180,000 cfs. At this flow, the probability that a planktonic organism moving past the Plant will be withdrawn is

$$P_e = Q_C/Q_T = 2650/180{,}000 \cong 0.015.$$

This estimate is an average probability of withdrawal since the tidal flow ranges from zero to a peak that may exceed 300,000 cfs. With lower tidal flows, the Q_C/Q_T ratio would increase and thereby increase the probability of withdrawal. On the other hand, the 180,000-cfs estimate of average tidal flow would often be exceeded, thereby decreasing the probability of withdrawal from the maximum value. Based on these considerations, the staff agrees that the applicant's estimate of 0.015 (1.5%) seems reasonable.

Figure A-V-5 gives the probability of organisms being withdrawn as a function of transport flow for different amounts of recirculation.

Some measurements made at the intake while Indian Point Unit No. 1 was in operation[2] showed an increase of about 1.5 to 2.0F° over the ambient temperature. This increase in intake water temperature indicates the amount of recirculation at the outfall for Unit No. 1. The basic condenser temperature difference is reported to be 14.9F°. If these data are taken as representative the percentage recirculation can be estimated by

$$\nu = \frac{\text{additional increase in condenser } \Delta T}{14.9}$$

$$\nu \approx 2/14.9$$

$$\nu \cong 0.14.$$

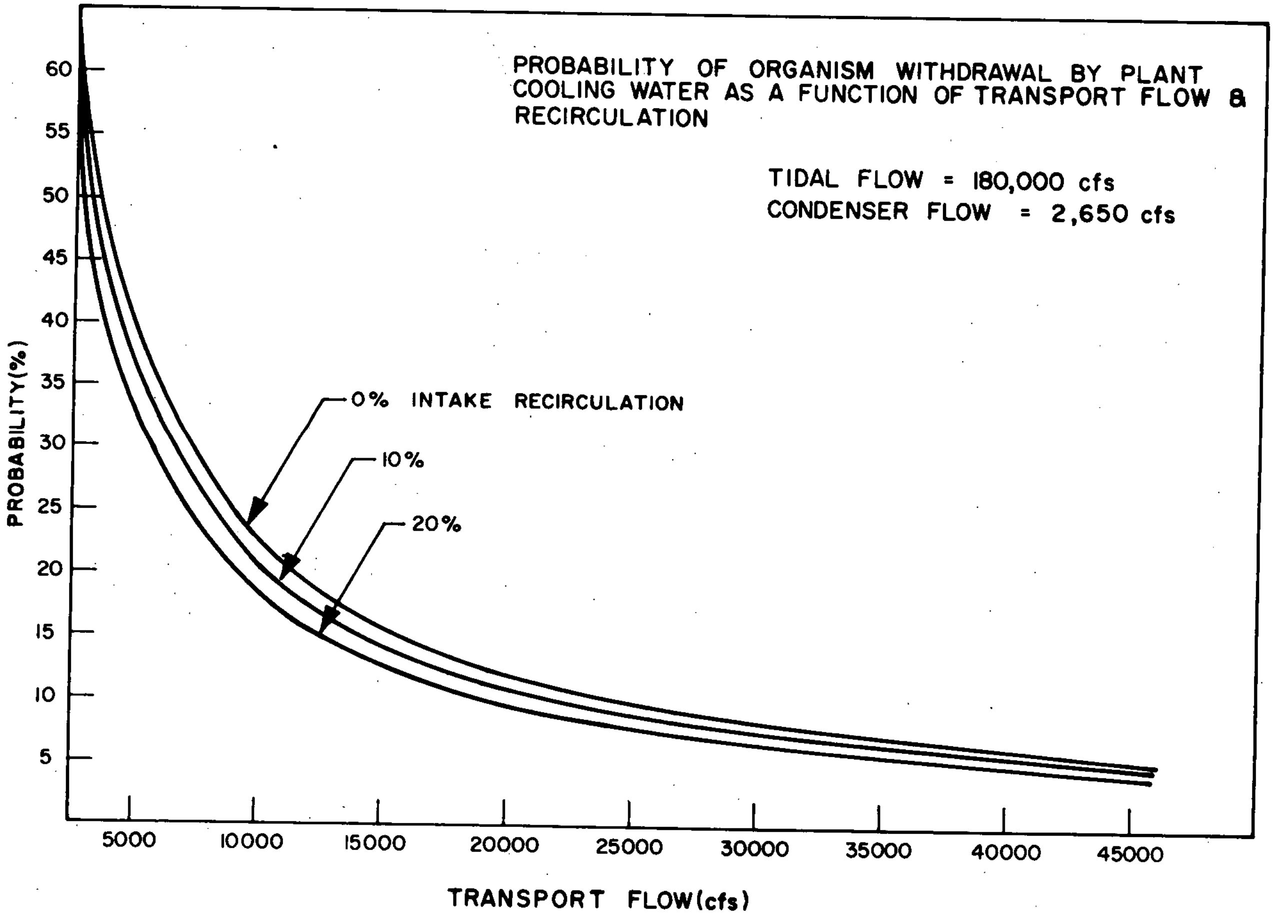

Fig. A-V-5
Entrainment by Indian Point Units No. 1 and 2 vs Transport Flow.
(Probability Based on Dilution Flow.)

The 1.5 to 2.0F° increase in condenser ΔT could occur only under conditions of incoming tide and is not expected to be this great. The assumption of an average recirculation of 10 to 15% seems reasonable, but measurements during operation of Unit No. 2 are necessary for verification. Figure A-V-5 is used to estimate the total entrainment probability once the net downstream transport flow (Q_{TR}) is established.

B. EVALUATION OF TRANSPORT FLOW FOR PASSIVE ORGANISMS

During the spring, high runoff flows drive the salt intrusion zone downstream, resulting in single layer fresh water flows at Indian Point. Under this circumstance, the net downstream transport flow will be equal to the freshwater flow. Field observations show that the salt front will penetrate the Hudson as far upstream as Indian Point when the freshwater flow is around 20,500 cfs. Figure A-V-6 shows that this will happen during the months of March, April, and May. Using Figs. A-V-5 and A-V-6, the staff finds that the entrainment probabilities for those three months are:

Month	Runoff flow (cfs)	Entrainment (%)
March	28,000	8.0
April	38,000	5.5
May	21,000	10.0

However, for the rest of the year, the salt front is upstream of Indian Point, and it is difficult to establish the correct transport flow because of the complex flow patterns created by the combined effects of freshwater flow, tidal flow, and density-induced flow. (See Section II.E.1 for the description of the hydraulics of the Hudson River.)

There are two viewpoints on the method to be used for calculating the net downstream transportation of a substance along the river. One sees the apparent upper layer of the river as the main vehicle that determines the rate of transport of any passive organism downstream toward the ocean, while the second sees the net dilution of the fresh water by saline water penetrating from the ocean to a certain point into the estuary as the resultant flow for net downstream transport.

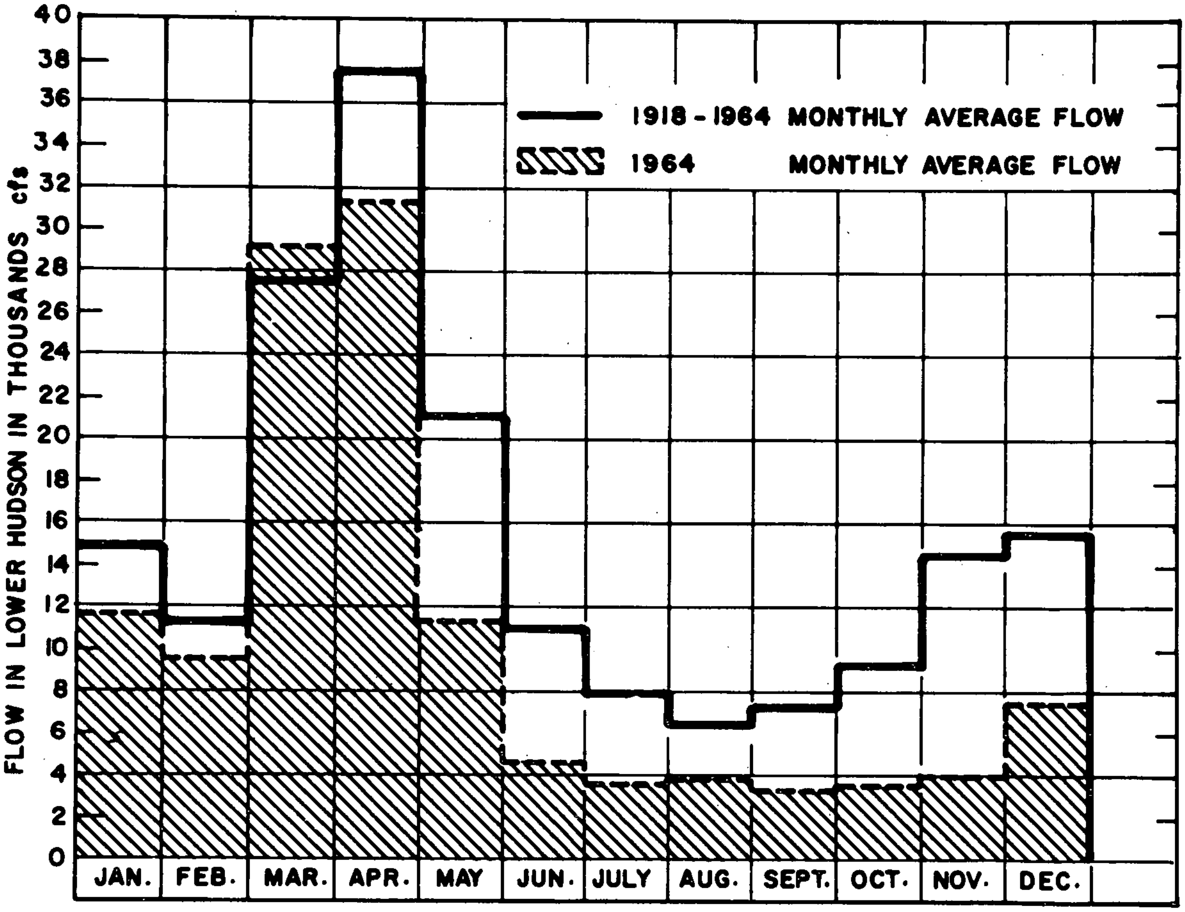

Fig. A-V-6
Freshwater Flow in Lower Hudson at Indian Point.

The relative amounts of fresh and salt water at any point in the river can be determined by the salt concentration at that point.[3] Thus, at Indian Point when the salt concentration is 2 ppt, the water is 1/16 seawater and 15/16 fresh water. To maintain this concentration, a particular volume of seawater must move up through the Hudson River to Indian Point to provide sufficient salt to change the salt concentration of the fresh water to the observed concentration (2 ppt). This volume may be calculated by the following formula:[3]

$$V_s = \frac{(V_f)(S_X)}{S_o - S_X} , \qquad (7)$$

where

V_s = volume of the source water (ocean water at estuary mouth containing 30 ppt of salt),

V_f = volume of fresh water discharge,

S_X = salinity of sample at location X averaged over both tidal period and cross-sectional area,

S_o = salinity of the source (ocean).

Since the water derived from the ocean is diluted with the freshwater flow, the amount of water containing S_X ppt of salt that is generated by the dilution is equal to the sum of the volume of fresh water moving downstream and the volume of salt water that must move upstream to change the salinity of the fresh water to the local salinity value. This total dilution volume can be expressed as:

$$V_T = V_f + \frac{(V_f)S_X}{S_o - S_X} , \qquad (8)$$

where

V_T = total volume of water of particular salinity.

Equation (8), when expressed in terms of flows, will have the form

$$Q_D = Q_R \; 1 + \frac{Sx}{So - Sx} , \qquad (9)$$

where

Q_R = river freshwater flow,

Q_D = dilution flow.

It should be pointed out that the dilution flow, as computed from Equation 9, represents a much lower flow rate than the so called upper layer flow rate thought to exist the Hudson River (see Section III.E.1.d.).

If the first approach is used, the transport flow will be considered equal to the upper layer flow. If the dilution approach is used, the transport flow will be considered equal to the dilution flow as calculated by Ketchum's model (Equation 9). The quantitative difference between the two methods is quite large. For example if the freshwater flow is 4,000 cfs, Fig. II-8 in Section II.E.1 shows that the average salinity at Indian Point is 7.15 ppt, where the salinities of the upper and lower layers are 6.9 and 7.4 ppt, respectively. Ketchum's model, expressed by Equation 9, gives a transport flow of

$$Q_{TR} = Q_D = Q_R(1 + \frac{S_X}{S_o - S_X}) = 4000(1 + \frac{7.15}{30 - 7.15}) = 5250 \text{ cfs.}$$

which gives (Fig. A-V-5) an entrainment probability of about 32%.

However, under the two-layer approach, considering the upper layer flow as the effective flow for downstream transport and using the applicant's claim[4] of an upper layer flow of about 35,000 cfs, one gets (Fig. A-V-5) an entrainment probability of about 7%.

Clearly then, the estimated entrainment probability of passive organisms will depend strongly on the model adopted for calculation of the net downstream transport flow. In addition, if the upper-layer model is used, the magnitude of the upper layer flow will be of major importance and must be correctly established.

The reasoning behind the dilution model can be more clearly understood when based on a transient real-time approach. The time-averaged quantities are good for calculation convenience only. When the velocity profiles in a full cross section of the Hudson River are averaged over a full tidal period, the result is a net effect of two-layer flow, where the lower layer moves upstream and the upper layer moves downstream. However, in reality, at no time, except maybe at tidal flow reversal, does any single cross section of the river experience such opposing velocities at the lower and upper layers. As is well known, the tidal flows predominate all other flows in the Hudson River estuary. However, because of large scale density-driven horizontal circulation, the lower layer velocities are augmented during the flood phase of the tide and retarded during the ebb phase. Figure A-V-7 shows tidal velocity observations,[5] as a function of depth, for 10% intervals throughout a tidal period. Very clearly, the "two-layer" flow reversal does not really exist as such. Only when velocity profiles are averaged over a complete tidal period is there a net effect of two-layer flow.

If a particle is visualized as being inserted in the upper layer in such a way that it could move only in the horizontal direction but was constrained from moving vertically, the net downstream movement of this particle will be the same as the upper layer net-tidal-averaged velocity. On the other hand, the same particle can be visualized as having a vertical motive power of its own such that if the water were stagnant it would move back and forth in a vertical direction only. This vertical motion can be assumed to be rapid so that during a complete tidal period, which is indeed relatively long (about 12 hours), the particle could complete a large number of such vertical trips from top to bottom. In such a hypothetical case, the net downstream movement of the particle will be equal to the net velocity of the river freshwater runoff. These two extreme cases demonstrate that the net downstream movement of a particle depends very strongly on its superimposed vertical motion. The degree of such vertical motion that can be imposed by the fluid on a passive particle in the zone of salt intrusion in an estuary will depend a great deal on the existence and extent of vertical mixing. The more vertical mixing, the slower the net downstream movement of a neutral substance.

Observation of the salt concentration distribution in the Hudson River near the Indian Point site (see Fig. II-8 in Section II.E.1) shows that the vertical salt concentration profiles are not at all sharp and certainly do not show any clear distinction between two layers. This is evidence that vertical mixing is indeed an important phenomenon in the Hudson River estuary. Of course, the existence of some vertical difference in salt concentration means that the estuary is certainly not completely mixed vertically. The correct degree of vertical mixing must be established from field data.

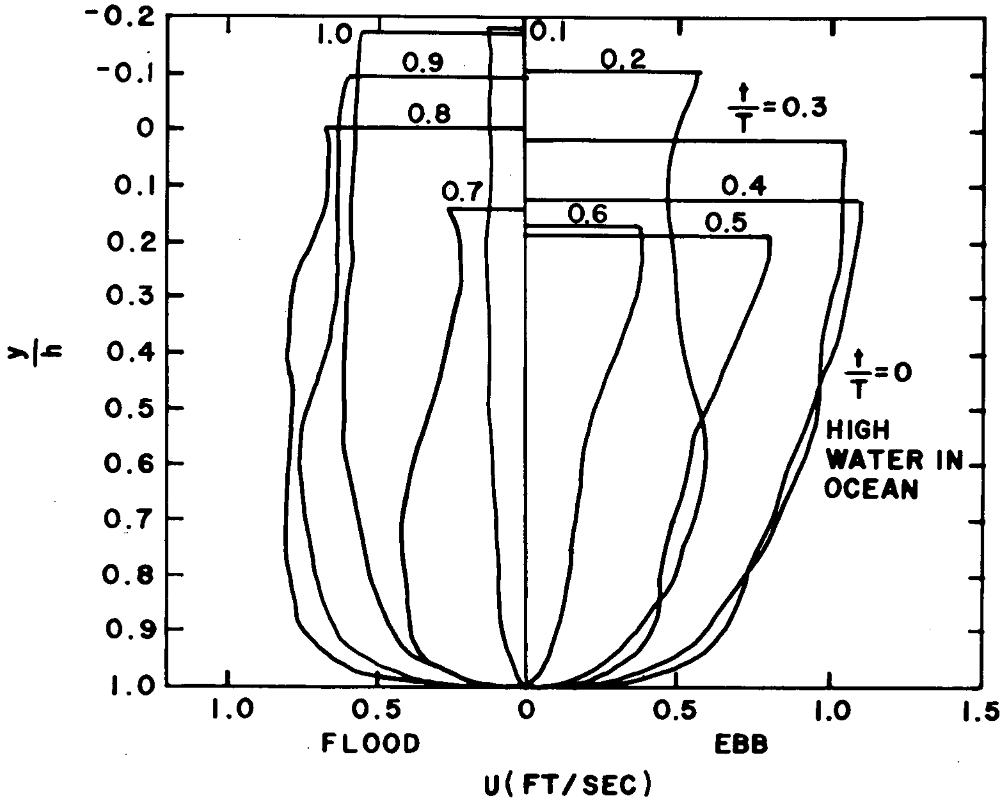

Fig. A-V-7
Horizontal Velocities Throughout Tidal Cycle, Test 14, Sta. 40. From Harleman and Ippen (1962). Indian Point

Based on the above, the staff tends to believe that the net downstream movement of a neutral substance cannot be correlated by the two-layer concept even though the phenomenon is a real one as far as average convective flows are concerned. The dilution approach is probably more proper for estimating downstream movement although it will probably tend to underestimate this movement for a neutral substance since it assumes complete vertical mixing. If for some reason, the substance has a preference for the lower layer, the dilution approach will actually overestimate this downstream movement.

Some evidence that the upper layer flow can not be equated with net downstream transport can be found in a large tracer study made by Hohman and Parke.[6] Figure A-V-8 shows the results of this study in terms of net downstream movement of a passive dye. This movement seems to be below 5 miles/week past the Indian Point site when the average freshwater flow is about 3,000 cfs. This is much closer to what might be predicted by the dilution model than that predicted by the upper layer concept. Based on the upper layer concept and assuming 35,000-cfs upper layer flow as claimed by the applicant, the downstream velocity is estimated to be about 50 miles/week. Even if we recognize that this upper layer flow is grossly overestimated, the contrast is apparent.

Additional comparisons can be made with Pritchard's analysis of the Calvert Cliffs Plant (Reference 14 in Appendix V-3) where he found (using a compartment model for that site where Q_U = 207,500 cfs, Q_L= 166,000 cfs, and Q_R = 41,500 cfs) that the value of net dilution water was 90,000 cfs. This value corresponds to the value predicted from Equation (2) at a salinity of about 16.5 ppt, which is approximately the mean salinity for the specified conditions. Note also that Pritchard does not use the apparent upper layer flow as equal to the "dilution flow."

The high concentration of aquatic organisms observed at Indian Point also seems to indicate that the upper layer downstream flow probably is not the effective mechanism for transporting these organisms from the site. The downstream transport of organisms represents a loss from local populations; thus, for these populations to maintain themselves, each must recruit additional members. This recruitment may consist of immigration from upstream populations or of increased reproduction of organisms in the local population. Passive downstream migration above the salt water front would occur at a rate determined by the freshwater flow; thus, immigration of organisms from fresh water to locations within the saline zone is dependent

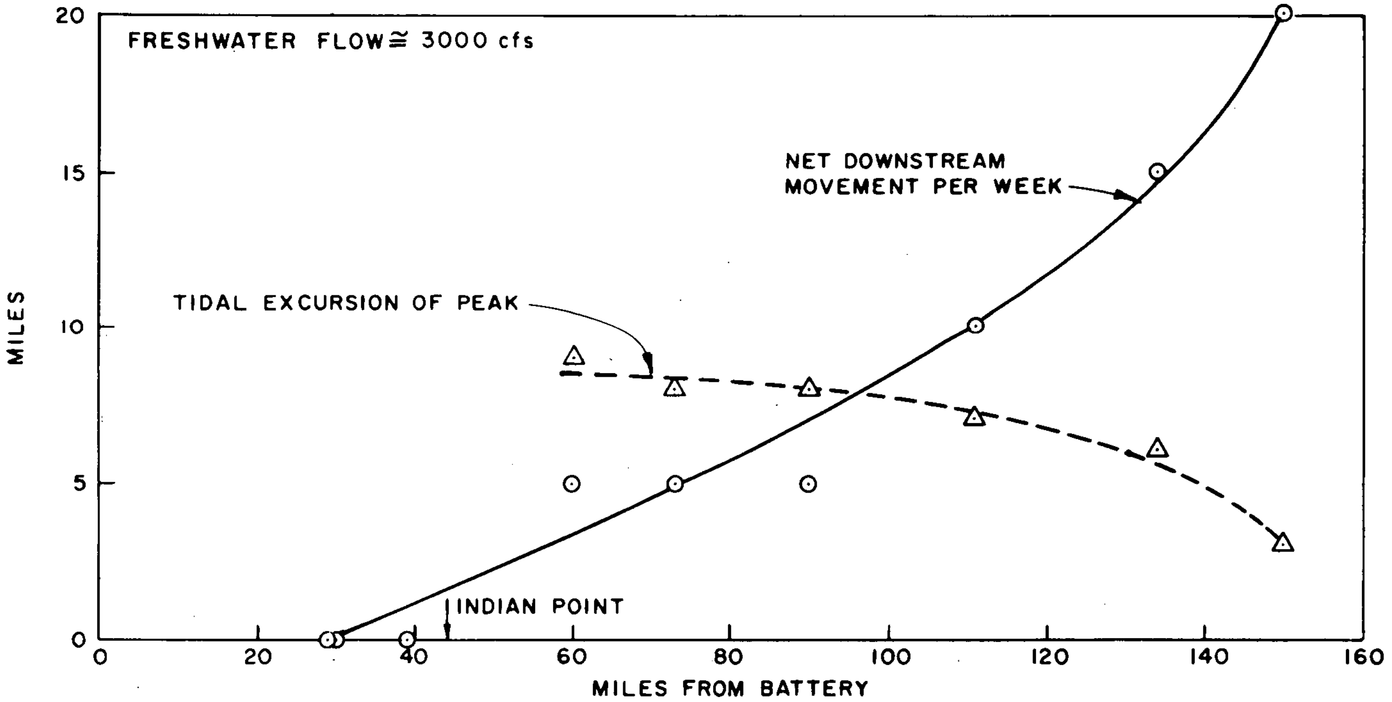

Fig. A-V-8
Transport of a Conservative Dye Downstream Past the Intake of Indian Point Unit l and 2.

on the magnitude of the freshwater flow. On the other hand, populations that originate in saline water must be able to reproduce at a rate sufficient to compensate for the continuous loss of individuals that results from net downstream transport. Thus, population densities and reproductive capabilities of the various species provide an indication of the relative magnitude of the net downstream loss.

Movement of 50 miles/week is about equal to one tidal excursion per day at Indian Point; thus, the assumption that the upper layer flow is the net transport flow would require that the daily recruitment to passive plankton populations in the Indian Point area would be equal to the total population present. This is clearly not possible for species of estuarine microcrustaceans that have generation times in excess of this period. For example, Heinle[7] found that the populations of the copepod, *Arcartia tonsa,* could not survive losses in excess of about 20 to 25% per day. Thus, a net downstream transport flow of 35,000 cfs would not permit populations of this species to survive at Indian Point. However, *Arcartia tonsa* is known to be a dominant species at Indian Point when the freshwater flow is below 8,000 cfs; thus the more conservative estimate of dilution flow would appear to describe better the net downstream transport of these organisms.

The dilution flow concept of net downstream transport flow was used to calculate the entrainment probabilities for passive organisms for each month of the year, based on monthly average freshwater flows for the years 1918-1964. The results are summarized in Fig. A-V-9. The withdrawal probability ranges from a low value of 6% (for April) to a high value of 31% (for August). The average annual value for the years 1918 to 1964 is about 17%. However, in some dry years, e.g., 1964, the yearly average might be close to 30%, and monthly averages may exceed 45% during dry months.

C. PREDICTIVE CAPABILITY

A probability value of 17% refers to the average likelihood of withdrawal of randomly distributed planktonic forms that originate upstream of Indian Point. Various sections in the river would have different probabilities. Organisms in areas close to the intake structure would have the greatest probabilities and organisms in areas near the opposite west shore would have the smallest probabilities of being withdrawn with each pass. With tidal flows of 180,000 cfs and a net downstream transport flow of 7,000 cfs, a typical organism near the west bank on its first pass would have about 8 days' exposure to the intake and would be mixed through 25 cycles of the tide; its susceptibility at this flow would be higher than that at a higher transport flow where proportionally less mixing would occur before the organism left the area. The importance

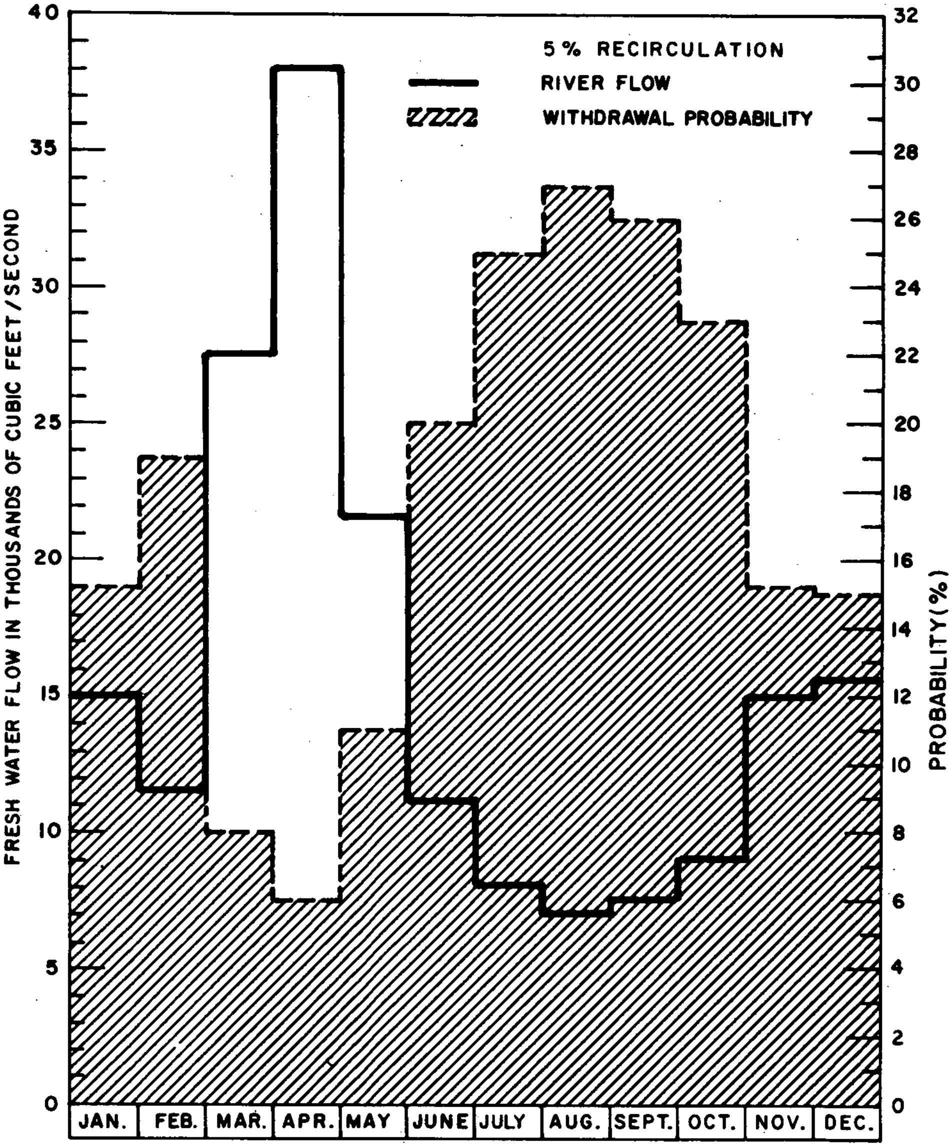

Fig. A-V-9
Probability of Entrainment of Downstream Moving Plankton Which Orginates Above Indian Point for Average Monthly Flow Conditions from 1918-1964. (Transport Flow Based on Dilution Concept.)

of horizontal mixing is related to the possibility of passing the same organism through the condensers more than one time. The greater the value of this factor, the less the overall percentage of organisms entrained. However, the greater the magnitude of the density flow and the intensity of the stratification, the less will be the recirculation factor.

The computational procedures just presented are applicable to organisms that are transported in exactly the same manner that water is transported. By contrast, many planktonic organisms are known to regulate their vertical position in the water column. In the presence of convective flow, this type of behavior is often used for migratory purposes and allows planktonic organisms to maintain position within the estuary without expending a great deal of energy to do so. Under some circumstances, this behavior pattern can alter entrainment susceptibility a great deal from that of a truly passive organism. Thus, the migration of organisms through the zone of exposure can occur at rates faster or slower than those of passive organisms. Likewise, their concentration in the intake water can be greater or smaller than their average concentration in the river.

The area-average susceptibility as discussed in this appendix would require that the organisms be randomly distributed. As should be expected, no such random distribution exists for many species. As a consequence, the behavior of each species must be considered separately to obtain a quantitative estimate of its population's susceptibility to entrainment. The manner in which distribution influences susceptibility of withdrawal is associated with the vertical migration patterns of the organisms and the relative velocities within the different areas. At present, inadequate data are available to quantify precisely the flow volume and velocity in the various zones. The importance of this factor must be evaluated in relation to the entrainment susceptibility of each species considered.

As an example, entrainment estimates for striped bass are presented in Appendix V-3.

REFERENCES FOR APPENDIX A-V-2

1. Consolidated Edison, "Supplement No. 1 to Environmental Report," September 9, 1971.

2. Raytheon Company, "Ecology of Thermal Additions, June-December 1969," Appendix D of Supplement No. 1 to Environmental Report, Consolidated Edison, September 9, 1971.

3. Ketchum, B. H., "Eutrophication of Estuaries, Eutrophication: Cause, Consequences, Correctives," National Academy of Sciences, Washington, 1969, p. 197.

4. Quirk, Lawler, and Matusky Engineers, "Environmental Effects of Bowline Generating Station on the Hudson River," Volumes I-IV, QL&M Project No. 169-1, March 1971.

5. Harleman, D. R. F., Chapter 3, Estuarine Modeling: An Assessment," Environmental Protection Agency, Doc. 16070 DZV 02/71, February 1971.

6. Hohman, M. S., and Parke, D. P., "Hudson River Dye Studies, 150 Miles of Red Water," *Hudson River Ecology*, Hudson River Valley Commission of New York, 1966, p. 60.

7. Heinle, D. R., "Temperature and Zooplankton," *Chesapeake Sci.*, 10(3/4): 186-209 (1969).

APPENDIX V-3

ENTRAINMENT OF LARVAL STRIPED BASS*

Adult striped bass move upstream in later winter to early spring and most spawn upstream from Indian Point. The eggs and larvae drift with the currents in a net downstream direction; large numbers pass the Plant. Several studies have indicated that the principal nursery area for the species is below Indian Point in Haverstraw Bay and the Tappen Zee, but there are some less extensive nursery areas upstream (Fig. A-V-10). High entrainment mortality of larvae and eggs as they drift past Indian Point Units Nos. 1 and 2 would result in loss of the larvae and eggs that pass the Plant en route to their major nursery area.

The importance of entrainment is believed to be associated with the withdrawal of significant proportions of the water in the river. Thus, the ratio of the amount of water circulated through the condensers over various periods of time to the volume of various reaches of the river provides a meaningful evaluation of the need for in depth analysis (Table A-V-2). Comparison of these values with the distribution of larvae in the estuary in three different years (Figs. A-V-11 to A-V-13) indicates the potential magnitude of the entrainment situation. During a period equal to the length of time the juvenile fish will be susceptible to entrainment (6 to 8 weeks), Units Nos. 1 and 2 will use more water than is contained within the reach from mile point 40 to mile point 51, where larvae are in greatest abundance.

A. DISTRIBUTION OF SPAWNING

The most comprehensive data for the spawning activity in the Hudson were collected during the periods 1966 through 1968.[1] These data were summarized by week and converted to total production by correcting for the incubation time (Table A-V-3). These estimates indicate that total egg production ranged from 3.6×10^8 eggs, although, as the authors pointed out, sampling difficulties probably caused the low values in 1967. It is also apparent the peak production of eggs occurs at about 60 to 63°F, with little or no spawning at temperature of 70°F or more.

The zones within the river where spawning activity is most apparent have been described in several reports (Fig. A-V-14). Rathjen and Miller[2] found eggs in the region from Iona Island (mp 45) upstream to Cruger Island (mp 90), with heaviest concentrations between Lady Cliff (mp 49) and Denning Point (mp 57) in essentially fresh water.

*Manuscript by C. P. Goodyear, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

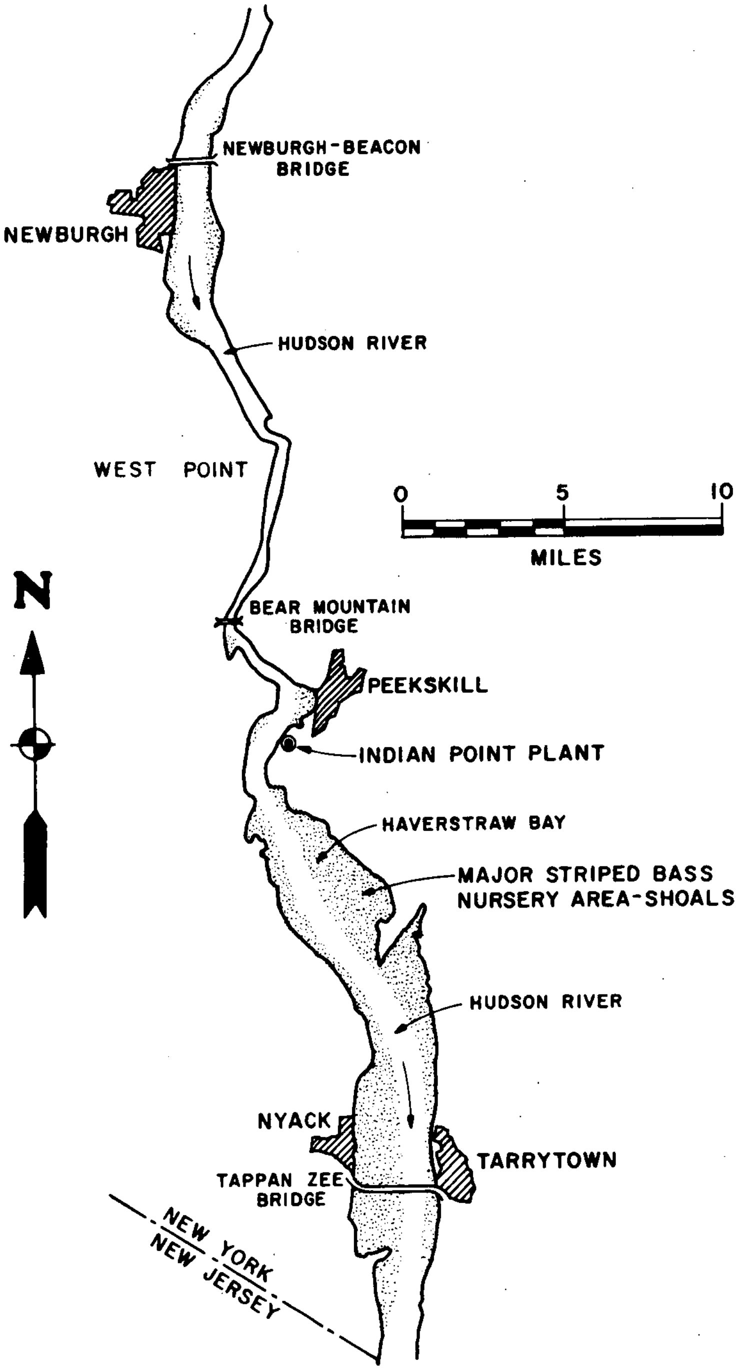

Fig. A-V-10. Major nursery and spawning areas of striped bass in the Hudson River.

Table A-V-2. Relative water usage[a] by Indian Point Units Nos. 1 and 2 in comparison with the volume[b] of various reaches of the Hudson River in fractions of cumulative plant flow divided by volume of the river segment

Reach (mile points)	Number of weeks of operation							
	1	2	3	4	5	6	7	8
39–47	0.39	0.79	1.19	1.58	1.98	2.37	2.77	3.17
40–51	0.179	0.359	0.538	0.718	0.897	1.077	1.257	1.44
35–51	0.11	0.22	0.33	0.44	0.55	0.66	0.77	0.88
20–51	0.050	0.100	0.150	0.200	0.251	0.301	0.351	0.40
20–63	0.038	0.077	0.116	0.154	0.193	0.232	0.270	0.31
20–75	0.033	0.066	0.099	0.132	0.165	0.199	0.232	0.27
20–86.3	0.029	0.059	0.088	0.118	0.147	0.177	0.206	0.24
20–96.5	0.026	0.052	0.078	0.104	0.130	0.156	0.182	0.21
20–115.8	0.024	0.048	0.073	0.097	0.122	0.146	0.171	0.20

[a] Volume used by plant = $V_P = Q_cT$ = (2600 cfs) (3600 sec/hr) (24 hr/day) (7 days/week) (*n* weeks).

[b] Volume of reaches = V_R = (*n* miles) (5280 ft/mile) (avg. cross section)

*Volume normally withdrawn by Plant. Maximum amount is about 2650 cfs if the full service water system of Unit No. 1 is in operation.

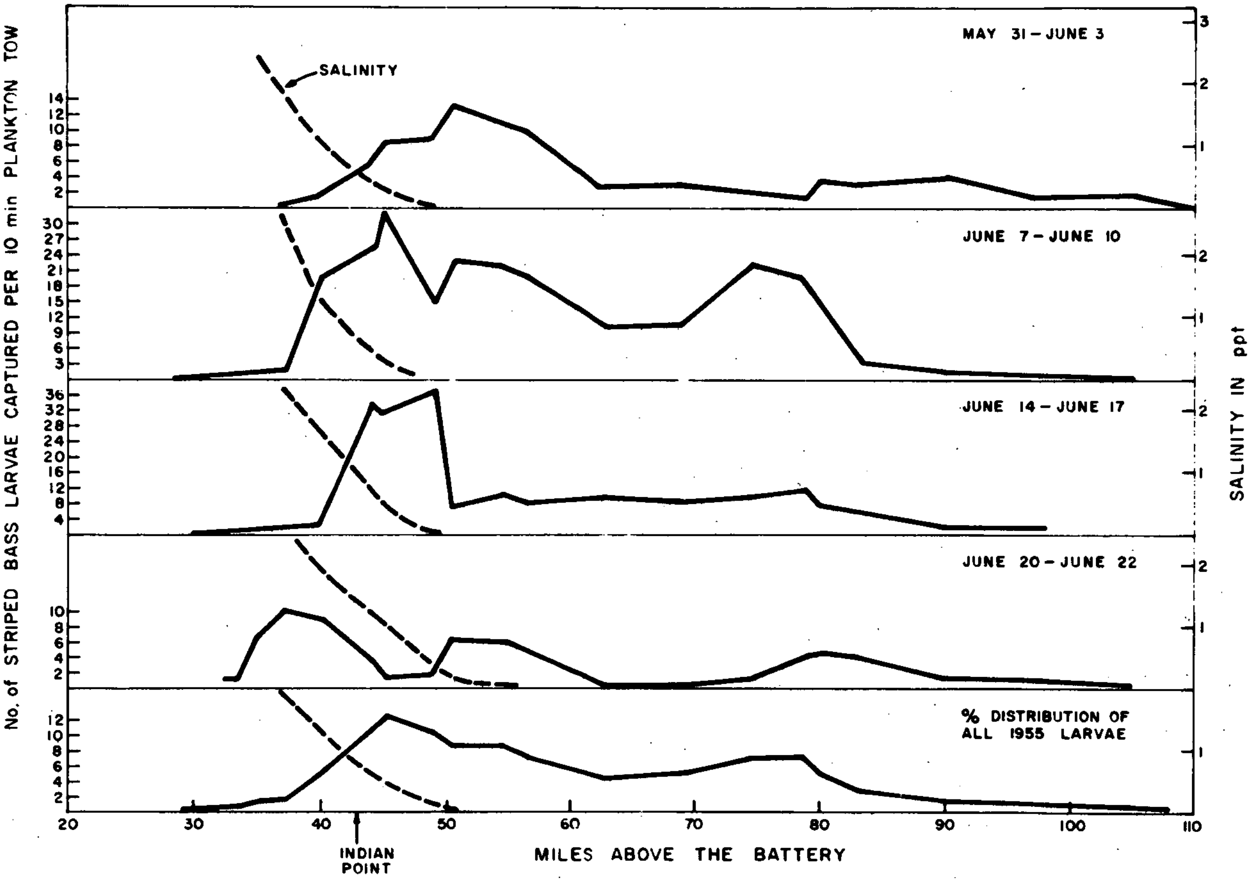

Fig. A-V-11. Longitudinal distribution of larval striped bass in the Hudson during 1955. 1955 data - Rathjen and Miller.

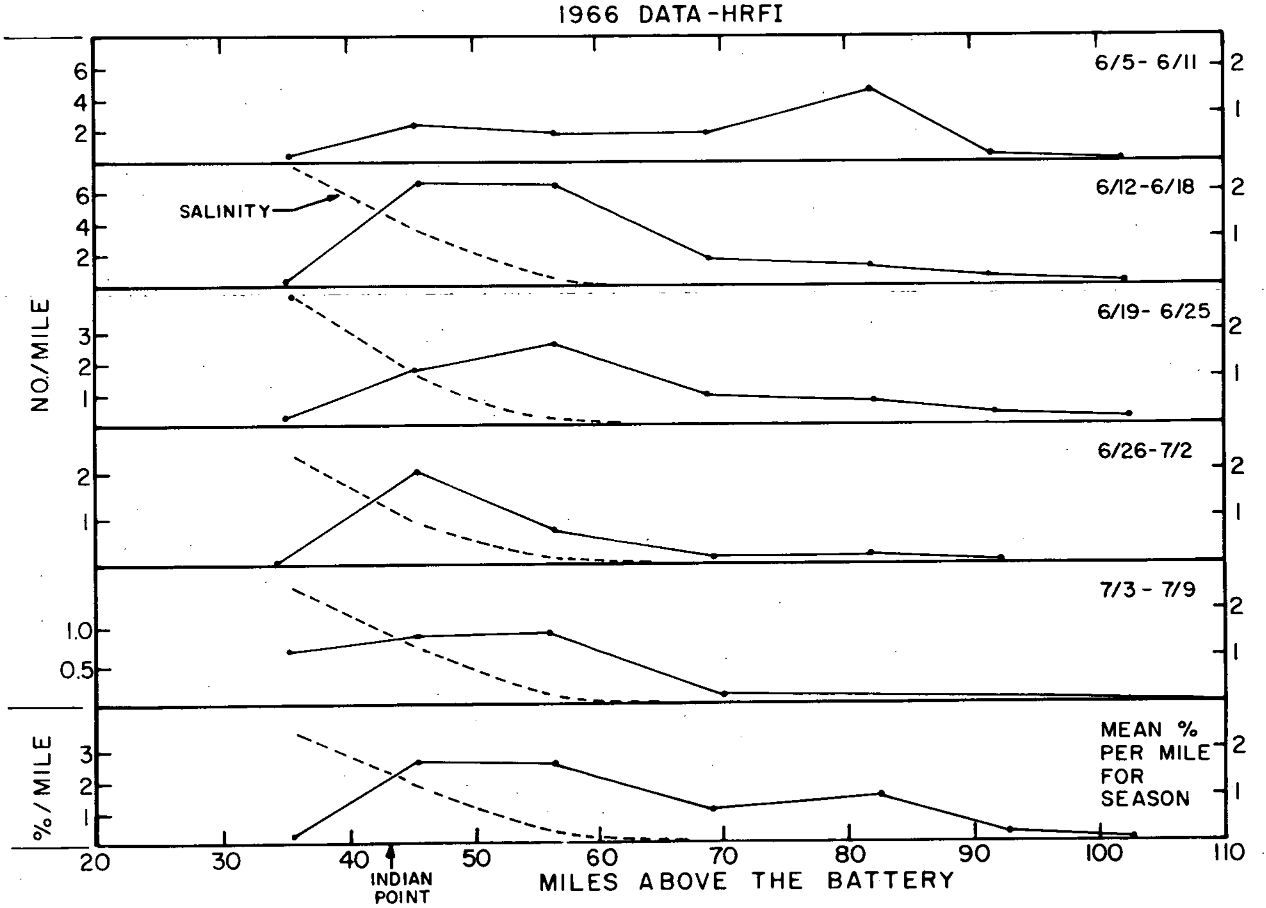

Fig. A-V-12. Longitudinal distribution of larval striped bass in the Hudson during 1966.

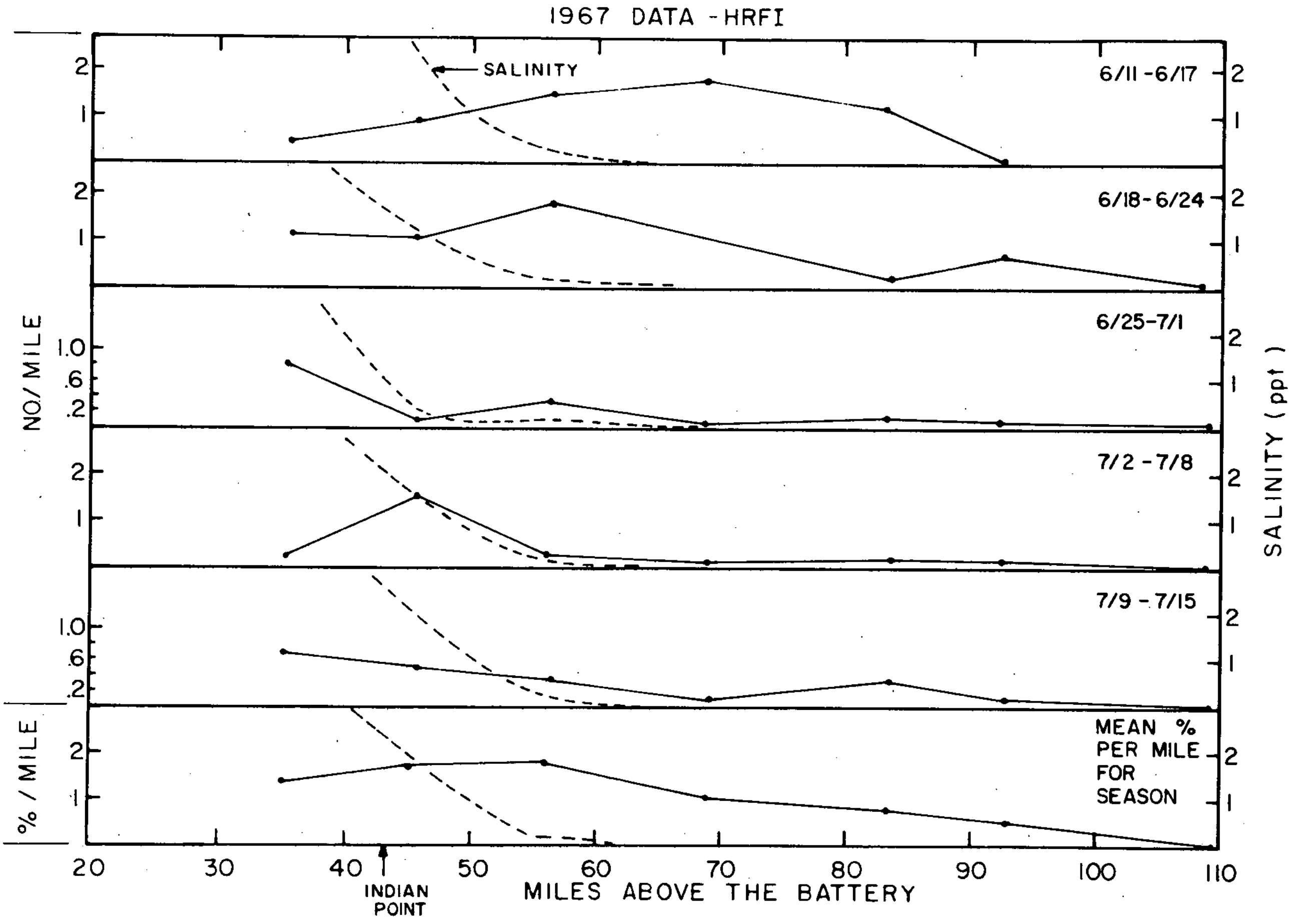

Fig. A-V-13. Longitudinal distribution of larval striped bass in the Hudson during 1967.

Table A-V-3. Effect of temperature on spawning of striped bass in the Hudson River during the Hudson River Fisheries Investigation (1966–1968)

Week	Temp (°F)	Incubation time, I (hr)	Weekly average	Total weekly egg production	Weekly % of total spawn
1966			× 10^6	× 10^6	
4/24–4/30	50.1	100	0.36	0.6	0.3
5/1–5/7	50.0	100	12.48	21.0	1.1
5/8–5/14	50.3	99	11.71	19.9	1.0
5/15–5/21	53.4	88	15.68	29.9	1.5
5/22–5/28	58.9	70	274.04	657.7	33.3
5/29–6/4	62.6	58	250.37	725.2	36.7
6/5–6/11	66.2	45	102.80	383.8	19.5
6/12–6/18	69.1	36	16.74	78.1	3.6
6/19–6/25	73.7	21	7.15	57.2	2.3
				1973.4	
1967					
5/7–5/13	50.7	98	9.00	15.43	4.3
5/14–5/20	52.5	92	4.15	7.58	2.1
5/21–5/27	55.4	82	26.46	54.21	15.0
5/28–6/3	57.6	77	66.51	145.11	40.2
6/4–6/10	64.4	52	42.03	135.8	37.7
6/11–6/17	68.5	38	0.17	0.75	0.2
6/18–6/24	69.5	35	0.29	1.39	0.4
				360.27	
1968					
4/21–4/27	53.1	90	0.29	4.0	0.2
4/28–5/4	56.0	81	10.25	96.0	4.7
5/5–5/11	58.3	73	24.18	413.0	20.4
5/12–5/18	60.4	66	42.41	796.0	39.3
5/19–5/25	61.5	63	14.87	295.0	14.6
5/26–6/1	62.7	58	11.32	243.0	12.0
6/2–6/8	65.2	50	3.07	74.0	3.7
6/9–6/15	66.6	44	3.55	96.0	4.7
6/16–6/22	68.4	39	0.096	4.0	0.2
6/23–6/29	70.7	31	0.096	4.0	0.2
6/30–7/6	73.2	23	0.096	0.6	0
				2025.6	

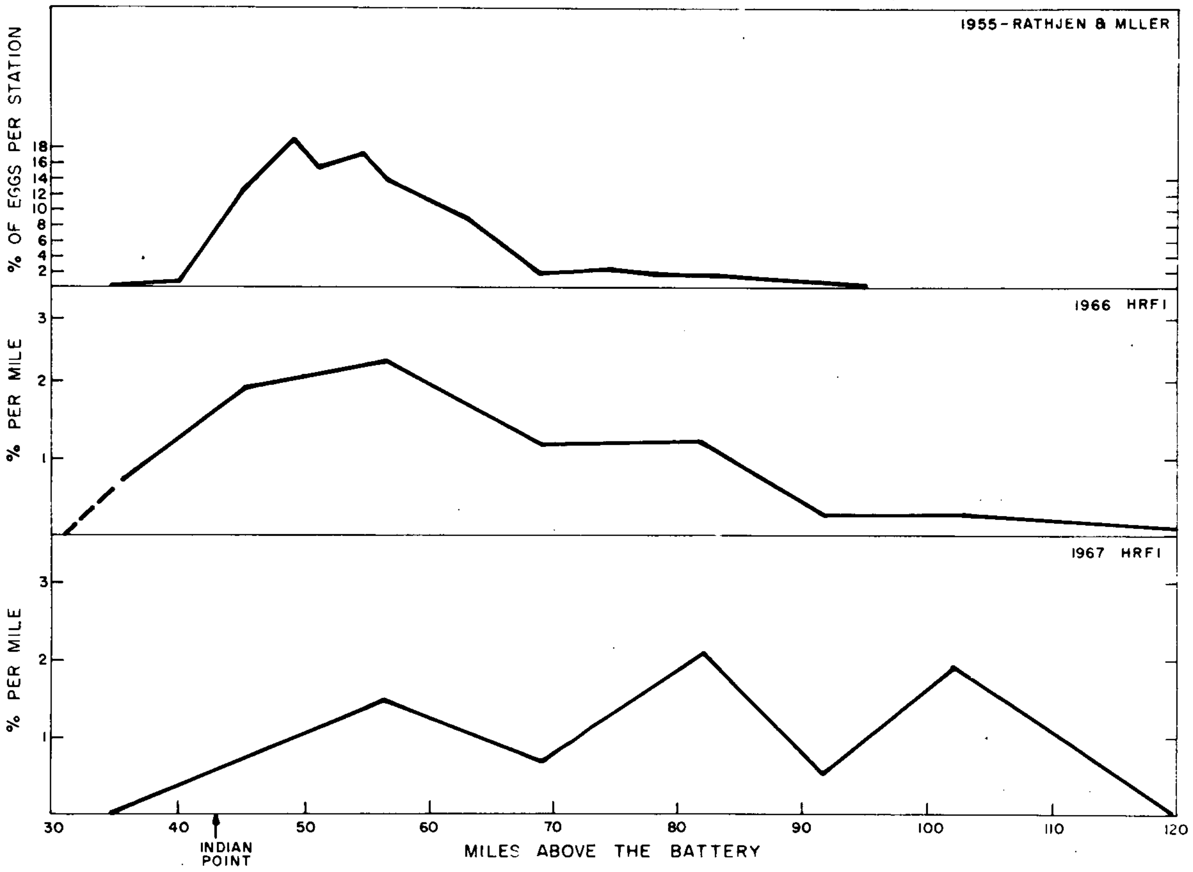

Fig. A-V-14. Longitudinal distribution of striped bass spawning in the Hudson as estimated by collection of eggs in plankton nets.

Data from the Cornwall report[3] generally agree with the Rathjen and Miller data except that more upstream spawning activity was observed. These authors concluded

> "In 1966, striped bass eggs were collected between Coxsackie and Croton (m.p. 125.0 to 35.5), but they were more abundant between Hyde Park and Peekskill (m.p. 82.0 to 45.5). Water temperature during the period of egg collections ranged from 50°F in late April to 75°F in late June, although most eggs were collected at temperatures of 59° to 63°F in late May and early June.
>
> In 1967, eggs were collected from Saugerties to Peekskill (m.p. 102.5 to 45.5) with the greater concentrations at Suagerties (m.p. 102.5) and Hyde Park (m.p. 82.0). Overall they were less abundant than in 1966. The period of their greatest abundance occurred again in late May to early June at water temperatures of 59° to 60°F although they were collected from early May to mid-June at temperatures from 50° to 68°F.
>
> North of Peekskill, striped bass eggs generally were more abundant near the bottom in the deeper part of a cross section sampled. At that location they were concentrated in the strata 15 to 30 ft off the bottom. Few eggs were taken at the surface at any location.
>
> Our data on the spatial distribution of striped bass eggs supported the findings of Rathjen and Miller (1957) that the Hudson River was restricted to fresh or slightly brackish water. With two exceptions, striped bass eggs were not collected in salinites greater than 0.3% and most were collected where salinity measured less than 0.1%.
>
> The upstream limit of striped bass spawning appeared to be in the vicinity of Coxsackie. Most probably the mature fish spawned throughout the reach north of the salinity threshold when the water temperature was suitable and the estuary south of Coxsackie was large enough to accommodate them. Water temperature did not rise at a uniform rate throughout the estuary in spring.

> Our finding that striped bass eggs increased in abundance with increasing depth also was noted in earlier studies. Most of the eggs collected by Woodhull (1947) in the San Joaquin River in California were taken within 5 ft of the bottom. Rathjen and Miller (1957) collected more striped bass eggs in the Hudson River in nets towed at a depth of 12 to 18 ft than at the surface. McCoy (1959) determined that concentrations of eggs in the Roanoke River increased with depth. The concentrations of eggs off the bottom at Peekskill suggested that the increased density of the water there, combined with turbulence, prevented the eggs from sinking closer to the bottom as at upstream locations."

These data are consistent with actual observation of spawning,[4,5] and these collections of recently-spawned, developing eggs by other researches[5-9] have shown that striped bass spawn in fresh water in a moderate to swift current. Mansueti[10] inferred that suspension of the semibuoyant striped bass egg by water current is necessary for its survival, because of the failure of striped bass to reproduce in freshwater impoundments. His arguments were further developed by Talbot[11] in reference to the importance of the estuarine environment for striped bass reproduction.

B. DISTRIBUTION OF LARVAE AND JUVENILES

The passive transport of striped bass eggs and larvae is generally accepted. Since the adult bass spawn in fresh water, the eggs and early larvae drift downstream with the net movement of water in the river. This was the situation which was observed during the Hudson River Fisheries Investigations (HRFI),[12] a project designed to evaluate the potential effect of the proposed pumped storage generating station at Cornwall. A summary of the 1966 and 1967 egg and larval distribution data from the study is given in Tables A-V-4 to A-V-6. It is apparent that downstream drift was important. For example, in 1966, the periods of peak larval abundance were not preceded by periods of peak egg abundance at downstream locations. In addition, collections during 1967 showed greater concentrations of eggs than larvae at upstream locations while larvae became more abundant than eggs in the downstream direction. This same pattern was also apparent in the Raytheon Company data from 1969 and 1970[15] sampling between Bear Mountain Bridge and Croton Point. Thus, all of the more recent data show findings that confirm the 1955 study by Rathjen and Miller[2] (Table A-V-7).

The longitudinal distribution of larval bass during 1955, 1966, and 1967 all show increased concentrations of larval fish in the low

Table A-V-4. Weekly abundance (number per 1000 ft^3) of striped bass eggs and larvae in the Hudson River estuary in 1966

Week	Coxsackie	Saugerties	Kingston	Hyde Park	Marlboro	Cornwall	Peekskill	Croton
Eggs								
4/17–4/23								
4/24–4/30		0.05						
5/1–5/7						0.02		0.53
5/8–5/14						1.22		
5/15–5/21		0.18	0.17	0.11		1.31		
5/22–5/28	1.10	1.94	1.41	1.54	3.81	6.31	10.18	0.46
5/29–6/4	0.59	3.00	1.03	5.06	7.43	6.01	2.96	1.65
6/5–6/11	0.11	0.14	0.10	6.81	0.70	3.83	3.04	1.12
6/12–6/18				0.12	0.20	0.25		0.51
6/19–6/25						0.02		0.30
Total	1.80	5.31	2.71	13.64	12.14	18.97	16.18	4.57
corrected for volume (× 10^6)	7.48	38.15	15.46	96.76	100.73	182.02	145.65	105.97
%	1.08	5.50	2.37	13.96	14.53	26.26	21.01	15.29
Larvae								
5/15–5/21						0.02		
5/22–5/28					0.25	0.01		
5/29–6/4			0.17	1.31	0.18	0.05	0.11	
6/5–6/11			0.62	4.07	1.87	0.46	0.80	0.14
6/12–6/18		0.23	0.40	1.45	0.92	4.38	2.36	0.13
6/19–6/25		0.11	0.64	0.86	0.89	1.81	0.89	0.17
6/26–7/2			0.07	0.20	0.04	0.56	0.75	0.12
7/3–7/9			0.15	0.66	0.16	0.65	0.38	0.20
7/10–7/16			0.07	0.14	0.17	0.39		
Total	0	0.34	2.12	8.79	4.48	8.33	5.29	0.76
corrected for volume (× 10^6)	0	2.44	12.88	61.65	37.17	79.93	47.62	17.62
%	0	0.94	4.97	23.77	14.33	30.82	18.36	6.79
%/mile	0	0.05	0.59	2.1	1.2	2.6	1.7	0.34

Table A-V-5. Weekly abundance of striped bass larvae in the Hudson River in 1966 based on total tows, in number per tow

Week	Coxsackie	Saugerties	Kingston	Hyde Park	Marlboro	Cornwall	Peekskill	Croton
4/17–4/23								
4/24–4/30								
5/1–5/7								
5/8–5/14								
5/15–5/21						0.02		
5/22–5/28					0.13	0.02		
5/29–6/4			0.82	1.83	0.14	0.11	0.25	
6/5–6/11		0.20	0.78	7.11	2.76	2.15[a]	2.81	0.12
6/12–6/18		0.31	0.50	2.00	2.79	8.12	8.29	0.14
6/19–6/25		0.17	0.73	1.17	1.45	3.25	2.27	0.31
6/26–7/2			0.08	0.25	0.19[a]	0.92	2.24	0.12
7/3–7/9			0.08	0.17	0.14[a]	1.10	1.06	0.64
7/10–7/16			0.06	0.23	0.11	0.54		
7/17–7/23						0.63		
Total	0	0.68	3.05	12.76	7.71	16.86	17.12	1.33
corrected for volume (× 10^6)	0	4.89	18.53	90.52	63.97	161.77	154.11	30.84
%	0	0.09	3.53	17.26	12.19	30.8	29.38	5.88
%/mile	0	0.005	0.35	1.53	1.00	2.61	2.67	0.29

[a] Value corrected from original table.

Table A-V-6. Weekly abundance (number per 1000 ft^3) of striped bass eggs and larvae in the Hudson River estuary in 1967

Week	Coxsackie	Saugerties	Kingston	Hyde Park	Marlboro	Cornwall (regular)	Peekskill	Croton
				Eggs				
5/7–5/13		1.02	0.03	0.15	0.04	0.01		
5/7–5/13		0.09		0.31		0.07	0.07	
5/21–5/27		2.03	0.28	0.11		0.36	0.66	
5/28–6/3		4.45	0.70	1.70	0.45	1.06	0.48	
6/4–6/10		0.08	0.35	2.69	0.97	1.14	0.14	
6/11–6/17					0.02			
6/18–6/24						0.03		
Total	0	7.67	1.36	4.96	1.48	2.67	1.35	0.00
corrected volume (× 10^6)	0	55.10	8.26	35.19	12.28	25.62	12.15	0.00
%	0	37.08	5.56	23.68	8.26	17.24	8.18	0.00
				Larvae				
5/21–5/27			0.41					
5/28–6/3			0.10	0.13	0.06			
6/4–6/10				0.09	0.97	0.28	0.01	
6/11–6/17				2.00	2.49	1.72	1.18	0.43
6/18–6/24		0.26	1.01	0.06	*a*	2.17	1.51	1.08
6/25–7/1		0.03	0.18	0.16		0.44	0.05	0.71
7/2–7/8		0.03	0.37	0.45	0.26	0.33	1.63	0.19
7/9–7/15		0.10	0.16	0.58	0.13	0.48	0.58	0.59
7/16–7/22			0.08	0.04	0.02	0.11	0.03	0.03
7/23–7/29				0.01				0.07
Total	0	0.42	2.31	3.52	3.94	5.53	4.99	3.10
corrected for volume (× 10^6)	0	3.02	14.03	24.97	32.69	53.06	44.92	71.89
%	0	1.23	5.76	10.21	13.37	21.69	18.37	29.3
%/mile		0	0.51	0.9	1.09	1.82	1.66	1.47

[a] Not sampled.

Table A-V-7. Distribution of larval striped bass in the Hudson estuary during the spring of 1955 (data from Rathjen and Miller) (number collected at each station)

Mile point	Cruise					
	III 5/31–6/3	IV 6/7–6/10	V 6/14–6/17	VI 6/20/6/22	V + VI	Mean
21	0	0	0	0	0	0
29	0	0	0	0	0	0
33	0	2	1	0	1	0.2
35	0	1[a]	0	5	5	1.2
37	0	0	2	16	18	3.1
40	0	61	5	9[a]	14	0.9
44	5.5[a]	13	0	2	2	10.8
45	11	25	93	0	93	20.0
49	9[a]	5	2	1.5[a]	3.5	5.5
50.5	7	40	14	3	17	5.0
54.5	24	20	5	15	20	14.4
56.5	1	2	15	0	15	6.5
63	5	16	4	0	4	1.9
69	1	21	8	0	8	5.0
74.5	3	30	13	0	13	7.7
78.5	2	7	7	3	10	8.2
80	0	1	15	9	24	5.5
83	9	3	1	1	2	2.2
90	0	0	1	2	3	1.0
97	3	0[a]	0	1	1	0.7
105	1.5[a]	0	0	0	0	0
108	0	0	0.5[a]	0[a]	0.5	0
111	0	0	1	0	1	0.2

[a] Missing value extrapolated from adjacent station values.

salinity areas near the salt front (Tables A-V-4 to A-V-7 and Figs. A-V-11 to A-V-13).

The importance of the downstream drift is even more obvious when it is realized that because of the protracted spawning period (and downstream drift) the larval concentrations upstream would be composed of younger fish on the average. The relationship would tend to underestimate the importance of the downstream concentrations of larvae because of the higher mortality rates of smaller larvae. This effect would largely disappear after most of the fish were beyond the yolk sac stage. Thus, the post-spawning distribution would be a better indication of larval movement patterns than would the average distribution over the entire season. For this reason, the data presented in Table A-V-8 will be used in later comparisons. However, it should be noted at this point that these data should not be too rigorously applied from a quantitative standpoint, because of the type of sampling that they represent. However, they do provide strong indications of the relative distribution.

The relationship between low salinity areas and larval abundance is particularly obvious in the 1967 data (Fig. A-V-13). During sampling in the last week of June, the salinity at the Peekskill site was depressed and most larvae were downstream; on the following week the salt front had moved back upstream and was accompanied by an influx of larval bass.

During July of 1966 and 1967, the plankton gear catches of small bass began to decline at similar rates throughout the sampling area. A similar pattern that occurred in 1968 (Table A-V-9) coincided with the period when a sharp increase in growth was observed (Fig. A-V-15). This sharp increase in growth rate is generally believed to be associated with the change in food habits and is probably a sign that the fish are beginning to become more bottom oriented.

An additional support for this conclusion - the Raytheon Company data for 1970 - shows that the decreased catches by plankton gear and surface trawls occurred at the same time that bottom trawling showed the bass were moving onto the shoals of Haverstraw and Peekskill Bays (Table A-V-10).

The affinity of small bass for comparatively shallow water is obvious from their distribution in both the Raytheon Company data reproduced in Table A-V-10 and the 1966 HRFI trawl data (Table A-V-11). In 1968, shoal surveys were conducted by HRFI investigators by making periodic 10-minute trawl samples on shoals between

Table A-V-8. Post-spawning distribution (%) of larval striped bass in the Hudson estuary during the 1966 and 1967 Hudson River Fisheries Investigation

Segment	1966 (6/26–7/16)				1967 (7/2–7/22)			Average 66–67
	a	*b*	*c*	Mean	*a*	*c*	Mean	
Coxsackie	0	0	0	0	0	0	0	0
Saugerties	0	0	0	0	1.5	1.5	1.5	0.8
Kingston	4.4	2.0	3.9	3.4	6.7	5.9	6.3	5.2
Hyde Park	9.3	5.2	8.1	7.5	12.5	11.8	12.2	9.8
Marlboro	5.9	4.1	6.8	5.6	5.3	5.5	5.4	5.5
Cornwall	29.8	23.0	30.0	27.6	14.3	13.9	14.1	20.9
Peekskill	32.2	44.7	34.4	37.1	33.5	31.8	32.7	34.9
Croton	18.3	20.9	16.8	18.7	25.7	29.7	27.7	23.2

[a] Estimated from ratio of number of larvae collected to the total volume strained for each segment over entire interval.

[b] Estimated from ratio of number of larvae collected to the number of tows for each segment over entire interval.

[c] Estimated from mean of weekly average concentrations for each segment over interval.

Table A-V-9. Weekly abundance of striped bass eggs and larvae in the Hudson River estuary in 1968.

Week	Mean water temperature (° F)	Mean salinity (ppt)	Number of tows	Volume strained (ft^3)	Striped bass eggs		Striped bass larvae	
					Number collected	Number per 1000 ft^3	Number collected	Number per 1000 ft^3
4/21–4/27	53.1	<0.1	113	348,372	10	0.03	0	
4/28–5/4	56.0	<0.1	448	1,226,095	791	0.65	82	0.18
5/5–5/11	58.3	<0.1	369	873,853	2,206	2.52	54	0.15
5/12–5/18	60.4	<0.1	481	1,183,148	5,224	4.42	1,219	2.53
5/26–6/1	62.7	<0.1	329	814,043	964	1.18	3,201	9.73
6/2–6/8	65.2	<0.1	490	1,136,685	369	0.32	861	1.76
6/9–6/15	66.6	<0.1	609	1,255,141	459	0.37	6,207	12.19
6/16–6/22	68.4	<0.1	524	1,250,388	16	0.01	2,279	4.35
6/23–6/29	70.7	<0.1	415	1,278,049	13	0.01	729	1.76
6/30–7/6	73.2	<0.1	331	884,125	1	0.01	122	0.37
7/7–7/13	73.7	<0.1	400	1,449,948	0		695	1.74
7/14–7/20	76.8	<0.1	179	489,743	0		193	1.08
Total			5,106	13,368,901	11,926		18.939	

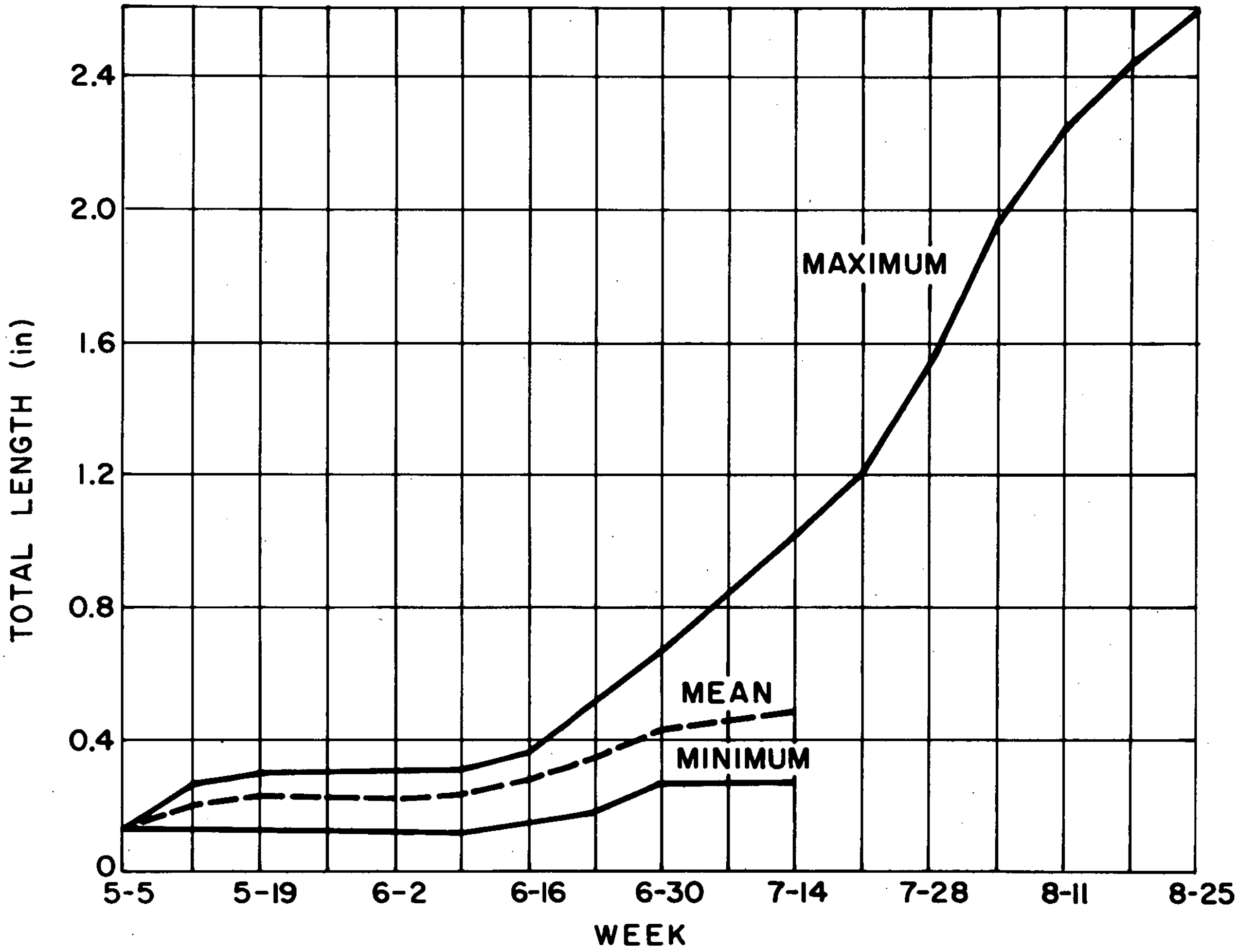

Fig. A-V-15. Growth of striped bass in Hudson River.

Table A-V-10. Catch of striped bass in bottom trawls in the Lower Hudson estuary in 1969 and 1970, showing importance of shallow shoals as nursery grounds (number per 7-min trawl haul)

Depth level	Station	Mile point	Depth (ft)	1969						1970									
				July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Shallow	1	29	10	77	58	98	231												
	5	36	12	291	126	108	354	88	21						12	196	555	308	0
	3	35	10	355	61	28	14	4	5						41	14	112	252	39
	7	38	11	115	217	168	168	31	1				1	18	9	84	100	56	196
	8	39	12	485	64	39	69	61	20			6			19	22	84	145	145
	9	40	12	149	119	335	146	29	3			0	1	0	2	78	112	112	140
	12	44	12	100	144	87	19	83	21	39		0	0	10	3				
Intermediate	2	29	26	4	51	0	21												
	4	35	34	10	19	1	120	3	3						0	0	0	0	0
	6	38	30	62	312	4	122	0	1				1	<1	9	0	0	0	0
Deep	15	40	45			0	7	1	3			1	0		0	0	0	0	0
	16	41	45			1		0	4			16			0	0	0	0	0
	11	42	50	1	1	1	1	<1	4	22	1	3	0	2	2	0	0	0	0
	10	42	45	0	4	8	16	1	0	61	4	2	0	<1	<1	0	0	0	0
	13	45	50	1	3	3	1		0				0	1	1	0	0	0	0
	14	47	47	0	1	3	1	2	1						0	0	0	0	0

[a] Raytheon Company stations.

Table A-V-11. Relationship between water depth and abundance of young-of-the-year striped bass at Cornwall in 1966 as determined by catch per 7-in. trawl haul

Depth (ft)	No. of tows	No. of fish	Fish/tow
15	34	1941	57.1
20	29	115	3.97
40	34	85	2.5
65	12	18	1.5

Table A-V-12. Data on distribution of young-of-the-year striped bass taken by shoal trawls in July – August 1968

Reach	Index of shoal area	Period						Mean of means	
		July 28–Aug. 3		Aug. 11–Aug. 17		Aug. 25–Aug. 31			
		No.	Index	No.	Index	No.	Index	No.	Index
Coxsackie	17.3	0	0	0	0	0	0	0	0
Saugerties	16.5	0.2	3.3	0	0	0	0	0.1	1.1
Kingston	10.0	1.7	16.7	0	0	0.3	3	0.7	6.6
Hyde Park	2.1								
Marlboro	4.8	0.3	1.4		2.4	1	4.8	0.60	2.9
Cornwall	7.6	22.9	173.4	0	0	104	787.3	42.3	320
			194.8		2.4		795.1		330.8
Peekskill	4.8								
Haverstraw Bay	24.1	102	2458.2	12	289	29.7	715.8	48	1156.8
Tappan Zee	38.5	9.6	369.6	36	1386	29.7	1074	25.1	962.5
			2827.8		1675.2		1789.8		2119.3
TOTAL			3022.6		1677.6		2584.9		2449.9
% above Indian Point			6.4		0.1		30.8		13.5
% below Indian Point			93.6		99.9		69.2		86.5[b]

[a] The period index is the product of the shoal area index and the number of fish caught per trawl haul.

[b] From the published mean of samples, this value is 85.4% (Ref. 1).

mile points 11 and 125. The catch data were then corrected for the size of the shoals, and the relative longitudinal distribution was examined (Table A-V-12). The overall average of three periods corresponds to an estimate of 85% of the young-of-the-year bass below Indian Point. Similar corrections must be applied for proper interpretation of annual seine haul abundance estimates; however, the predominance of the lower estuary is reflected even without such corrections (Fig. A-V-16).

Based on the available data, the staff has concluded that distribution of the young-of-the-year in late July and August is largely determined during the 6- to 8-week period of pelagic life. The seasonal peaks in abundance and annual estimates of longitudinal distribution of young-of-the-year bass all support this conclusion (Figs. A-V-17 and A-V-18).

C. FACTORS CONTRIBUTING TO LARVAL DISTRIBUTION

The increased abundance in the low salinity zone in the estuary shows that the striped bass do not drift with the flow of fresh water once they enter the salt-intruded region. The principal reason for this relationship is believed to be a result of the vertical distribution of the larvae and their corresponding diurnal migration patterns. The interactions of these patterns with the vertical variations in velocity would tend to retard the downstream movement of the larvae and concentrate them in the region below the salt front.

Vertical and lateral variations in distributions were observed both in the HRFI and Raytheon Company studies.[15] However, the 1968 HRFI data were far more extensive and were, therefore, selected for analysis. The degree of lateral variation in mean concentration was determined by averaging the day/night concentrations with respect to the 15-foot depth intervals that were sampled. Considerable variation was apparent, but no pattern of decreased lateral abundance was evident (Table A-V-13). The less extensive 1967 data showed similar results (Table A-V-14).

Vertical variation was similarly treated, except the data were averaged according to depth for this situation. A significant diurnal variation was observed (Table A-V-15). Thus, the data used in this analysis showed a vertical variation for each transect (but one) which was confined to the transect and did not contribute any large degree of lateral movement to deeper water during the day. As a consequence, the susceptibility of larvae to an intake in this region of the river would not be altered by a day-night vertical

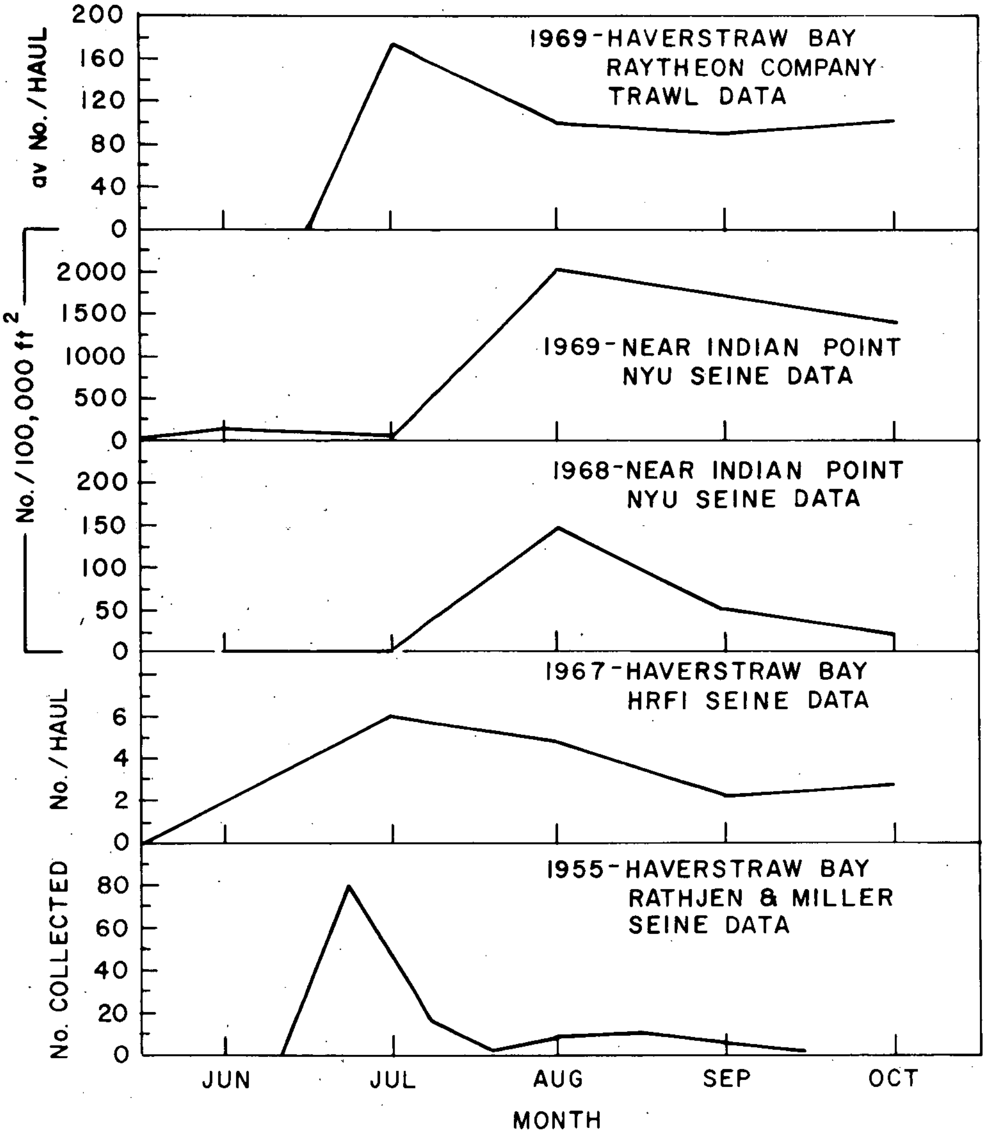

Fig. A-V-16. Season of peak abundance of young striped bass in the Hudson estuary below Peekskill.

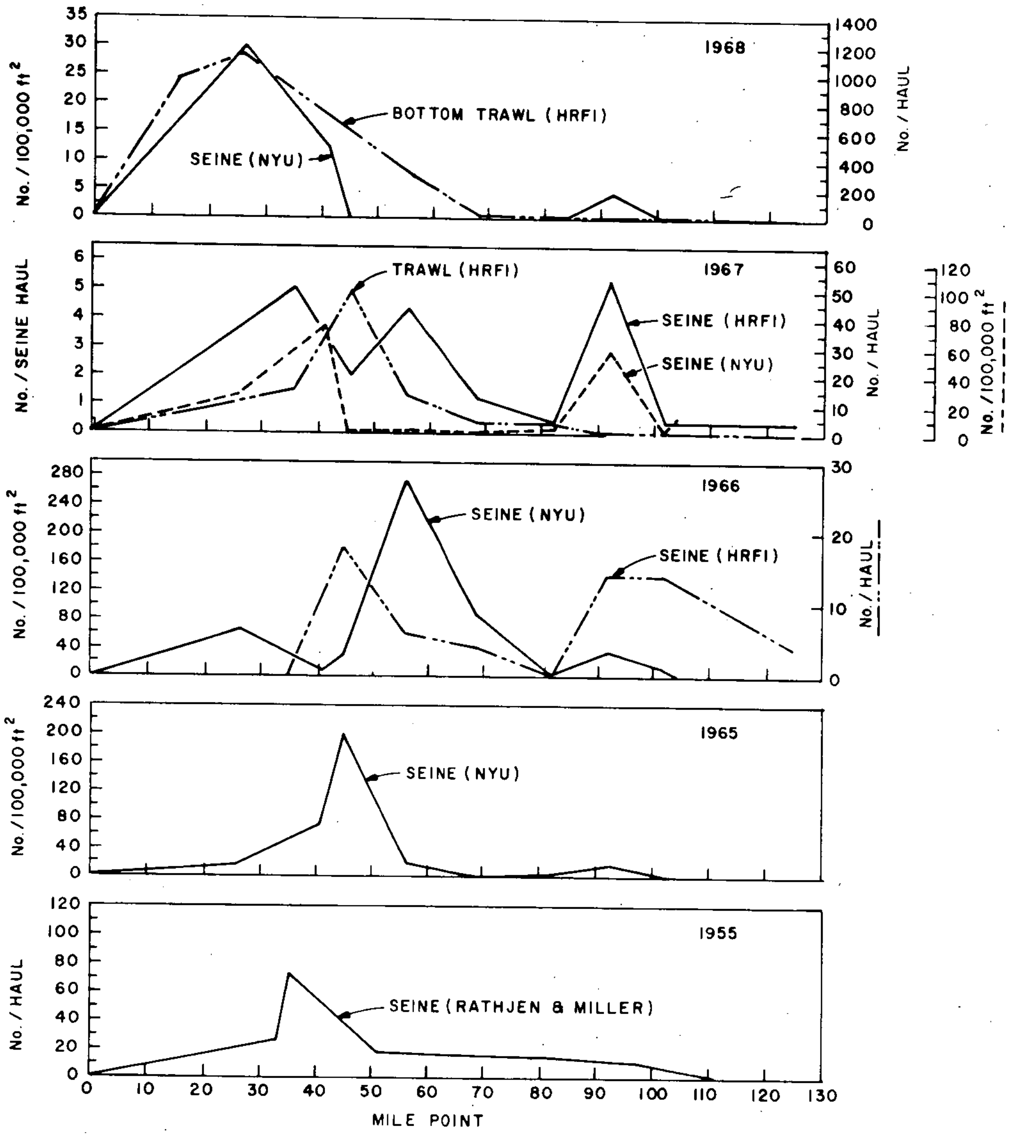

Fig. A-V-17. Annual estimates of longitudinal distribution of young-of-the-year striped bass in the Hudson.

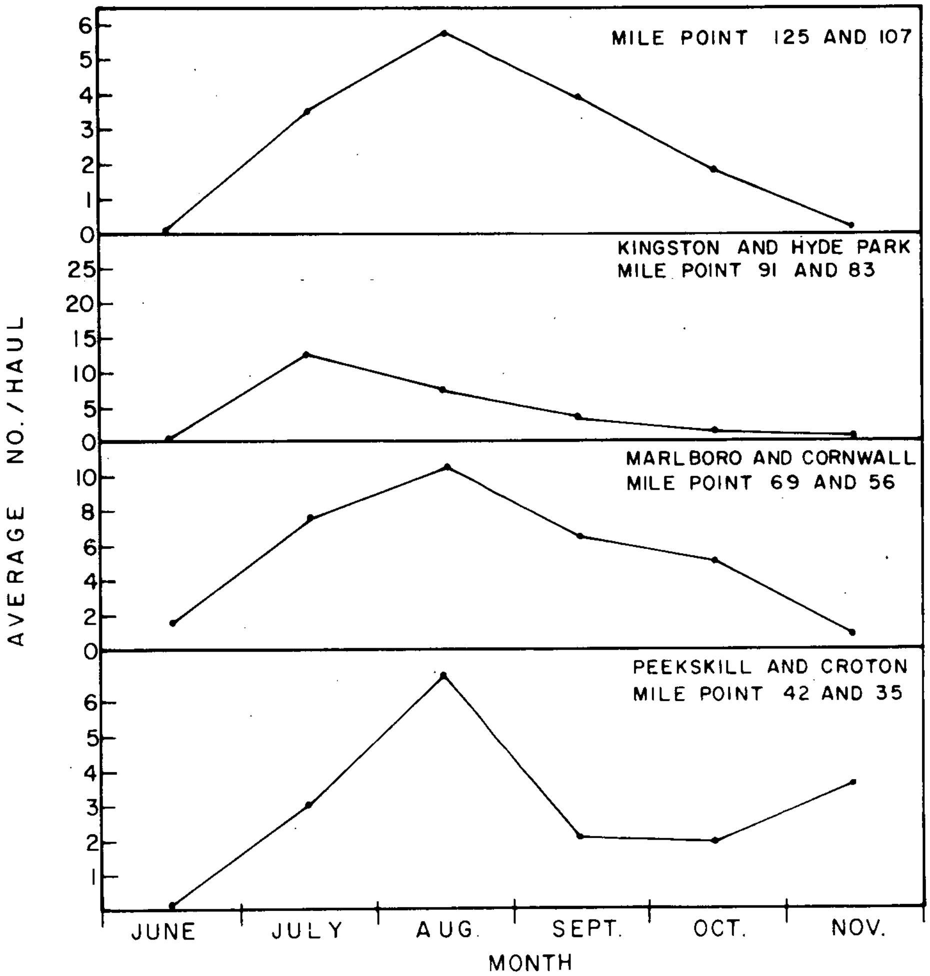

Fig. A-V-18. Seasonal abundance of young-of-the-year striped bass as determined from the 1967 seine haul data of the Hudson River fisheries investigation.

Table A-V-13. Lateral distribution of larval striped bass for a 12-week period at Cornwall in 1968

(average concentration of larvae per 15-ft interval)

Period[a]	W 15	W 30	W 45	W 60	C 75	E 60	E 45	E 30	E 15	E 5	Mean concentration of larvae (number per 1000 ft^3)	Standard error
4/28–5/4												
D	0.06	0.067	0.13	0.034	0.01	0.05	0.035	0.097	0.04	0.0	0.052	0.012
N	0.315	0.02	0.098	0.264	0.042	0.188	0.085	0.137	0.03	0.0	0.118	0.034
5/5–5/11												
D	0.03	0.027	0.102	0.04	0.03	0.052	0.09	0.0	0.15	0.0	0.079	0.015
N	0.0	0.0	0.0	0.11	0.608	0.0	0.0	0.08	0.0	0.0	0.080	0.060
5/12–5/18												
D	0.26	0.54	0.79	0.878	1.57	1.48	1.837	1.95	3.535	2.96	1.58	0.331
N		2.13	1.30	1.008	0.64	1.26	1.235	1.237		1.06	1.234	0.149
5/19–5/25												
D	1.13	2.653	4.05	3.752	4.11	3.296	2.478	3.33	2.325	1.77	2.889	0.313
N	2.11		4.133	5.07	3.242	2.054	4.062	1.693	3.01	3.00	3.153	0.372
5/26–6/1												
D	0.945	4.523	4.468	3.172	1.825	3.542	2.43	4.913	1.705	0.81	2.833	0.478
N	3.445	23.483	7.22	7.818	7.242	2.494	4.213	4.70	3.375	2.81	6.68	1.967
6/2–6/8												
D	0.29	0.75	0.783	0.488	1.112	0.65	1.037	0.71	1.2	1.23	0.825	0.090
N	0.18	0.577	0.997	0.756	0.812	1.032	0.66	0.923	0.995	1.05	0.795	0.086
6/9–6/15												
D	6.975	6.477	6.175	5.945	5.737	3.674	4.382	4.46	2.65	1.23	4.771	0.308
N	7.835	24.197	6.61	4.57	2.185	2.336	1.018	4.13	5.725	2.80	6.141	2.116
6/16–6/22												
D	2.975	3.56	1.882	1.592	1.363	0.752	1.417	1.793	1.765	0.95	1.805	0.638
N	2.28	2.993	0.702	0.526	0.99	1.444	1.83	4.817	3.385	3.58	2.255	0.447
6/23–6/29												
D	0.49	0.763	0.478	0.644	0.322	0.864	0.59	0.653	1.09	0.70	0.659	0.139
N		0.62	1.118	0.262	0.622	1.12	0.938	1.943	1.13	1.13	0.987	0.157
6/30–7/6												
D	0.04	0.07	0.0	0.028	0.0	0.04	0.072	0.227	0.155	0.54	0.117	0.055
N	0.0	0.07	0.115	0.394	0.095	0.0	0.478	0.037	0.0	0.0	0.119	0.063
7/7–7/13												
D									1.48	0.44	0.96	0.520
N									1.055	0.22	0.638	0.417
7/14–7/20												
D	0.18	0.11	0.435	0.0	0.0	0.518	0.048	1.107	0.34	0.0	0.274	0.109
N			0.0		0.177	1.056	0.35	0.533	0.485	2.83	0.776	0.365
$\overline{D}$	1.216	1.785	1.754	1.507	1.462	1.356	1.311	1.749	1.37	0.886	1.440	0.088
$\overline{N}$	2.021	6.010	2.027	2.078	1.514	1.180	1.352	1.839	1.745	1.540	2.131	0.441

[a] D = day; N = night..

Table A-V-14. **Abundance of striped bass larvae in the Hudson River estuary by station sampled per location, 1967**

Station	Mile point	Depth (ft)	Number of larvae per 1000 ft³								
Saugerties[a]	102.5			West			Center			East	
				45			60			45	
		0		0.00			0.00			0.00	
		15		0.08			0.00			0.00	
		30		0.14			0.18			0.04	
		45		0.04			0.05			0.27	
		60					0.00				
		Mean		0.07			0.05			0.08	
Kingston[b]	91.5			West			Center			East	
				30			45				
		0		0.00			0.15			30	
		15		0.17			0.09			0.00	
		30		0.28			0.69			0.03	
		45					0.45			0.41	
		Mean		0.15			0.35			0.15	
Hyde Park[a]	82.0			West			Center			East	
				60			45			45	
		0		0.04			0.24			0.20	
		15		0.11			0.32			0.77	
		30		0.24			0.44		0.42	0.42	
		45		0.18			0.48			0.36	
		60		0.24							
		Mean		0.16			0.37			0.44	
Marlboro[b]	69.0			West			Center			East	
				30			45			30	
		0		0.00			0.00			0.13	
		15		1.29			0.00			0.16	
		30		1.18			0.65			0.27	
		Mean		0.82			0.90			0.19	
Cornwall[a]	56.5		West	West	West	West	Center	East	East	East	East
			5[c]	15	30	45	75	45	30	15	5
		0	0.48	0.90	1.25	0.56	0.32	0.72	0.36	0.47	0.64
		5	0.49	*d*	*d*	*d*	*d*	*d*	*d*	*d*	0.57
		15		0.86	1.58	0.84	1.51	0.57	0.69	0.56	
		30			0.81	0.71	0.49	0.48	1.01		
		45				0.62	1.05	0.65			
		60					0.33				
		75					0.92				
		Mean	0.49	0.88	1.21	0.68	0.77	0.61	0.69	0.52	0.61
Peekskill[a]	45.5			West			Center			East	
				60			110			90	
		0		0.30			0.15			0.36	
		15		2.30			*d*			*d*	
		30		1.39			*d*			0.22	
		45		0.90			0.47			0.24	
		60		1.35			0.45			0.42	
		75					0.04			1.07	
		90					1.48			1.00	
		110					0.74				
		Mean		1.25			0.56			0.55	
Croton[b]	35.5			West			Center			East	
				30			45			30	
		0		0.03			0.00			0.13	
		15		0.03			0.32			0.69	
		30		0.29			0.11			1.63	
		45					0.83				
		Mean	0.12	0.12			0.32			0.82	

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[a] Day and night samples combined.

[b] Day samples only.

[c] Off Moodna Creek.

[d] Not sampled.

Table A-V-15. Mean concentration of larvae at Cornwall in 1968 averaged over depth across all sample locations, expressed as number per 1000 ft^3

Week	Depth (ft)	Day			Night		
		Total	Av	%	Total	Av	%
4/28–5/4	0	0.07	0.007	2.258	0.83	0.083	13.584
	15	0.31	0.034	10.968	1.00	0.111	18.167
	30	0.81	0.116	37.419	0.42	0.06	9.820
	45	0.45	0.09	29.032	0.52	0.104	17.021
	60	0.19	0.063	20.323	0.76	0.253	41.408
	75	0.0	0.0	0.0	0.0	0.0	0.0
			0.310			0.611	
5/5–5/11	0	0.0	0.0	0.0	0.14	0.014	0.393
	15	0.41	0.045	13.120	0.12	0.013	0.365
	30	0.45	0.064	18.659	0.40	0.057	1.601
	45	0.58	0.097	28.280	0.12	0.024	0.674
	60	0.41	0.137	39.942	0.31	0.103	2.892
	75	0.0	0.0	0.0	3.35	3.35	94.075
			0.343			3.561	
5/12–5/18	0	4.47	0.447	3.752	13.09	0.131	2.569
	15	9.19	1.021	8.570	5.47	0.781	15.475
	30	11.40	1.629	13.673	7.51	1.073	21.260
	45	14.02	2.804	23.535	5.91	1.182	23.420
	60	6.97	2.323	19.498	4.49	1.50	29.721
	75	3.69	3.69	30.972	0.38	0.38	7.529
			11.914			5.047	
5/19–5/25	0	3.81	0.381	1.092	39.24	3.924	16.947
	15	10.66	1.184	3.395	19.72	2.191	9.463
	30	27.73	3.961	11.356	8.09	1.348	5.822
	45	33.28	6.56	18.808	20.57	4.114	17.768
	60	21.55	7.183	20.594	16.10	5.367	23.180
	75	15.61	15.61	44.755	6.21	6.21	26.820
			34.879			23.154	
5/26–6/1	0	3.97	0.397	1.685	50.04	5.004	10.671
	15	13.32	1.48	6.283	54.53	6.059	12.920
	30	37.60	5.371	22.800	68.04	9.72	20.727
	45	24.68	4.936	20.953	37.81	7.562	16.125
	60	23.38	7.793	33.081	19.14	6.38	13.605
	75	3.58	3.58	15.197	12.17	12.17	25.952
			23.557			46.895	
6/2–6/9	0	1.79	0.179	2.541	7.10	0.710	13.485
	15	4.90	0.544	7.722	7.27	0.808	15.347
	30	5.96	0.851	12.079	4.73	0.676	12.839
	45	9.19	1.838	26.089	7.04	1.408	26.743
	60	4.18	1.393	19.773	2.35	0.783	14.872
	75	2.24	2.24	31.796	0.88	0.88	16.714
			7.045			5.265	
6/9–6/15	0	17.10	0.171	0.496	32.24	3.224	9.208
	15	40.81	4.534	13.148	47.28	5.253	15.003
	30	57.89	8.27	23.982	69.49	9.927	28.352
	45	33.33	6.666	19.331	27.6	5.52	15.765
	60	21.16	7.053	20.453	14.91	4.97	14.194
	75	7.79	7.79	22.590	6.12	6.12	17.479
			34.484			35.014	

Table A-V-15 (continued)

Week	Depth (ft)	Day			Night		
		Total	Av	%	Total	Av	%
6/16–6/22	0	6.10	0.610	5.763	26.87	2.687	29.737
	15	16.88	1.875	17.725	16.30	1.811	20.042
	30	20.95	2.993	28.279	10.23	1.461	16.169
	45	9.79	1.958	18.500	7.37	1.474	16.313
	60	4.19	1.397	13.199	2.83	0.943	10.436
	75	1.75	1.75	16.534	0.66	0.66	7.304
			10.584			9.036	
6/23–6/29	0	3.21	0.321	9.838	16.86	1.686	43.387
	15	9.54	1.06	32.485	5.14	0.643	16.547
	30	3.76	0.537	16.457	4.19	0.599	15.414
	45	3.71	0.742	22.740	2.89	0.578	15.106
	60	1.54	0.513	15.722	1.14	0.38	9.779
	75	0.09	0.09	2.758	0.0	0.0	0.0
			3.263			3.886	
6/30–7/6	0	0.62	0.062	20.130	1.92	0.192	18.234
	15	0.82	0.091	29.545	0.33	0.037	3.514
	30	0.83	0.119	38.636	0.49	0.07	6.648
	45	0.18	0.036	11.688	0.52	0.104	9.877
	60	0.0	0.0	0.0	1.97	0.65	61.728
	75	0.0	0.0	0.0	0.0	0.0	0.0
			0.308			1.053	
7/14–7/20	0	0.40	0.04	2.591	4.14	0.591	24.093
	15	1.95	0.217	14.054	7.40	0.925	37.709
	30	3.51	0.501	32.448	1.32	0.264	10.762
	45	1.02	0.204	13.212	1.21	0.303	12.352
	60	2.33	0.582	37.694	0.0	0.0	0.0
	75	0.0	0.0	0.0	0.37	0.37	15.084
			1.544			2.453	

movement pattern. On the other hand, the longitudinal transport of the population may well be affected by this pattern of movement. This additional complication results from their vertical diurnal movement pattern that tends to keep them in the lower, inland moving zone for sufficient time so that net migration in the saline region would appear to be in the upstream direction.

However, because the upstream transport of larval fish in the lower layer depends upon downstream larval concentrations, the downstream transport in the upper layer depends upon upstream concentrations of larvae. Because the source of larvae is upstream, there would initially be a longitudinal concentration gradient with highest concentrations in the upstream direction. Subsequently, downstream transport will occur until sufficient larvae have accumulated in the downstream areas to cause the upstream and downstream transport to be equal. This endpoint would depend upon both the temporal mean vertical distribution and the nature of the variance around this mean, including changes in behavior patterns as the larvae grow. However, the interaction of the vertical migration with water currents would tend to concentrate the fish in the low salinity portions of the estuary. Thus, a physical rationale exists for the observed distribution which can be used to predict the movement patterns and the distribution of larval fish.

D. ESTIMATE OF ENTRAINMENT

The staff estimate of entrainment is based on a transport model that couples the observed diurnal fluctuations in vertical distribution with the density-induced flow which, although not adequately quantified, is known to exist in the salt-intruded reaches of the Hudson. Because the vertical and horizontal net velocities are unknown, the staff used a spectrum of assumed conditions ranging from low-velocity, underestimated transport to high velocity two-layer flows. All predicted distributions were compared with the field data collected in 1955, 1966, and 1967. 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 entrainment.

E. MODEL DESCRIPTION

Because of the kind of system being modeled, it was concluded that the simplest and most useful approach would be to divide the estuary into a series of compartments and to describe relationships which govern the dynamics of the larval population within and between these compartments (Fig. A-V-19). In this manner, populations of one or more species which have originated at various locations within the estuary can be considered simultaneously.

This general approach has been used by several investigators in relation to problems of estuarine circulation.[13] However, most of these methods are designed for other purposes and are not readily adapted to the complex inter-relationships between the spatial and temporal distributions of organisms and flows which must be adequately modeled to provide realistic predictions of entrainment effects. Because of this situation, a mathematical formulation of the compartmental approach had to be developed for application to problems of estuarine transport with respect to population movements.

Many methods could be used to develop such a model. However, an adaptation of the technique presented by Pritchard[14] would seem to be most applicable for use in where partly stratified conditions predominate.

Mathematically, the model is simple and is basically similar to other compartmental approaches. Specifically, the amount of any substance within any compartment over a specific period of time is equal to the inputs from adjacent compartments plus the production within the compartment minus the loss within the compartment and the loss by outputs to adjacent compartments. In the present case, the model is designed to accommodate various transport situations which result from the combined interactions of the spatial and temporal distributions of organisms and flows. By solving the difference equation given below for a finite interval of time, an estimate can be obtained of the change in concentration of organisms within compartment *n* in that interval. Likewise, by solving a series of simultaneous equations of the same form, the concentrations of organisms within all of the compartments through time can be estimated.

$$C_n = [s_n \cdot C_n \cdot V_n + R_n + \mu_{n-1} \cdot Q_{\mu_{n-1}} \cdot C_{n-1} + \ell_{n+1} \cdot Q_{\ell_{n+1}} \cdot C_{n+1}$$

$$- C_n(\mu_n \cdot Q_{\mu_n} + \ell_n \cdot Q_{\ell_n} + m \cdot r \cdot Q_{c_n})]\, V_n^{-1}$$

where:

C_n = concentration of *x* in compartment *n*
V_n = volume of conpartment *n*

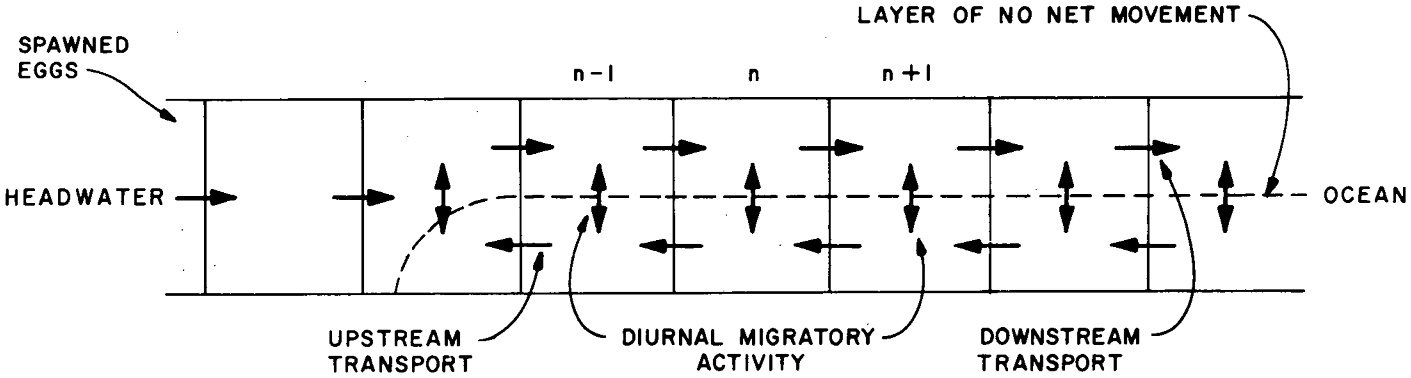

Fig. A-V-19. Diagram of estuarine transport model used to predict the downstream migration of larval striped bass and the mortality resulting from entrainment.

Q_{μ_n} = upper layer flow leaving compartment *n*

Q_{ℓ_n} = lower layer flow leaving compartment *n*

μ_n = average fraction of population in compartment *n* that is in the upper layer

ℓ_n = average fraction in lower layer

r = coefficient of susceptibility to condenser flow

m = average fraction killed on entrainment

Q_c = withdrawal flow through condenser

R_n = rate of reproduction addition of *x* in compartment *n*

s_n = 1 minus the fractional loss from natural mortality in compartment *n*.

For convenience, the Hudson River was divided into 19 compartments, each with a volume of 4.5×10^8 ft^3, and was assumed to be completely mixed. Several sets of transport factors were applied for a number of different assumed flow conditions (Tables A-V-16 to A-V-21).

Table A-V-16. Predicted percentage reduction in Hudson River striped bass larvae as a result of entrainment by Indian Point Units Nos. 1 and 2 operating at 2650 cfs. Unless otherwise specified, condenser mortality is assumed to be 100%, natural mortality is a constant, and computation interval is equivalent to a 24-hr period

Case	Spawning	Flow	Migration[a]	Other[b]	Basis of percentage	Percentage reduction at weekly intervals after spawning							
						1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks
1	A	I	a		Total	3.51	7.03	10.77	14.89	19.44	24.42	29.73	35.23
					Nursery	14.79	23.69	29.86	34.37	37.96	41.14	44.22	47.36
2	A	I	b		T	3.56	7.17	11.02	15.24	19.86	24.85	30.09	35.42
					N	13.39	21.10	26.61	30.78	34.22	37.32	40.34	43.41
3	A	I	c		T	3.53	6.99	10.55	14.37	18.48	22.86	27.38	31.90
					N	12.40	19.17	23.90	27.41	30.25	32.79	35.26	37.76
4	A	I	d		T	3.48	6.72	9.93	13.28	16.85	20.59	24.40	28.13
					N	11.72	17.79	21.90	24.82	27.10	29.10	31.03	32.96
5	A	I	f		T	2.10	1.86	1.70	2.13	2.64	3.16	3.68	4.15
					N	6.32	9.43	8.75	8.71	8.78	8.86	8.94	9.03
6	A	I	c	m	T	1.80	3.67	5.68	7.86	10.26	12.85	15.57	18.35
					N	6.36	10.09	12.84	14.98	16.80	18.49	20.15	21.86
7	A	I	d	n	T	1.77	3.53	5.32	7.22	9.26	11.43	13.66	15.89
					N	6.02	9.35	11.71	13.47	14.91	16.21	17.47	18.75
8	A	I	a	6	T	3.28	6.84	10.49	14.51	18.94	23.78	28.94	34.29
					N	14.27	22.92	28.92	33.35	36.93	40.12	43.22	46.38
9	A	I	a	12	T	3.45	6.90	10.58	14.63	19.11	23.99	29.20	34.60
					N	14.44	23.17	29.23	33.69	37.27	40.45	43.55	46.70
10	A	I	b	6	T	3.45	6.97	10.72	14.82	19.32	24.16	29.25	34.42
					N	12.99	20.47	25.80	29.89	33.29	36.39	39.41	42.47
11	A	I	b	12	T	3.49	7.03	10.82	14.96	19.50	24.39	29.52	34.75
					N	13.12	20.68	26.06	30.18	33.59	36.69	39.72	42.78
12	A	I	a	6	T	3.14	6.06	9.07	12.35	15.98	19.97	24.29	28.85
					N	14.22	22.72	28.47	32.54	35.68	38.41	41.02	43.67
13	A	I	b	6	T	3.14	6.16	9.36	12.89	16.80	21.07	25.63	30.37
					N	12.85	20.06	25.09	28.89	32.01	34.81	37.53	40.28
14	A	I	c	6	T	3.10	6.03	9.08	12.38	15.99	19.88	23.97	28.13
					N	11.89	18.15	22.48	25.71	28.35	30.71	33.00	35.31
15	A	I	d	6	T	3.05	5.83	8.64	11.61	14.80	18.19	21.70	25.22
					N	11.24	16.85	20.61	23.34	25.50	27.41	29.23	31.05
16	A	II	a		T	2.78	4.97	6.98	9.00	11.12	13.38	15.81	18.39
					N	12.86	20.48	25.49	28.79	31.07	32.86	34.44	36.00
17	A	II	b		T	2.92	5.52	8.14	10.89	13.86	17.04	20.44	24.00
					N	11.73	18.39	23.16	26.80	29.76	32.34	34.73	37.04
18	A	II	c		T	2.98	5.70	8.46	11.37	14.47	17.77	21.24	24.85
					N	10.90	16.77	21.03	24.38	27.19	29.68	32.01	34.27
19	A	II	d		T	2.99	5.68	8.35	11.10	13.98	17.00	20.13	23.33
					N	10.32	15.57	19.31	22.22	24.63	26.75	28.72	30.62
20	A	II	e		T	2.97	5.54	7.99	10.42	12.90	15.45	18.03	20.62
					N	9.75	14.38	17.55	19.91	21.81	23.43	24.91	26.32
21	C	IV	a		T	2.69	5.91	10.14	15.34	21.27	27.57	33.78	39.55
					N	19.39	25.84	29.88	33.22	36.34	39.48	42.70	45.95
22	C	IV	a	*	T	2.69	5.91	10.14	15.34	21.27	27.57	33.78	39.55
					N	19.39	25.84	29.88	33.22	36.34	39.48	42.70	45.95
23	C	IV	b		T	2.70	5.99	10.19	15.14	20.55	26.06	31.25	35.85
					N	17.50	22.97	26.45	29.26	31.82	34.37	36.96	39.56
24	C	IV	b	*	T	2.70	5.99	10.19	15.14	20.55	26.06	31.25	35.85
					N	17.50	22.97	26.45	29.26	31.82	34.37	36.96	39.56
25	C	IV	c		T	2.69	5.94	9.96	14.53	19.39	24.19	28.62	32.48
					N	16.25	21.07	24.12	26.52	28.67	30.80	32.98	35.17
26	C	IV	c	*	T	2.69	5.94	9.96	14.53	19.39	24.19	28.62	32.48
					N	16.25	21.07	24.12	26.52	28.67	30.80	32.98	35.17

Table A-V-16 (continued)

Case	Spawning	Flow	Migration[a]	Other[b]	Basis of percentage	Percentage reduction at weekly intervals after spawning							
						1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks
27	C	IV	d		T	2.67	5.86	9.69	13.93	18.36	22.69	26.64	30.06
					N	15.42	19.82	22.56	24.70	26.60	28.47	30.39	32.35
28	C	IV	d	*	T	2.67	5.86	9.69	13.93	18.36	22.69	26.64	30.06
					N	15.42	19.82	22.56	24.70	26.60	28.47	30.39	32.35
29	C	IV	e		T	2.65	5.74	9.36	13.27	17.29	21.19	24.73	27.81
					N	14.67	18.68	21.16	23.07	24.75	26.40	28.10	29.86
30	C	IV	e	*	T	2.65	5.74	9.36	13.27	17.29	21.19	24.73	27.81
					N	14.67	18.68	21.16	23.07	24.75	26.40	28.10	29.86
31	A	V	a		T	3.29	6.25	9.06	11.80	14.54	17.33	20.19	23.16
					N	15.94	26.07	33.57	39.34	43.88	47.51	50.47	52.94
32	D	VI	f		T	1.37	3.65	6.12	8.60	11.03	13.38	15.64	17.80
					N	14.03	18.68	20.93	22.28	23.26	24.08	24.79	25.44
33	D	VI	f	*	T	1.37	3.65	6.12	8.60	11.03	13.38	15.64	17.80
					N	14.03	18.68	20.93	22.28	23.26	24.08	24.79	25.44
34	E	VI	f		T	0.43	2.05	4.38	6.98	9.65	12.27	14.80	17.19
					N	11.21	16.45	19.42	21.22	22.45	23.41	24.25	25.01
35	A	VI	*	f	T	3.04	5.36	7.43	9.50	11.65	13.84	16.02	18.14
					N	11.61	15.84	18.24	20.06	21.57	22.82	23.84	24.70
36	A	VII	a		T	3.51	6.76	10.00	13.44	17.23	21.46	26.13	31.17
					N	17.65	29.00	36.57	41.84	45.76	48.95	51.78	54.45
37	A	VII	b		T	3.65	7.26	11.00	15.05	19.52	24.46	29.79	35.39
					N	17.48	28.51	35.89	41.09	45.02	48.28	51.20	53.98
38	A	VII	c		T	3.77	7.63	11.71	16.14	20.98	26.26	31.87	37.64
					N	17.55	28.18	35.45	40.61	44.53	47.79	50.72	53.50
39	A	VII	d		T	3.85	7.90	12.19	16.83	21.88	27.31	33.03	38.83
					N	17.25	27.97	35.18	40.29	44.18	47.41	50.31	53.07
40	A	VII	e		T	4.66	9.85	14.87	19.83	24.91	30.13	35.32	40.28
					N	16.51	26.47	32.83	36.94	39.95	42.54	45.01	47.45
41	A	X			T	3.40	6.79	10.37	14.30	18.63	23.34	28.34	33.52
					N	14.50	23.21	29.20	33.61	37.15	40.29	43.32	46.38
42	A	IX	a		T	2.92	4.89	6.44	7.82	9.10	10.32	11.51	12.74
					N	11.30	15.26	17.56	19.40	20.89	21.98	22.69	23.14
43	A	IX	b		T	2.83	4.62	5.94	6.95	7.71	8.40	9.17	10.08
					N	10.08	13.31	15.48	17.17	18.23	18.69	18.84	18.93
44	A	IX	c		T	2.75	4.39	5.47	6.08	6.46	6.90	7.53	8.34
					N	9.29	12.19	14.30	15.73	16.31	16.35	16.30	16.35
45	B	VI	a		T	3.00	5.86	8.87	12.18	15.62	19.76	23.93	28.18
					N	16.06	24.84	30.21	33.95	36.83	39.22	41.30	43.18
46	B	VI	b		T	3.11	6.22	9.52	13.07	16.86	20.81	24.83	28.81
					N	15.49	23.54	28.45	31.86	34.47	36.59	38.39	40.01
47	A	III	f		T	1.71	1.70	1.28	1.29	1.49	1.74	2.00	2.26
					N	15.60	7.60	7.48	7.14	7.10	7.14	7.20	7.25
48	A	XI	a		T	3.26	6.46	9.88	13.65	17.82	22.34	27.10	31.98
					N	13.03	20.60	25.74	29.58	32.81	35.84	38.87	42.01
49	A	XI	b		T	3.42	6.94	10.75	14.93	19.50	24.37	29.42	34.50
					N	11.98	18.82	23.78	27.72	31.13	34.34	37.53	40.79
50	A	XI	c		T	3.46	6.92	10.55	14.44	18.61	22.98	27.41	31.78
					N	11.20	17.27	21.61	25.00	27.91	30.63	33.32	36.04
51	A	XI	d		T	3.39	6.38	9.24	12.14	15.11	18.09	20.96	23.65
					N	10.07	14.79	17.81	19.96	21.70	23.27	24.77	26.24
52	A	XI	a	s	T	2.24	4.52	7.02	9.82	12.95	16.39	20.06	23.88
					N	8.98	14.48	18.36	21.36	23.94	26.39	28.89	31.50

Table A-V-16 (continued)

Case	Spawning	Flow	Migration[a]	Other[b]	Basis of percentage	Percentage reduction at weekly intervals after spawning							
						1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks
53	A	XI	b	s	T	2.35	4.86	7.63	10.73	14.16	17.87	21.77	25.76
					N	8.24	13.19	16.90	19.93	22.62	25.19	27.79	30.47
54	A	XI	c	s	T	2.38	4.84	7.47	10.34	13.44	16.74	20.13	23.52
					N	7.69	12.07	15.30	1789	20.15	22.30	24.45	26.65
55	A	XI	d	s	T	2.33	4.44	6.50	8.61	10.78	12.97	15.11	17.12
					N	6.91	10.29	12.52	14.14	15.47	16.67	17.83	18.98
56	C	XIII	a	*	T	2.69	5.83	9.78	14.40	19.48	24.77	30.07	35.19
					N	19.39	26.16	30.65	34.45	37.95	41.32	44.62	47.87
57	C	XIII	b	*	T	2.70	5.92	9.87	14.37	19.20	24.16	29.09	33.86
					N	17.50	23.28	27.21	30.55	33.64	36.63	39.62	42.60
58	C	XII	c	*	T	2.69	5.87	9.67	13.87	18.28	22.74	27.13	31.38
					N	16.25	21.37	24.85	27.77	30.47	33.10	35.74	38.41
59	C	XII	d	*	T	2.67	5.79	9.42	13.33	17.37	21.42	25.38	29.20
					N	15.42	20.10	23.25	25.90	28.33	30.70	33.09	35.52
60	C	XII	e	*	T	2.65	5.68	9.10	12.71	16.37	20.00	23.54	26.95
					N	14.67	18.94	21.81	24.20	26.39	28.52	30.68	32.89
61	C	XII	a		T	2.69	5.83	9.78	14.40	19.48	24.77	30.07	35.19
					N	19.39	26.16	30.65	34.45	37.95	41.32	44.62	47.87
62	C	XII	b		T	2.70	5.92	9.87	14.37	19.20	24.16	29.09	33.86
					N	17.50	23.28	27.21	30.55	33.64	36.63	39.62	42.60
63	C	XII	c		T	2.69	5.87	9.67	13.97	18.28	22.74	27.13	31.38
					N	16.25	21.37	24.85	27.77	20.47	33.10	35.74	38.41
64	C	XII	d		T	2.67	5.79	9.42	13.33	17.37	21.42	25.28	29.20
					N	15.42	20.10	23.25	25.90	28.33	30.70	33.09	35.52
65	C	XII	e		T	2.65	5.68	9.10	12.71	16.37	20.00	23.54	26.95
					N	14.67	18.94	21.81	24.20	26.39	28.52	30.68	32.89
66	A	X	a		T	3.4	6.8	10.4	14.3	18.6	23.3	28.3	33.5
					N	14.5	23.2	29.2	33.6	37.2	40.3	43.3	46.4
67	A	X	b		T	3.5	7.0	10.7	14.8	19.2	24.9	28.9	33.9
					N	12.3	20.1	26.0	29.9	33.2	36.2	39.1	42.0
68	A	X	c		T	3.5	6.8	10.4	14.2	18.2	22.5	26.7	31.0
					N	12.5	19.0	23.5	26.8	29.5	32.0	34.4	36.7
69	A	X	e		T	3.4	6.5	9.5	12.5	15.5	18.6	21.6	24.5
					N	11.3	16.6	19.8	22.1	23.8	25.4	26.8	28.1
70	A	X	a		T	3.1	6.1	9.1	12.4	16.0	20.0	25.3	28.9
					N	14.2	22.7	28.5	32.5	35.7	38.4	41.0	43.7
71	A	X	c		T	3.1	6.0	9.1	12.4	16.0	20.0	24.0	28.1
					N	11.9	18.1	22.5	25.7	28.4	30.7	33.0	35.3

[a] Migration factors:

Condition	Upstream factor	Downstream factor
a	0.75	0.25
b	0.67	0.33
c	0.60	0.40
d	0.55	0.45
e	0.50	0.50
f	0	1.00

[b] * = exponential decay rate in natural mortality,
m = 50% mortality upon condenser passage,
s = 60% susceptibility to intake,
6 = computation interval of 6 hr,
12 = computation interval of 12 hr.

Table A-V-17. Predicted distribution (%) of larval striped bass four weeks after spawning, using the staff larval transport model with various assumed conditions

Segment	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.14	0.12	0.14	0.12	0.14	0.14	0.14	0.14	0.41	0.41	0.41
3	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.73	0.69	0.73	0.69	0.73	0.73	0.73	0.73	1.74	1.74	1.74
4	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.96	1.90	1.96	1.90	1.96	1.96	1.96	1.96	3.69	3.69	3.69
5	3.49	3.49	3.49	3.49	3,49	3.49	3.49	3.60	3.57	3.60	3.57	3.60	3.60	3.60	3.60	5.53	5.53	5.53
6	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	7.01	7.01	7.01
7	6.79	6.79	6.79	6.79	6.79	6.79	6.79	6.72	6.74	6.72	6.74	6.72	6.72	6.72	6.72	8.07	8.07	8.07
8	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.82	7.76	7.72	7.76	7.72	7.72	7.72	7.72	8 48	8.48	8.48
9	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.16	8.21	8.16	8.21	8.16	8.16	8.16	8.16	19.90	12.91	9.25
10	17.44	12.17	9.45	8.01	3.05	9.45	8.01	17.27	17.33	12.03	12.07	21.93	15.94	12.60	10.73	18.89	14.83	11.29
11	18.05	13.65	10.35	8.31	2.10	10.35	8.31	18.02	18.03	13.60	13.62	19.03	15.43	12.29	10.18	12.86	12.94	11.08
12	18.04	17.89	15.55	13.20	2.31	15.55	13.20	18.09	18.07	17.91	17.91	14.57	15.22	13.75	11.98	8.15	11.23	11.63
13	7.36	10.15	10.82	10.36	2.22	10.82	10.36	7.39	7.38	10.18	10.17	6.03	8.69	9.55	9.35	3.19	6.15	7.92
14	2.98	5.65	7.33	7.91	2.05	7.33	7.91	2.99	2.99	5.67	5.66	2.48	4.88	6.48	7.12	1.26	3.36	5.32
15	1.19	3.07	4.84	5.89	1.90	4.84	5.89	1.19	1.19	3.08	3.08	1.01	2.68	4.30	5.30	0.50	1.82	3.53
16	0.47	1.64	3.13	4.31	1.71	3.13	4.31	0.47	0.47	1.64	1.64	0.40	1.45	2.80	3.89	0.20	0.98	2.34
17	0.18	0.86	2.02	3.19	1.45	2.02	3.19	0.18	0.18	0.87	0.87	0.16	0.77	1.82	2.90	0.08	0.54	1.58
18	0.07	0.46	1.34	2.49	1.13	1.34	2.49	0.07	0.07	0.46	0.46	0.06	0.41	1.22	2.28	0.03	0.30	1.13
19	0.03	0.25	0.95	2.13	27.87	0.95	2.13	0.03	0.03	0.25	0.25	0.02	0.22	0.87	1.96	0.00	0.00	0.00
% retained (4 weeks)	99.97	99.75	99.05	97.87	52.13	99.05	97.87	99.97	99.97	99.75	99.75	99.97	99.77	99.13	98 04	100.00	100.00	100.00
% retained (8 weeks)	99.95	99.38	97.35	93.94	18.45	97.35	93.94	99.94	99.95	99.37	99.38	99.95	99.46	97.63	94.47	100.00	100.00	100.00

Table A-V-17 (continued)

Segment	Case 19	Case 20	Case 21	Case 22	Case 23	Case 24	Case 25	Case 26	Case 27	Case 28	Case 29	Case 30	Case 31	Case 32	Case 33	Case 34	Case 35	Case 36
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.01	0.09	0.0	0.0
2	0.41	0.41	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	1.15	0.52	0.03	0.57	0.14	0.10
3	1.74	1.74	0.14	0.01	0.14	0.01	0.14	0.01	0.14	0.01	0.14	0.01	3.77	1.58	0.09	1.74	0.73	0.61
4	3.69	3.69	0.46	0.03	0.46	0.03	0.46	0.03	0.46	0.03	0.46	0.03	6.03	3.25	0.19	3.57	1.96	1.79
5	5.53	5.53	1.14	0.07	1.14	0.07	1.14	0.07	1.14	0.07	1.14	0.07	7.32	5.14	0.30	5.66	3.60	3.49
6	7.01	7.01	2.21	0.13	2.21	0.13	2.21	0.13	2.21	0.13	2.21	0.13	8.29	6.79	0.40	7.47	5.28	5.28
7	8.07	8.07	3,58	0.21	3.58	0.21	3.58	0.21	3.58	0.21	3.58	0.21	8.96	7.94	0.47	8.73	6.72	6.79
8	8.48	8.48	5.01	0.29	5.01	0.29	5.01	0.29	5.01	0.29	5.01	0.29	8.55	8.59	0.50	9.45	7.72	7.84
9	7.36	6.01	6.26	0.37	6.26	0.37	6.26	0.37	6.26	0.37	6.26	0.37	7.67	8.90	0.52	9.80	8.16	8.30
10	8.98	7.13	7.19	0.42	7.19	0.42	7.19	0.42	7.19	0.42	7.19	0.42	13.05	9.03	0.53	9.93	8.08	16.44
11	9.17	7.26	29.15	1.71	23.12	1.36	19.56	1.15	17.44	1.02	15.56	0.92	13.02	9.07	0.53	9.89	7.75	17.22
12	10.73	9.16	23.23	1.36	20.62	1.21	18.04	1.06	16.14	0.94	10.59	0.84	13.16	6.72	0.53	9.43	7.52	21.33
13	8.38	8.03	12.10	0.71	13.67	0,80	13.72	0.81	13.27	0.78	9.45	0.74	5.41	6.50	0.50	8.26	7.54	5.24
14	6.43	6.92	5.69	0.33	8.21	0.48	9.52	0.56	10.03	0.59	7.84	0.60	2.19	5.83	0.44	6.43	7.59	3.70
15	4.88	5.91	2.41	0.14	4.46	0.26	6.04	0.35	6.99	0.41	6.05	0.45	0.85	4.64	0.34	4.34	7.30	1.45
16	3.71	5.11	0.92	0.05	2.21	0.13	3.50	0.21	5.56	0.26	4.30	0.31	0.32	3.21	0.23	2.53	6.45	0.34
17	2.92	4.79	0.32	0.02	0.99	0.06	1.84	0.11	2.60	0.15	2.79	2.20	0.11	1.91	0.13	1.27	4.12	0.05
18	2.51	4.85	0.10	0.01	0.39	0.02	0.85	0.05	1.33	0.08	1.58	0.11	0.04	0.97	0.07	0.55	3.63	0.01
19	0.00	0.00	0.02	0.00	0.11	0.01	0.27	0.02	0.46	0.03	0.60	0.04	0.01	0.43	0.03	0.20	4.71	0.00
% retained (4 weeks)	100.00	100.00	99.95	99.95	99.70	99.70	99.11	99.11	98.30	98.30	97.06	97.06	99.99	99.23	99.23	99.70	95.28	100.00
% retained (8 weeks)	100.00	100.00	99.07	99.07	95.05	95.05	87.91	87.91	80.24	80.24	71.25	71.25	99.97	81.57	81.57	86.18	69.95	99.98

Table A-V-17 (continued)

Segment	Case 37	Case 38	Case 39	Case 40	Case 41	Case 42	Case 43	Case 44	Case 45	Case 46	Case 47	Case 48	Case 49	Case 50	Case 51	Case 52	Case 53	Case 54
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.10	0.10	0.10	0.10	0.14	0.41	0.41	0.41	0.52	0.52	0.41	0.14	0.14	0.14	0.14	0.14	0.14	0.14
3	0.61	0.51	0.61	0.61	0.73	1.74	1.74	1.74	1.58	1.58	1.74	0.73	0.73	0.73	0.73	0.73	0.73	0.73
4	1.79	1.79	1.79	1.79	1.97	3.69	3.69	3.69	3.25	3.25	3.69	1.96	1.96	1.96	1.96	1.96	1.96	1.96
5	3.49	3.49	3.49	3.49	3.60	5.53	5.53	5.53	5.14	5.14	3.53	3.60	3.60	3.60	3.60	3.60	3.60	3.60
6	5.28	5.28	5.28	5.28	5.28	7.01	7.01	7.01	6.79	6.79	7.01	5.28	5.28	5.28	5.28	5.28	5.28	5.28
7	6.79	6.79	6.79	6.79	6.72	8.07	8.07	8.07	7.94	7.94	8.07	6.72	6.72	6.72	6.72	6.72	6.72	6.72
8	7.84	7.84	7.84	7.84	7.72	8.48	8.48	8.48	8.59	8.59	8.48	7.72	7.72	7.72	7.72	7.72	7.72	7.72
9	8.30	8.30	8.30	8.30	8.89	8.26	6.32	5.30	8.90	9.90	4.26	9.94	8.10	7.17	6.38	9.94	8.10	7.17
10	13.22	11.35	10.23	4.78	18.13	7.71	6.11	5.19	17.14	13.35	3.17	19.44	12.64	8.97	5.72	19.44	12.64	8.97
11	14.93	14.71	13.72	7.22	16.71	5.13	1.16	3.55	14.94	12.70	2.18	18.11	14.41	10.81	6.39	18.11	14.41	10.81
12	24.01	25.54	26.37	25.48	17.97	5.07	4.11	3.59	19.67	19.78	1.42	15.94	17.51	15.83	10.95	15.94	17.51	15.83
13	6.10	6.79	7.29	10.31	7.66	5.41	4.30	3.60	11.29	13.17	1.41	5.32	9.80	11.01	9.70	6.32	9.80	11.01
14	4.00	4.29	4.54	7.57	3.24	5.93	4.71	3.88	6.28	7.91	1.50	2.50	5.42	7.52	8.44	2.50	5.42	7.52
15	1.94	2.15	2.38	5.05	1.36	6.24	5.25	4.33	3.05	4.23	1.39	0.99	2.96	5.06	7.30	0.99	2.96	5.06
16	0.55	0.74	0.90	2.97	0.56	6.02	5.65	4.85	1.16	1.89	1.38	0.39	1.61	3.39	6.41	0.39	1.61	3.39
17	0.12	0.18	0.25	1.49	0.23	5.20	5.71	5.28	0.34	0.68	1.39	0.16	0.89	2.33	6.03	0.16	0.89	2.33
18	0.02	0.04	0.05	0.68	0.10	4.00	5.29	5.42	0.09	0.23	1.41	0.06	0.51	1.74	6.53	0.06	0.51	1.74
19	0.00	0.00	0.01	0.19	0.00	0.15	0.26	0.32	0.01	0.02	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% retained (4 weeks)	100.00	99.99	99.99	99.76	100.00	93.90	86.54	79.82	100.00	100.00	54.34	100.00	100.00	100.00	100.00	100.00	100.00	100.00
% retained (8 weeks)	99.95	99.89	99.82	96.21	100.00	68.79	54.92	47.21	100.00	100.00	27.84	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table A-V-17 (continued)

Segment	Case 55	Case 56	Case 57	Case 58	Case 59	Case 60	Case 61	Case 62	Case 63	Case 64	Case 65	Case 66	Case 67	Case 68	Case 69	Case 70	Case 71
1	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2	0.14	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.07	0.07	0.14	0.14	0.14	0.14	0.14	0.14
3	0.73	0.02	0.02	0.02	0.02	0.02	0.30	0.30	0.30	0.30	0.30	0.73	0.73	0.73	0.73	0.73	0.73
4	1.96	0.05	0.05	0.05	0.05	0.05	0.87	0.87	0.87	0.87	0.87	1.96	1.96	1.96	1.96	1.96	1.96
5	3.60	0.11	0.11	0.11	0.11	0.11	1.89	1.89	1.89	1.89	1.89	3.60	3.60	3.60	3.60	3.60	3.60
6	5.28	0.19	0.19	0.19	0.19	0.19	3.28	3.28	3.28	3.28	3.28	5.28	5.28	5.28	5.28	5.28	5.28
7	6.72	0.28	0.28	0.28	0.28	0.28	4.78	4.78	4.78	4.78	4.78	6.72	6.72	6.72	6.72	6.72	6.72
8	7.72	0.36	0.36	0.36	0.36	0.36	0.36	6.12	6.12	6.12	6.12	7.72	7.72	7.72	7.72	7.72	7.72
9	6.38	0.42	0.42	0.42	0.42	0.42	7.12	7.12	7.12	7.12	7.12	8.89	8.04	7.60	7 18	8.16	8.16
10	5.72	0.45	0.45	0.45	0.45	0.45	7.75	7.75	7.75	7.75	7.75	17.13	11.96	9.23	6.66	21.93	12.60
11	6.39	1.75	1.39	1.17	1.03	0.92	29.91	23.72	19.93	17.63	15.69	16.71	13.14	10.35	7.11	19.03	12 29
12	10.95	1.22	1.12	0.99	0.89	0.80	20.78	19.06	16.95	15.25	13.59	17.97	17.96	15.99	11.80	14.57	13.75
13	9.70	0.58	0.69	0.72	0.71	0.68	9.95	11.82	12.24	12.04	11.52	7.66	10.42	11.24	10 25	6.03	9.55
14	8.44	0.26	0.40	0.48	0.52	0.53	4.41	6.75	8.14	8.79	9.09	3.24	5.90	7.64	8.62	2.48	6.48
15	7.30	0.10	0.21	0.29	0.35	0.39	1.78	3.53	4.99	5.94	6.68	1.36	3.24	5.01	7.01	1.01	4.30
16	6.41	0.04	0.10	0.16	0.22	0.27	0.66	1.69	2.80	3.69	4.53	0.56	1.73	3.19	5.59	0.40	2.80
17	6.03	0.01	0.04	0.08	0.12	0.16	0.22	0.73	1.43	2.09	2.80	0.23	0.93	2.07	4.70	0.16	1.82
18	6.53	0.00	0.02	0.04	0.06	0.09	0.07	0.28	0.64	1.03	1.51	0.10	0.54	1.53	4.43	0.06	1.22
19	0.00	0.00	0.00	0.01	0.02	0.03	0.01	0.08	0.20	0.35	0.54					0.02	0.87
% retained (4 weeks)	100.00	99.98	99.78	99.32	98.66	97.62	99.97	99.78	99.32	98.66	97.62	100.00	100.00	100.00	100.00	100.00	100.00
% retained (8 weeks)	100.00	99.69	97.92	93.98	89.01	82.39	99.69	97.92	93.98	89.01	82.39	100.00	100.00	100.00	100 00	100 00	100.00

Table A-V-18. Flow condition XII – variation with weeks (migration factor d). Flows[a] in cfs.

Segment	Week 1		Week 2		Week 3		Week 4	
	U	D	U	D	U	D	U	D
1	0	13,000	0	12,000	0	11,000	0	10,000
2	0	13,000	0	12,000	0	11,000	0	10,000
3	0	13,000	0	12,000	0	11,000	0	10,000
4	0	13,000	0	12,000	0	11,000	0	10,000
5	0	13,000	0	12,000	0	11,000	0	10,000
6	0	13,000	0	12,000	0	11,000	0	10,000
7	0	13,000	0	12,000	0	11,000	0	10,000
8	0	13,000	0	12,000	0	11,000	0	10,000
9	0	13,000	0	12,000	0	11,000	0	10,000
10	0	13,000	0	12,000	0	11,000	0	10,000
11	0	6,063	0	5,760	0	5,486	0	5,236
12	261	8,410	440	8,227	655	8,052	900	7,884
13	3,129	8,617	3,455	8,438	3,791	8,265	4,136	8,100
14	3,382	9,035	3,713	8,862	4,052	8,694	4,400	8,533
15	3,893	9,458	4,231	9,289	4,576	9,126	4,930	8,969
16	4,410	10,099	4,754	9,936	5,104	9,779	5,462	9,626
17	5,193	11,398	5,544	11,244	5,902	11,094	6,265	10,948
18	6,781	13,813	7,143	13,669	7,509	13,528	7,881	13,390
19	9,732	24,300	10,106	24,300	10,484	24,300	10,865	24,300

Segment	Week 5		Week 6		Week 7		Week 8	
	U	D	U	D	U	D	U	D
1	0	9,000	0	8,000	0	7,000	0	6,000
2	0	9,000	0	8,000	0	7,000	0	6,000
3	0	9,000	0	8,000	0	7,000	0	6,000
4	0	9,000	0	8,000	0	7,000	0	6,000
5	0	9,000	0	8,000	0	7,000	0	6,000
6	0	9,000	0	8,000	0	7,000	0	6,000
7	0	9,000	0	8,000	0	7,000	0	6,000
8	0	9,000	0	8,000	0	7,000	0	6,000
9	0	9,000	0	8,000	0	7,000	0	6,000
10	0	9,000	0	8,000	0	7,000	0	6,000
11	0	5,000	0	4,800	0	4,608	0	4,431
12	1,172	7,723	1,467	7,569	1,782	7,421	2,115	7,278
13	4,490	7,941	4,851	7,788	5,220	7,642	5,595	7,500
14	4,756	8,378	5,119	8,229	5,490	8,084	5,867	7,945
15	5,290	8,817	5,657	8,670	6,031	8,528	6,410	8,390
16	5,826	9,478	6,197	9,334	6,573	9,195	6,955	9,060
17	6,634	10,806	7,008	10,667	7,388	10,532	7,773	10,401
18	8,257	13,255	8,638	13,122	9,023	12,992	9,412	12,865
19	11,250	24,300	11,638	24,300	12,029	24,300	12,424	24,300

[a] U, upstream; D, downstream.

Table A-V-19. Distribution of spawning for various assumed conditions (% of total in each segment)

Segment	Condition				
	A	B	C	D	E
1	0.08	9.09	8.33	9.09	10.0
2	10.55	9.09	8.33	9.09	10.0
3	10.55	9.09	8.33	9.09	10.0
4	4.20	9.09	8.33	9.09	10.0
5	11.23	9.09	8.33	9.09	10.0
6	11.23	9.09	8.33	9.09	10.0
7	6.00	9.09	8.33	9.09	10.0
8	6.00	9.09	8.33	9.09	10.0
9	6.70	9.09	8.33	9.09	10.0
10	6.70	9.09	8.33	9.09	10.0
11	10.00	9.09	8.33	9.09	0
12	10.00	10.00	8.33	0	0
13	3.44	3.44	0	0	0
14	3.33	3.33	0	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0

Table A-V-20. Flow conditions for all cases

Segment	Conditions (roman numerals) and flows[a] (thousands of cfs)																			
	I		II		III		IV		V		VI		VII		IX		X		XI	
	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D
1	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
2	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
3	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
4	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
5	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
6	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
7	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
8	0	8	0	6	0	6	0	13	0	4	0	8	0	8	0	6	0	8	0	8
9	0	8	0	12	0	12	0	13	0	4	0	8	0	8	0	12	0	9	0	12
10	0	11	6	16	0	16	0	13	0	5.5	0	8	0	7	0	16	1	11	4	16
11	3	16	10	23	0	23	0	16	1.5	8	0	8	0	4.5	0	23	3	16	8	23
12	8	29	17	35	0	35	3	29	4.5	14.5	0	8	0	2	0	35	8	24	15	35
13	21	30	29	35	0	35	16	30	10.5	15	0	8	0	4	0	35	16	24	27	35
14	22	32	29	35	0	35	17	32	11	16	0	8	0	4	0	35	16	24	27	35
15	24	34	29	35	0	35	19	34	12	17	0	8	0	4	0	35	16	24	27	35
16	26	37	29	35	0	35	21	37	13	18.5	0	8	0	4	0	35	16	24	27	35
17	29	43	29	35	0	35	24	43	14.5	21.5	0	8	0	4	0	35	16	24	27	35
18	35	54	29	0	0	35	30	54	17.5	27	0	8	0	3	0	35	16	24	27	0
19	46	0	0	0	0	0	41	54	23	0	0	8	0	3	0	0				

[a] U, upstream; D. downstream.

Table A-V-21. Effect of migration factors on transport flows[a] (cfs) of week 6 of flow condition XII

Segment	Factor a		Factor b		Factor c		Factor d		Factor e	
	U	D	U	D	U	D	U	D	U	D
1	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
2	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
3	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
4	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
5	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
6	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
7	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
8	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
9	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
10	0	8,000	0	8,000	0	8,000	0	8,000	0	8,000
11	0	2,667	0	3,556	0	4,267	0	4,800	0	5,333
12	2,000	4,205	1,778	5,607	1,600	6,728	1,467	7,569	1,333	8,410
13	6,615	4,327	5,88-	5,769	6,923	6,923	4,851	7,788	4,410	8,654
14	6,981	4,571	6,205	6,095	5,585	7,314	5,119	8,229	4,654	9,143
15	7,714	4,817	6,857	6,422	6,171	7,707	5,657	8,670	5,143	9,633
16	8,450	5,186	7,511	6,914	6,760	8,297	6,197	9,334	5,633	10,371
17	9,557	5,926	8,495	7,902	7,645	9,482	7,008	10,667	6,371	11,853
18	11,779	7,290	10,470	9,720	9,423	11,664	8,638	13,122	7,853	14,580
19	15,870	13,500	14,107	18,000	12,696	21,600	11,638	24,300	10,580	27,000

[a] U, upstream; D, downstream.

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APPENDIX XI-1

COOLING TOWER CHEMICALS--POTENTIAL ENVIRONMENTAL DEGRADATION*

Introduction

Cooling towers dissipate heat directly into the atmosphere without first utilizing a reservoir or heat sink as in once-through cooling. The main justification for the towers has been concern for the environmental effects of once-through cooling on aquatic life. However, cooling towers, too, have the potential for environmental damage that should be carefully studied prior to their widespread installation and use. The principal impact to be studied is long-range meteorological changes caused by large amounts of heat and water vapor added to the atmosphere from the towers. Other environmental impacts, most notably dispersion of the chemical discharges of the blowdown and drift from cooling towers, have been little studied.

Wet cooling towers require large amounts of chemicals in the recirculating water to prevent corrosion and to inhibit biological attack. Because large amounts of water evaporate, salt concentrations build up in the remaining tower water, and some of this--the blowdown--must be bled off and discharged. In addition to losses from blowdown and evaporation, there is drift (droplets of water that escape from the tower stacks along with the vapor plume) that contains chemicals in the same concentration as in the recirculating water and blowdown. Thus, chemicals added to tower water can find their way directly into surrounding aquatic or terrestrial ecosystems through blowdown and drift.

Although untreated blowdown is undoubtedly the major source of environmental problems connected with cooling towers (its quantity and content of chemicals are easily determined), drift is too often considered negligible. Depending upon tower design and drift eliminators, calculated drifts vary from 0.01% to 0.3% of the recirculating water rate, the losses usually being higher for small towers. Drift from large natural draft cooling towers serving a 2,500 megawatt power plant has been calculated to be 4 tons of solids per day, assuming makeup water with 200 ppm of total dissolved solids (TDS) and drift of 0.2% of the recirculation rate. Most of the solids would be calcium and magnesium salts occurring naturally in the makeup water, and the rest would be chemicals added to the tower water.

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*Manuscript, by S. H. Hale, R. S. Carlsmith, and C. C. Coutant, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Relative volumes of blowdown to the aquatic environment and drift to the terrestrial environments have been calculated for smaller towers. Drift is 30% to 45% of the water loss, so that treatment of the blowdown alone removes only 55% to 70% of the chemical pollution. In order to further reduce the chemical effluents from cooling towers, drift eliminators must be used.

COMPOSITIONS AND CONCENTRATIONS OF COOLING TOWER CHEMICALS

Corrosion and Scale Inhibitors

Commonly used corrosion inhibitors for open recirculating systems include various mixtures of zinc, chromate, phosphate (organic or inorganic), sodium silicate, nitrate, borate, and organic inhibitors. To prevent scale deposition and to provide effects, organic phosphate compounds such as aminimethylenephosphonate are used in concentrations up to 3 ppm. Mr. R. J. Cunningham, Calgon Corporation, listed the following corrosion and scale-inhibiting chemicals (with their concentrations) in an open letter to Mr. Frank Rainwater of the Environmental Protection Agency:[3]

1. Chromate plus zinc	5 to 30 mg/liter* CrO^4 1 to 15 mg/l Zn
2. Chromate plus zinc plus phosphate	5 to 30 mg/l CrO_4 1 to 15 mg/l Zn 1 to 5 mg/l PO_4 (inorganic) 1 to 5 mg/l PO_4 (organic)
3. Zinc plus inorganic phosphate	10 to 30 mg/l PO_4 2 to 10 mg/l Zn
4. Zinc plus organic phosphate	1 to 10 mg/l Zn 3 to 15 mg/l PO_4 (organic)
5. Organic phosphate scale inhibitor	1 to 18 mg/l PO_4 (organic)
6. Specific copper corrosion inhibitors	1 to 5 mg/l sodium mercaptobenzothiazole or benzotriazole

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*1 mg/liter = 1 ppm

As seen in numbers 1 and 2 above, chromate, zinc, and phosphate are often used together because of the synergistic anticorrosive effects produced when they are combined.

Biocides

Of the commonly used biocides, chlorine or hypochlorite or nonoxidizing organic compounds such as chlorophenols, quaternary amines, and organo-metallics such as organotin compounds, organosulfur, and organothiocyanate (Table A-XI-1) are most frequently employed. They are all used to prevent deterioration of tower wood, loss of heat transfer efficiency, general fouling or plugging arising from microbial growths, and corrosion that results from microbial attack.[2] Organotin must be formulated with quaternary ammonium and other complex amines to produce a synergistic effect and to be dispersible. Chlorophenols, as soluble potassium and sodium salts, are more persistent than free chlorine and remain in systems longer. Common chlorophenols include: 2,4,5-trichlorophenate; 2,4,6-T; 2,3,4,6-T; tetrachlorophenol; and pentachlorophenol. Organosulfurs are noted for low toxicity to animals, yet effective action against bacteria, fungi, and especially sulfate-reducing bacteria. Quarternary and complex amines are effective wetting agents and destroy microbial agents by surface-active properties; these are the least toxic of all antimicrobial compounds to animals, although they may form and so cause anesthetic problems. The organothiocynates, the most modern of the nonoxidizing biocides, are widely effective. Oils, organic chemicals, water hardness, and other materials seem to cause little reduction in their effectiveness, especially if they are combined with chlorophenols. The nonoxidizing biocides are used whenever the problems are rather severe and where the use of free chlorine is not acceptable. Typical concentrations for continuous use are 1 to 25 ppm; higher (200 ppm or so) if applied in periodic treatments. Elemental chlorine is an oxidizing agent and can cause rapid deterioration of wood. The use of free chlorine as a biocide is usually restricted to 1.0 ppm as free residual chlorine and to 1 to 2 hours per day.[3]

The use of biocides that contain mercury, arsenic, lead, or boron is limited by stringent regulations on their release to the environment than do most of the compounds previously discussed, because of their extreme toxicity.[4] These are rarely if ever used now; however, a review of label names in Table A-XI-1 reveals that the potentially toxic materials, copper and thiocyanate ions, are present in some commercial compounds. Tin is probably also questionable as far as toxicity is concerned. All of the chemical labels note that precautions should

Table A-XI-1. CHEMICAL COMPOSITION OF TRADE NAME MICROORGANISM CONTROL CHEMICALS

(From company sources and Environmental Protection Agency)

	COMPOSITION (%)	USAGE
NALCO 21-S		
Sodium pentachlorophenate	21.3	periodically, as needed
Sodium 2,4,5-trichlorophenate	11.9	25-400 ppm
Sodium salts of other Chlorophenols	3.0	or
Inert ingredients	63.8	continuously
NALCO 25-L or NALCO 425-L		weekly
1-Alkyl (C_6 to C_{18})-amino-3-aminopropane propionate-copper acetate complexes	15.0	20-300 ppm
Isopropanol	30.0	
Copper sulfate expressed as metallic copper	0.55	
Inert ingredients	55.0	
NALCO 201		
Potassium pentachlorophenate	15.7	periodically, as needed
Potassium 2,4,5-trichlorophenate	9.0	300-400 ppm
Potassium salts of other chlorophenols	1.8	or
Inert ingredients	70.3	12-60 ppm continuously
NALCO 202		
Methyl-1, 2-dibromopropionate	29.7	5-200 ppm periodically or
Inert ingredients	70.3	continously
NALCO 207		weekly
Methylene bisthiocyanate	10.0	25-50 ppm
Inert ingredients	90.0	
NALCO 209		
1.3-Dichloro-5, 5 dimethyl hydantoin	25.0	as needed 50-100 ppm
Inert ingredients	75.5	

	COMPOSITION (%)	USAGE
NALCO 321		
1-Alkyl (C_6 to C_{18})* amino-3-aminopropane monoacetate	20.0	weekly 5-200 ppm
Isopropanol	30.0	
Inert ingredients	50.0	
* As in fatty acids of coconut oil		
NALCO 322		
1-Alkyl (C_6 to C_{18})* amino-3-aminopropane monoacetate	19.8	as needed 10-200 ppm
2,4,5-Trichlorophenol	9.5	
Isopropanol	27.0	
Inert ingredients	43.7	
* As in fatty acids of coconut oil		
NALCO 405		
2, 4-Dinitrochlorobenzene	22.2	as needed 100-200 ppm
2, 6-Dinitrochlorobenzene	2.8	
Inert ingredients	75.0	
Betz A-9		
Sodium pentachlorophenate	24.7	
Sodium 2, 4, 5-Trichlorophenate	9.1	
Sodium salts of other chlorophenates	2.9	
Sodium dimethyl dithiocarbamate	4.0	
N-Alkyl (C_{12}-4%, C_{14}-50%, C_{16}-10% dimethyl benzyl ammonium chloride	5.0	
Inert ingredients (including solubilizing and dispersing agents)	54.3	
Betz C-5		
1, 3, Dichloro-5, 5-Dimethylhydantoin	50	
Inert ingredients (including solubilizing and dispersing agents)	50	

	COMPOSITION (%)	USAGE
Betz C-30		
Bis (trichloromethyl sulfone	20.0	
Methylene disthiocyanate	5.0	
Inert ingredients (including solubilizing and dispersing agents)	75.0	
Betz C-34		
Sodium dimethyl dithiocarbamate	15.0	
Nabam (disodium ethylene bisdithiocarbamate)	15.3	
Inert ingredients (including solubilizing and dispersing agents)	69.7	
Betz J-12		
N-Alkyl (C_{12}-5%, C_{14}-60%, C_{16}-30%, C_{18}-5%) dimethyl benzyl ammonium chloride	24.0	
Bis (tributyltin) oxide	5.0	
Inert ingredients (including solubilizing and dispersing agents)	71.0	
Betz F-14		
Sodium pentachlorophenate	20.0	
2,4,5, T or Sodium 2,4,5 trichlorophenate	7.5	
Sodium salts of chlorophenate	2.5	
Dehydrobutyl ammonium phenoxide	2.0	
Inert ingredients, including dispersants	68.0	

be used in handling of the product, and two indicate that the product may be harmful or fatal if absorbed through the skin. Only two, however, cautioned against dumping them directly into lakes, streams, or ponds. Some of the products containing 2,4,5-T listed no such precautions; yet the compound is now expressly banned in waterways.

pH Adjustors and Silt Control (Antifoulant) Polymers

Scale and corrosion inhibitors and biocides require the addition of acid or alkali to makeup water to keep the pH at an optimum level, usually a range from 5.5 to 7.5. Silt-control polymers may be used if makeup is raw water from a nearby lake or river. Lignin-tannin dispersives such as 1 to 50 ppm sodium lignosulfonate may be employed. Antifoulants such as 0.1 to 5 ppm of acrylamids, polyacrylate, polyethyleneimine, or other high molecular synthetic organic polyelectrolytes may also be used.[3]

Chemical Action

Corrosion Inhibition

Chromate ion is one of the most effective corrosion inhibitors. It is effective where it can react with iron-containing alloys to form alpha ferric oxide and chromic oxide film on the iron surface. Usually this treatment is most effective when a high concentration of chromate is circulated throughout the system until the film forms; then maintenance of a low concentration of chromate is sufficient to maintain the protective film.

Phosphate acts both as a corrosion and a scale inhibitor and may be found as sodium tripolyphosphate, sodium hexametaphosphate, and several types of "glassy" phosphates of high molecular weight. These compounds also form a protective film on metal, mostly on cathodic areas. However, at high temperature, low pH, or high calcium concentrations, the polyphosphates revert to orthophosphates, or low molecular weight or react with iron or water hardness salts to form an insoluble sludge.

Zinc ion alone is a relatively weak corrosion inhibitor but has strong synergistic qualities. It is a cathodic inhibitor that forms a deposit of zinc hydroxide on cathodic areas, thereby diminishing the cell potential.

Sodium silicate forms a thin protective gelatinous film over the first layer of corrosion product on the metal surface. High concentrations of chloride or sulfate ions may disturb the protective layer.

Organic inhibitors aid in developing protective metal oxide films by forming a protective layer of insoluble material or by creating a surface-active barrier.

Nitrate is a passivator for steel that makes the steel effectively a more noble metal. A similar passivation is provided by tin alloys; copper is a bit weaker. High concentrations of chlorides reduce the effectiveness of nitrites; for example, about 4,000 ppm of NO_2^- is required in a 3% NaCl solution, as compared with only 50 ppm in distilled water to achieve the same effect.

Borax is often included in nitrite-based inhibitors to maintain a pH of 8 to 10 in the water. It has not been demonstrated to be effective as an inhibitor.

Antifoulant Polymers[2]

Flocculants agglomerate individual particles so that they remain suspended and are easily bled off. Dispersants interfere with the agglomeration of colloidal particles that are attracted to metal surfaces, often modify their crystallization, and allow them to slough off. Chelating agents react with certain metal ions to form stable, soluble complexes; calcium, magnesium, iron, aluminum, and manganese ions may be chelated to prevent their precipitation but the reaction is stoichiometric and chelation of water hardness ions is generally uneconomical.

Toxicity

General

In Table A-XI-2 are listed some elements (present in different valent states in chemical compounds) which, historically have been used in cooling towers, along with their concentration factors by plankton and blown algae.[5] The concentration factors may signify increased toxic effects of various elements through a food chain, and suggest that even low concentrations of some contaminants in water may be harmful by the third or fourth trophic levels. Some high concentration factors, such as those exhibited by *Foraminifora* and *Porifora* for silicon, are normal. Some elements, not toxic to aquatic life, may unbalance the ecosystem by overstimulating the growth of certain plants or animals. It is well established that nitrogen and phosphorus, particularly in combination, cause massive algal blooms under conditions where these elements were previously the limiting factors. While the

Table A-XI-2. TOXICITY AND CONCENTRATION FACTORS OF ELEMENTS ONCE - OR PRESENTLY USED IN COOLING TOWERS

ELEMENT SYMBOL (a)	CONCENTRATION FACTOR (b)		FUNCTIONS	ENVIRONMENTAL TOXICITY (c) (not injected)
	Plankton	Brown algae		
*As		2,500		carcinogenic; moderately toxic to plants, highly to mammals--especially as AsH_3;
B		6.6	essential for green algae, angiosperms	moderately toxic to plants, slightly to mammals
*Br		2.8	essential for marine organisms; amino acids	Br_2 is very toxic; Br^- is relatively harmless to organisms
*Cl	1	0.062	essential for mammals and angiosperms	Cl^- is relatively harmless; Cl_2, ClO^- ClO_3^- are highly toxic
*Cr	17,000	6,500	may serve some physiological function	Cr(III) is moderately toxic; Cr(VI) is highly toxic to organisms and is probably carcinogenic (by inhalation)
*Cu	17,000	920	essential to all organisms	very toxic to algae, fungi, and seed plants; highly so to invertebrates; moderately so to mammals
*Hg	-	250	---	a cumulative poison in mammals very toxic to fungi and green plants; highly to mammals in some forms
N	19,000	7,500	essential as structural atom	relatively harmless; concentrations higher in plankton and fish
*P	15,000	10,000	vital in many ways	
*Pb	41,000	70,000	none	very toxic to most plants, moderately so to mammals; cumulative poison.
*S	1.7	3.4	---	S^{2-} high to bacteria and fungi; relatively harmless to green algae, seed plants and mammals; H_2S is highly toxic to mammals; SO_3^{2-} moderately to highly; SO_4^{2-} is relatively harmless.

Table A-XI-2 (Cont'd)

*Si	-	-	essential to some plants	scarcely toxic, but large amounts in mammalian lung harmful (used by Foraminifera and Porifera etc.)
*Sn	2,900	92	none	very toxic to plants and green algae
*Zn	-	-	essential to all organisms	moderately toxic to plants; slightly toxic to mammals; uptake by plant roots not linked to metabolic process.

(a) The elements listed above exist in the form of different chemical compounds with the element in different valent forms to which biota are toxic but concentrations are expressed in terms of ppm of the element not the actual compound.

(b) ppm in fresh organism/ppm in sea water

(c) Toxicity terms: very, 1-10 ppm; highly, 10-100 ppm; moderately, 100-1,000 ppm; slightly, over 1,000 ppm

(as 24 hr TLm in moderate sized organisms--i.e., fish)

*accummulator species or genera known

accumulating poisons, mercury and lead, are no longer marketed for use in cooling towers, any of the heavy metals (e.g., chromium, zinc, or tin) may cause environmental problems by remaining in sediments or by concentrating in some forms of aquatic life. Establishment of the potential threat to the environment becomes extremely difficult because the different forms and valence states of the element may vary greatly in toxicity--as with sulfur, chlorine, and mercury. Factors contributing to the change from one state to another and synergistic toxic effects must be known before cooling tower chemicals can be ranked in order of potential environmental threat.

Chromium*

Because of its widespread use and high toxicity, chromium present in different valent states in compounds merits careful attention in its relation to aquatic life. It is a principal alternative should the expected effects of phosphorus (present in different chemical compounds primarily as a phosphate salt) and zinc (as the zinc ion) be deemed unacceptable. Some sources say the trivalent form shows none of the toxicity of the hexavalent form (as in the chromate ion) and is not of concern in drinking water supplies.[6] However, according to *Water Quality Criteria*,[7] "Most evidence points to the fact that under long-term exposure the hexavalent form is no more toxic toward fish than the trivalent form." Thus total chromium in a water supply may be much more indicative of a possible environmental problem than hexavalent chromium alone. In environments containing chromium, fish have shown that the toxicity of chromium varies with the species of fish, pH of the water, valence state of the element, and hardness of the water--the last a synergistic or antagonistic effect. Although 0.05 ppm is set as the Federal drinking water standard, *Water Quality Criteria* states that data are too incomplete to warrant more than caution in the discharge of chromium.

Concentrations of 0.01 and 0.02 ppm chromium in soft water have been found safe for salmonid fish, but *Daphnia* and *Microregma* show threshold effects at Cr^{6+} concentrations of 0.016 to 0.7 ppm, and 0.032-0.32 ppm inhibits growth of diatoms.[7] Oyster mortality studies at long-term (2 years) concentrations of 0.01 and 0.012 ppm showed a definite increase with an increase in temperature, so that synergistic effects may intensify the damages resulting from exposure to chromium

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*Chromium can exist as Cr^{3+} (trivalent) or CrO_4^{2-} (hexavalent - Cr^{6+}) but concentrations are based on the weight of Cr.[4]

in low concentrations.[7] Thus, even these low levels (less than drinking water standards) were found to be toxic to certain forms of plant and animal life. As concentrations of chromium increase, the ingestion-elimination balance changes and accumulation takes place. Some fish accumulate chromium when it is in concentrations as low as 1 microgram per liter or 1 part per billion.[8]

In 1958 Fromm and Schiffman published a study of the toxic action of Cr^{6+} on largemouth bass in which they determined the 48-hour median tolerance limit, TL_m, to be 195 ppm.[9] However, the focus of the study was on the physiological effects of less than acutely lethal dosages. At 94 ppm of Cr^{6+} no changes were observed in the respiratory epithelium of the fish; a slight decrease in general metabolism did occur along with widespread destruction of the intestinal epithelium. These effects differ markedly from those caused by zinc, copper, and lead, where mucus is caused to be secreted by the gills and damage to gill tissue causes eventual death.

In 1959 the same authors reported a 24-hour median tolerance limit for rainbow trout to be 100 ppm of chromium.[10] A concentration of 20 ppm of Cr^{6+} was chosen for the study of chronic physiological changes. Red blood cell concentration (hematocrit) in the circulating blood of the trout significantly increased as a result of the exposure, most probably because of an unmeasurable decrease in plasma volume. Perhaps more importantly, the hematocrit is affected at 2 to 4 ppm of chromium, a concentration much lower than the median tolerance limit and one which could easily be found in a stream receiving blowdown.

Not all fish are as tolerant of Cr^{6+} as are trout, bass, and bluegill.[11] The median tolerance limit for 24-hour exposure to potassium dichromate in soft water was 4.10 ppm (as CrO_4^{2-} for guppies, 39.6 ppm for fathead minnows, and up to 284 ppm for bluegills. In these tests, there were insignificant differences for 24-, 48-, and 96-hour exposures. Trivalent chromium was found to be a toxicant; mortality rates, however, did not always increase with increasing concentration. At acutely toxic levels for fish (in the range of the medium tolerance limit), the hexavalent chromium was more toxic, but no comparisons were made of the two valence states at very low concentrations.

Water Quality Standards

Table A-XI-3 lists the Federal water quality criteria in drinking water for those chemicals used in cooling towers.[7] As yet, not all of the

Table A-XI-3. RECOMMENDED UPPER LIMITS TO IONIC CONCENTRATIONS IN DRINKING WATER (Ref. 7)

Element or Compound	Upper Limit (ppm)
As	0.05
B	1.00
Br	*
Cl	250
Cr	0.05
CN	0.01
Cu	1.0
Hg	*
K	*
N (total)	10.0
NO_3	45.0
P	*
Pb	0.05
S	250
Sn	*
Zn	5.0
Phenols	0.001

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[*] No criterion has been established.

elements have been assigned limits; some limits were set lower for aesthetic considerations than for health considerations; for example, the low concentration limit for phenol is probably the threshold for taste in water.

Severity of the Environmental Problem from Blowdown

The size of the environmental chemical dispersion problem, if any, connected with blowdown from a specific cooling tower depends upon: (1) the rate of blowdown, which is usually directly related to the size of the system and the number of cycles of concentration allowed by the quality of input water; (2) the choice of chemicals--a choice often dictated by the system's potential for corrosion or microbial attack, which in turn is often directly dependent on tower design and construction materials; and (3) the effectiveness of treatment of blowdown water before discharge to the environment. Drift has received less study, and the factors controlling its quantity and content are less well-known.

Environmental problems can be very substantial, although immediate impact on aquatic environments may depend more upon the ratio of the stream flow rate to blowdown rate, and hence the dilution factor, than on absolute amounts. Less immediate problems, such as the dispersion of heavy metals to the environment at large, would revolve more around absolute amounts.

Reducing Impact

1. Cycles of Concentration

Pretreatment techniques can increase cycling of water in cooling towers and thus decrease system discharge. They include: (1) clarification and chemical softening of makeup water, (2) partial zeolite softening or demineralization of makeup water, (3) bypass or side-stream filtration.[3] By removing from the makeup many of the original dissolved solids which could concentrate to unacceptable levels very quickly, many more cycles of concentration--more recirculation with less blowdown--are allowed before concentrations become too high.

2. Choice of Chemicals

Heat exchanger design and tower construction materials usually determine the potential corrosion and thus determine the choice of chemicals to be added to the recirculating water. Some towers, notably natural draft towers, use no corrosion inhibitors (except acid as a pH control), while others require high concentrations of chromium, zinc and PO_4^{3-} as inhibitors. Similarly, some towers can use chlorine as a biocide, while others use a nonoxidizing biocide. TVA's cooling tower at its Paradise Steam Plant uses only acid and chlorine in the cooling water. Owing to corrosion resistant construction materials, principally concrete, and a low heat flux at the exchanger, heavy metals and phosphate are not needed in that tower for corrosion control.

3. Construction of Towers

Certain design characteristics can be adopted to avoid galvanic corrosion and reduce the need for chemical treatment.[12,13] Operational factors influencing the corrosion rate (and thus choice of inhibitor chemicals) include mineral content of the system water (which also may dictate how many times it may be recirculated), dissolved gases, electrical conductivity, suspended matter (turbidity) in the water, slime and microbial activity. More important are the design factors such as the use of corrosion resistant metals and the use of dissimilar metals of which one is expendable, a common practice throughout the industry. If the metals differ significantly in electrochemical potential, one may serve as the anode of an electrochemical corrosion cell, and the expendable metal acts as an anode and corrodes rapidly at a rate determined to some extent by the difference between the electrode potentials of the metals. If the water had good electrical conductivity, the metals need not be coupled or adjacent to corrode. The choice of metals and proper construction of the heat exchanger are extremely important, as a mistake might necessitate heavy chemical applications for the life of the tower. The primary concern may not be with rapid destruction or perforation of the tube sheet, since design specifications normally call for adequate thickness, but with the buildup of corrosion products that effectively block tubes or restrict water flow. Under certain conditions, metals that are normally cathodic can corrode, particularly where deposits form on the metal surface to set up locally different corrosion cells. Metals to be concerned with most are those that are electropositive with respect to steel, since steel adjacent to copper or copper alloys can corrode rapidly. Other unsuitable metallic pairs are copper-aluminum or steel-aluminum. However, some copper alloys such as admiralty brass and stainless steel are extremely corrosion-resistant metals if they are prevented from galvanic activity.

4. Cooling Temperatures

Temperature of the heat exchanger has a major role in determining corrosion potential. Control of scale and corrosion in the heat exchanger is more difficult at high temperature.

5. Blowdown Treatment

Most effective blowdown treatment systems have been developed for removal of chromium. Basically two methods are recognized, reduction-precipitation that discards the chromium and ion exchange that provides for chromate recovery.[14] The best known process, reduction-precipitation, is commonly used in the chromeplating industry. When carried out correctly, it removes virtually all traces of chromium from the waste stream, leaving a chromium-containing sludge for disposal. This method also is effective in removing zinc and other heavy metals, phosphate, insoluble chromic hydroxide, and all dirt and suspended solids. Some biocides may also be reduced in concentration (by 1/2 or more).[15] Ion exchange, on the other hand, while effective for removing chromate for reuse (which must be in the dichromate form), is ineffective for zinc salts or phosphate even when these are used in combination with chromates. Accessory treatment must therefore be employed for these ions. Sodium hydroxide and sodium chloride are used to regenerate the ion exchange resin, and these may be detrimental if released to natural environments.

Conclusions

All the factors--environmental, economic, engineering design, and construction--must be weighed before a tower is constructed in order that adequate environmental protection can be built in. There is very little information concerning the biocides and their fate after discharge of the blowdown and methods to render them harmless. Evidence indicates that most will not remain unchanged for long periods of time, but their very purpose in the towers attributes to their toxicity and suggests danger to aquatic ecosystems receiving blowdown. Their breakdown and dilution must be monitored after release. Tests to ascertain necessary levels of usage are required in each tower since possible overuse in current practice is indicated by the broad ranges of concentrations suggested on product labels. Corrosion tests are perhaps more common and relatively easy to do, the results indicating the concentrations of chromium that are sufficient and whether nonchromate inhibitors such as phosphate could be substituted. However, trade-offs among alternative environmental damages are involved, since phosphate encourages the growth of noxious plants. Resort to biocides less toxic to animal life (such as the organo-sulfurs or quaternary and complex amines) or those that volatilize quickly and are not released in the blowdown would reduce environmental impact, if blowdown treatments are not used. Redesigning of common industrial heat exchangers may result in use of little or no corrosion inhibitors, but some biocide will still be required.

Blowdown treatment seems to be the final determinant over what does or does not get to the environment. Increased use of chemical additives for recirculating cooling water must be matched by blowdown treatment.

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