ENIRONMENTAL REPORT

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MANMADE RADIONUCLIDES IN THE HUDSON RIVER ESTUARY

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ABSTRACT

As part of a large scale ecological research program, in progress since 1964, we have examined the identity, abundance, and distributions of natural, fallout, and reactor produced radionuclides in the Hudson River estuarine environment. The annual rates of introduction of the most commonly detected radionuclides have been estimated for the purpose of placing the importance of the various artificial and natural sources in perspective, and explaining the measured distributions in space and time.

Radionuclides investigated include isotopes of cesium, cobalt, and manganese. The Cs-137 content of fish is in part related to the cumulative deposition in sediments. However, cesium of recent origin appears to be more biologically available. Co-60 accumulates in estuarine sediments with limited, if any, transfer back into aquatic food chains. Mn-54 deposits by sedimentation in the fresh-water regions of the estuary, but leaches from sediments during seasonal salt water intrusions. Sedimentary build-up of Mn-54 is limited by its 303 day half-life. The maintenance of constant stable manganese concentrations by fish during periods of highly variable aqueous manganese concentrations is indicative of regulated uptake and loss of this element. Accordingly, the use of concentration factors to predict radionuclide concentrations in fish is not strictly appropriate for manganese. The finding that most radionuclides are at least partially associated with sediments further limits the applicability of the concentration factor approach, particularly for cesium.

Rooted aquatic plants concentrate all of the radionuclides measured except tritium and are useful stationary integrators of aqueous radioactivity levels.

The most important radionuclides with respect to exposure of man from reactor releases appear to be Cs-137 and Cs-134, and the critical pathway ingestion of fish. The fraction of maximum permissible intake during 1969 was less than 10^{-4}. It appears that present regulations restricting the concentrations of radionuclides in cooling water effluents are more than adequate for this aquatic environment.

INTRODUCTION

The Hudson River Estuary, a major body of water draining southwardly through New York State, has been the recipient of radioactive fallout from nuclear weapons tests and low-level discharges of radioactivity from a pressurized water nuclear power plant, Indian Point Unit 1. Measurements of the types and quantities of radionuclides from these manmade sources, together with measurements of radionuclides present naturally in the river system, have been underway since 1964. Results are used to ascertain the relative and absolute importance of the radionuclides with respect to human radiation exposure. Samples measured routinely have included water, bottom sediment, and the more abundant biological organisms.

The main region of the river selected for the study is located from HRM 30 (Hudson River mileage measured north from the Battery in New York Harbor) to HRM 50 and is centered about the Indian Point location at HRM 42 where the Indian Point Unit 1 reactor has been in operation since 1962. In addition to Indian Point Unit 1 (615 MWt), two reactors are under construction and two additional reactors are in the planning stage. The total generating capacity of all five reactors upon completion will be 12,984 MWt, only slightly less than the total of all commercial U. S. reactors presently in operation.

The Hudson River has an abundant fish population and is fished moderately by local inhabitants above the heavily polluted waters near New York City, mostly for anadromous species, during the spring and summer months. The water quality of the river has declined over the years, but substantial reductions of municipal and industrial pollutant sources will be achieved by about 1976 and should help restore the river. Such a restoration of water quality would attract many more of the 10½ million local inhabitants to the Hudson for fishing, swimming, boating, and enjoyment of the river's natural scenic beauty.

Assurance of the safe operation of future multiple nuclear facilities by adherence to release standards, and maintenance of well-designed monitoring programs serve to minimize hazards to local inhabitants and, thereby, avoid any restrictions placed on river usage from radioactive contamination.

Many of the radionuclides present in weapons fallout are also present in liquid reactor wastes. Accordingly, radioecological processes observed for radionuclides from either source can be applied in assessing the potential impact of future reactor releases. Measurements of both past and existing radionuclide levels provide first-hand information on the types, behaviors, and relative importance of those radionuclides anticipated from nuclear power expansion. Other approaches which can be taken to assess future reactor releases can be based upon stable element data or experimentally determined values of concentration factors. Results from this study indicate, however, that these latter methods are of limited value when applied to waters such as the Hudson having highly variable conditions of salinity and stable element composition. The use of concentration factors is useful and strictly appropriate only when the content of stable elements or radionuclides in biota is proportional to a steady state content in the water. Whenever biologically available sedimentary deposits exist, this condition is not necessarily fulfilled, and the use of concentration factors alone may not produce a reasonable estimate of reconcentration.

SOURCES OF RADIOACTIVITY IN THE HUDSON RIVER

Radionuclides occur in the Hudson from natural sources, weapons fallout, and aqueous releases at nuclear facilities along the river. Amongst the naturally occurring radionuclides, K-40, Ra-226, and Ra-228 are most abundant. Potassium, a major constituent of seawater, accounts for elevated K-40 levels in water from the more brackish areas of the system nearest the Atlantic, whereas potassium leached from terrestrial minerals contributes lesser amounts of K-40 to the freshwater areas. In the region of highest salinity near the mouth of the estuary, K-40 concentrations of about 300 pCi/l are typical, while about 2 pCi/l of K-40 are found in the freshwater regions. Seasonal fluctuations in freshwater flows, rates of evaporation, and tidal influences result in seasonally variable K-40 concentrations at any given location. Longitudinal salinity profiles as measured along the length of the estuary during the summer of 1959[1] indicate that 100-200 Curies of K-40 existed in the estuary at that time.

Both Ra-226 and Ra-228 are carried into the river as natural constituents of suspended material, or in soluble forms from the leaching of soils. From analysis of water one can estimate that about 0.5 Curies of Ra-226 and 0.5 Curies of Ra-228 in the form of suspended material, and from one to five Curies of dissolved Ra-226 and Ra-228, respectively, are introduced into the estuary each year.

The periodic testing of nuclear weapons in the atmosphere has contributed readily detectable quantities of artificial radionuclides to the Hudson. The intermittancy of such tests, and the paucity of fallout deposition measurements, together with uncertainties about the contribution of terrestrial runoff to surface water radioactivity, complicate estimation of the amount of radioactivity contributed to the Hudson by fallout. However, an upper and lower bound to such fallout contributions can be arrived at by utilizing available fallout data and assuming deposition either on the river surface alone or on the entire drainage basin. Table 1 shows the results of such a calculation for the fission products Sr-90, Cs-137, and Ce-144, and the activation product Mn-54, as well as for tritium. Many other radionuclides, most notably Zr-Nb-95, I-131, Ce-141, Ru-103, Ru-106, Sb-125, Ba-140, La-140, Co-60, Zn-65, and Fe-55, have been similarly introduced into the Hudson River from weapons fallout.

The only major nuclear facility discharging low-level radioactive waste directly into the Hudson River is the Indian Point Unit 1 reactor. Knolls Atomic Power Laboratory in Schenectady, New York, contributes such wastes indirectly by way of discharge into the Mohawk River, a northern tributary of the Hudson. Measurements indicate, however, that in spite of measurable radionuclide levels in the Mohawk downstream from K.A.P.L.[5], at the point of discharge into the Hudson these radionuclides are not measurable above natural and fallout radioactivity levels.[6]

At Indian Point low-level releases are first diluted by a normal condenser water flow of 300,000 gpm prior to release into the Hudson. Prior to the time that individual isotope analyses were performed, the percentages of MPC, 10^{-7} μCi/ml, for the unidentified mixture during 1962, 1963, 1964, 1965, and 1966 were 0.22, 0.26, 22, 43, and 70 respectively, as summarized by the USPHS.[7] Detailed radiochemical analyses which were initiated in mid-1966 revealed that the MPC for the mixture released was much larger than 10^{-7} μCi/ml. The percentages of MPC during the following years of 1967, 1968, and 1969 were 1.6, 1.7, and 4.1 respectively.[8]

The average monthly composition of undiluted aqueous radioactive wastes at Indian Point during 1969 is indicated in Table 2.[8] The relative magnitudes of the undiluted fractional MPC's for the individual nuclides, i.e., C_i/MPC_i, indicate the relative importance of each radionuclide with respect to radiation exposure from drinking of water. The sum of the entries under $C_i \times MPC_i/\Sigma C_i$ is the MPC for the identified mixture, 8×10^{-5} μCi/ml in 1968 and 4.6×10^{-5} μCi/ml in 1969. The quantities of Sr-90, Cs-137, Mn-54, Co-60, and tritium released at Indian Point on the year of maximum discharge are shown in Table 3.[8]

Overlooking differences in the manner of introduction of natural, fallout, and reactor-released radionuclides, one may compare the quantities of these radionuclides which have been introduced annually into the Hudson. It is seen from Table 3 that fallout on the river surface contributed approximately the same quantities of Cs-137, Mn-54, and tritium during the peak year of 1963 as did Indian Point Unit 1 on the year of maximum discharge, while 400 times more Sr-90 fell out on the river surface in 1963 than the maximum annual discharge at Indian Point. The leaching of terrestrial fallout deposits could result in up to 200-fold greater introduction rates of fallout nuclides than surface deposition on the river alone, as indicated in Table 3. The ratio of the introduction rate of each nuclide to its MPC_w (Table 3) is proportional to the dose contributed by each nuclide if only the drinking of water is considered. As seen in Table 3, this dose-related ratio is more than 1000-fold higher for the natural radium isotopes than for any reactor-produced nuclide, and is about 10-fold higher for radium isotopes than for Sr-90 falling out on the river surface. In addition to placing the various sources in perspective, the rates of radionuclide introduction are useful in interpreting observed radioactivity levels, and assessing the consequences of future introductions of similar radionuclides.

RADIOACTIVITY MEASUREMENTS

Our measurements were designed to determine the identity and spatial distribution of the radionuclides present in the physical and biological components of the Hudson River ecosystem, and to assess the resultant temporal changes associated with variable radionuclide inputs into the river. From 1964-1967, samples were collected only between late spring and autumn. Our primary objective then was to survey a large diversity of samples from as large an area of the river as possible (from HRM 20 to HRM 100). Except for the activation products Mn-54 and Co-60 in the immediate vicinity of Indian Point, located at HRM 42, the concentration of radionuclides in samples of water, biota, and sediments throughout the river was quite uniform, prompting us to concentrate our efforts in the following years on a region near Indian Point, while still maintaining several upstream stations for control purposes.

Gamma-ray spectroscopy has been the principal method of radionuclide analysis. Spectral information obtained with a multichannel analyzer coupled to a 4" x 4" NaI well crystal shielded by a 4" mercury incasement is processed by a computerized linear weighted least squares analysis described elsewhere.[9] A limited number of samples have been periodically analyzed radiochemically for Sr-90 (EHPA solvent extraction and beta counting of Y-90),[10] Fe-55 (solvent extraction and electroplating),[11] and tritium (distillation electrolytic enrichment).[12]

Annual average concentrations of the gamma emitters, Cs-137, Co-60, and Mn-54, which were measured in samples of bottom sediment, water, whole fish, and rooted aquatic plants collected near Indian Point are shown in Figures 1, 2 and 3. Samples of fish, plants, mud, and water used in computing the annual averages were collected at the same sites and with approximately the same frequency in the different years. Similar species of fish and plants were analyzed each year. Values given for radionuclide concentrations in water are for the dissolved fraction of grab samples. Water samples varied in volume from 6 to 40 liters, and were collected either on a biweekly or monthly basis. Radioactivity values measured in water are a better indication of the slowly varying fallout contributions than the variable releases from Indian Point. Bottom sediment radioactivities pertain to dredgings of the upper 10-12 cm of channel and near shore areas known to have sediments of fine textures, and for this reason probably represent samples of higher activity than would samples collected at random locations including sandy as well as silty-clayey bottoms.

Available data on annual fallout deposition and reactor releases of Cs-137, Mn-54, and Co-60 are shown in Figure 1, 2, and 3 for comparison with the resultant levels of these nuclides appearing in river samples.

From Figure 1 it is seen that during a period of decreasing deposition of Cs-137 from weapons fallout, 1964-1966, the concentration of Cs-137 dissolved in Hudson River water decreased approximately an order of magnitude. During this same period of time, the concentrations of Cs-137 in bottom sediments remained almost constant while levels in fish declined only slightly. From measurements of fish at upstream control stations (Table 5), it appears that weapons fallout was the source of Cs-137 at Indian Point during 1964, 1965, and 1966. Since the Cs-137 content of fish did not parallel the order of magnitude drop of Cs-137 dissolved in water, but instead followed more closely the Cs-137 concentrations in bottom sediments, it appears that the fish are indirectly obtaining most of their Cs-137 directly from river sediments or from food chains dependent on the bottom sediments. Gustafson studying freshwater lakes also came to the conclusion that bottom sediments act as a reservoir of Cs-137 which can be assimilated by fish.[13] Three-fold higher Cs-137 concentrations were found in bottom-feeding fish species such as carp, suckers, and catfish than in open water feeders such as white perch, bass, and sunfish. This supports our hypothesis that part of the Cs-137 in river sediments is biologically available.

Recent sampling has shown the Cs-137 content of suspended sediments (>0.45μ) is greater than for bottom sediment. For instance, in 1969 we found suspended sediments at upstream stations contained 3900 pCi/kg dry, while bottom sediments from similar locations averaged 2200 pCi/kg dry. This may reflect the differing particle size distributions of suspended and bottom sediments. In 1970 the Cs-137 content of plankton ranged from 65-200 pCi/kg wet or 1300-2000 pCi/kg dry. Thus, a hypothetical food chain for a pelagic feeding fish could be: resuspension of bottom sediments, uptake of suspended material by plankton, and subsequent ingestion of plankton by fish. A shorter food chain such as direct ingestion of bottom organisms or other bottom detritus relatively high in Cs-137 might account for the approximate three-fold higher content of Cs-137 in bottom feeders.

During the later years of this study, 1966-1970, Cs-137 concentrations at upriver control stations declined below detectability in water (<.02-.03 pCi/l), but remained constant in bottom sediments. As shown in Table 5, the Cs-137 content of upstream fish decreased with an approximate 2 year half-life reaching 16 pCi/kg in 1970. Similar observations were made for Cs-137 concentrations in samples from the vicinity of Indian Point, except during 1969 and 1970 when the Cs-137 content of fish from Indian Point was approximately twice the Cs-137 content of upstream fish (Table 5). This was presumably the result of a larger than usual release of Cs-137 at Indian Point during 1969 and 1970.

Co-60, one of the more abundant activation products in reactor wastes (Table 2) has been found only infrequently in upriver control samples, presumably as a result of its limited production in nuclear weapons tests. The concentrations observed in fish and water at Indian Point are only slightly above our detection limits of 4 and 0.04 pCi/kg respectively. The ability of aquatic plants to concentrate cobalt has been shown in various laboratory uptake experiments[14] and the concentration factor according to the usual definition was found to range from 10^4 to 10^5 for the plant species included in our measurements, Potamogeton, Myriophyllum and Vallisneria. As a result, aquatic plants reflect Co-60 concentrations in water that could not otherwise be easily measured.

Except for a five-fold decrease in Co-60 concentrations in aquatic plants from 1964 to 1965, the annual levels of this radionuclide in aquatic plants from the Indian Point vicinity has remained reasonably constant from 1965 through 1970. This is in agreement with a fairly constant reactor release of Co-60 during the same time period.

Noteworthy amongst the Co-60 measurements is the apparent accumulation of Co-60 in bottom sediments which has taken place through 1968. The decline of sedimentary Co-60 in 1969 may be an indication of the attainment of equilibria between introduction and removal rates.

Weapons fallout has contributed appreciable quantities of the activation product Mn-54 to the Hudson both during and immediately after the period of peak thermonuclear testing (Table 1 and Figure 3). Releases of this nuclide from Indian Point Unit 1 have contributed larger quantities to the Hudson on a yearly basis, however, than fallout on the river surface alone. This has accounted for Mn-54 levels in biota and sediment at Indian Point (Figure 3) in excess of those found at upstream locations. During 1965 and 1966, for example, two-fold higher concentrations of Mn-54 were found in fish (Table 5) and bottom sediments near Indian Point, as compared to upstream samples, while aquatic plants from Indian Point showed twenty-fold higher Mn-54 concentrations. Since bottom sediments and plants were not collected upstream in 1964, and isotopic analyses of reactor wastes were not performed until 1966, it is not possible to assign the origin of the higher levels occurring in 1964 to either fallout or reactor operations. Measurements of water, bottom sediments, fish and aquatic plants on subsequent years correlate fairly well with available annual Mn-54 release data at Indian Point. Owing to its 303 day half-life, continued accumulation of Mn-54 in sediments would not be expected after several years of reasonably constant release, and in fact such accumulations have not been found.

Detailed studies of the radioecology of manganese have been feasible due to the presence of an identifiable source of Mn-54 in the Hudson at Indian Point, and measurable levels existing in various phases of the Hudson near Indian Point.[15] Of most interest to date has been a rather unusual observation relating to the effect of periodic saltwater intrusion into a previously freshwater area on the chemistry of stable manganese. We have found that unexpectedly, such saltwater intrusions result in a pronounced elevation of manganese concentrations dissolved in water, as shown in Figure 4 for the summer and fall of 1969. As a result of the dissolved manganese depression in the latter part of August when salinity decreased due to an unusually large but transient freshwater discharge, the concentration of stable manganese in the aquatic plant Potamogeton fell by a factor of about 5 (Figure 5). When seawater intrusion reached Indian Point in mid-September, dissolved stable manganese concentrations resumed the previously elevated values, and the manganese content of aquatic plants increased in like fashion, reflecting the manganese content of the surrounding water. Both the concentration, pCi/kg wet, and the specific activity, pCi/mg Mn, of Mn-54 in these same plant samples, together with biweekly continuous measurements of the Mn-54 concentrations in reactor waste provide some insight into the mechanism accounting for manganese elevation in Hudson water during periods of salt water intrusion. From Figure 4 it is seen that a sustained release of Mn-54 occurring at Indian

Point throughout most of August was followed by a reduction of more than an order of magnitude from late August through mid-November. As a result, both the Mn-54 concentration and specific activity in aquatic plants dropped from late August through early September. However, in mid-September the Mn-54 concentration in aquatic plants increased rapidly without a corresponding increase in release at Indian Point Unit 1, while the Mn-54 specific activity slightly decreased. This observation can only imply that stable manganese and Mn-54 were both introduced from a similar source which was not the reactor directly. Upstream control samples indicated no fallout input of Mn-54. We have, therefore, concluded that the influx of seawater into a previously freshwater area resulted in the mobilization of both stable manganese and Mn-54 in bottom sediments. That manganese can be leached from bottom sediments by seawater has previously been shown by simulated leaching studies of Columbia River sediments.[16]

Mn-54 specific activities in fish at Indian Point during 1969 followed quite closely the specific activities measured for aquatic plants and indicate that no dilution of Mn-54 specific activities by stable manganese occurs between uptake by plants and uptake by fish. Stable manganese concentrations remained quite constant in fish during the observed period of rapidly changing manganese concentration in water. This implies a manganese concentration factor for fish that is inversely related to the stable manganese concentration in water. Of course, if water is not the direct source of manganese in fish, then the concept of concentration factor has limited applicability.

Samples of water, sediment, fish, aquatic plants, and crabs were analyzed for Sr-90 during 1964, 1965, and 1966 (Table 4). The concentration of Sr-90 in water decreased two-fold during this time period, while the fallout rate of Sr-90 decreased by a factor of about 6 during the same time period (Table 1). The near absence of Sr-90 in reactor wastes (Table 2 and Table 3) together with the decreasing fallout of this nuclide and the limited remaining sedimentary reservoir permit us to conclude that Sr-90 will not be among the more important radionuclides in this estuarine environment in the years to come.

Sizeable quantities of tritium have been introduced annually into the Hudson by weapons fallout and lesser amounts from reactor releases (Table 1 and Table 3). As a result predominantly of the fallout contribution, levels of tritium in Hudson River waters during 1967 were 1800-1900 pCi/l, almost identical to tritium levels in surrounding freshwater lakes, 1900 pCi/l, and northern Hudson tributaries, 2000 pCi/l.[12] Cessation of atmospheric weapons testing resulted in a decline of concentrations of tritium in surface waters, and during the early months of 1970 Hudson River water averaged approximately 500 pCi/l, with no observable increase in water near Indian Point as compared to remote upstream locations.[17]

Fe-55, one of the more abundant weapons fallout activation products having half-lives greater than about one year, has been periodically measured in Hudson River samples as part of a broader program to determine dietary sources of Fe-55 in man.[11] During 1968 and 1969 Fe-55 specific activities ranging from 1.5 to 3.8 pCi/mg Fe were measured in Hudson River fish and aquatic plants.[18] Expressed in terms of wet weight concentrations, these specific activities translate to 2000-3000 pCi/kg for aquatic plants and 200-250 pCi/kg for fish (white perch and sunfish). These activities are low compared to those reported in Pacific tuna during 1966 of 955 pCi/mg Fe.[11] A single analysis of primary coolant at Indian Point Unit 1 indicated that Fe-55 and Mn-54 were present in an approximate 1 to 6 ratio of activities,[18] while deposition data for fallout of recent origin shows a Fe-55/Mn-54 ratio of about 2 to 1.[3] The predominance of Fe-55 from fallout as compared to reactor releases accounts for the rather uniform specific activities observed throughout the Hudson.

Among the many other gamma-emitting radionuclides which are present in weapons fallout, the only ones detected with sufficient frequency to warrant mention here are the fission products Ce-144, Zr-Nb-95, and Ru-103. None of these radionuclides have been identified in liquid reactor wastes. The short physical half-lives of the latter two nuclides, 65 days and 40 days respectively, generally result in substantial measurement errors for samples not processed soon after collection. The low energy emissions from Ce-144 cannot be accurately quantitated in the majority of bulk samples. However, as an indication of the present levels of these three radionuclides, measurements made during 1969 are shown in Table 6 for samples from the vicinity of Indian Point and samples from our upstream control stations. Interestingly, significantly higher levels of all three nuclides occurred in samples collected upstream from Indian Point. This observation is possibly explained by the depletion of these radionuclides from the aqueous phase during their transport down the estuary. The higher concentrations of Ce-144, Zr-Nb-95, and Ru-103 in aquatic plants and bottom sediment as compared to fish and water may be interpreted to imply that surface adsorption processes play an important role in removing these radionuclides from solution, and hence from direct biological availability.

Only two radionuclides, Co-58 and Cs-134, have been identified in samples near Indian Point and not in upstream control samples. Since the presence of both of these nuclides is attributable to reactor releases, they serve as the only unique tracers of wastes discharged into the Hudson at Indian Point. Neither of these radionuclides are generally found in significant amounts in fallout from nuclear weapons testing.

Long term accumulation of Co-58 is limited by its half-life, 71 days, since it reaches rapid equilibrium between release rate and rate of physical decay. The long lived cobalt isotope Co-60 which has a half-life of 5.26 years, has undergone a gradual accumulation in Indian Point sediments (Figure 2). By comparing the ratio of Co-58 to Co-60 in water at the point of reactor release with the ratio of their concentrations in fish, aquatic plants, and bottom sediments (Table 7), one may conclude that the concentration of both these isotopes in biota is a reflection of the biological availability of radio-cobalt in "fresh" reactor releases, and of the non-availability of sedimentary radio-cobalt accumulations; i.e., if bottom sediments were an important source of Co-58 and Co-60 in biota, then one would expect to find a Co-58/Co-60 ratio in biota similar to that found in bottom sediments.

A similar calculation of the ratio of Cs-134 to Cs-137 in water at the point of reactor release and in biota and bottom sediments (Table 7) would seemingly lead to a similar conclusion; that freshly introduced cesium isotopes are more biologically available than the same isotopes present in bottom sediments. However, the difference between the Cs-134/Cs-137 ratio in biota and that in bottom sediment is not nearly as marked as is the case for Co-58/Co-60. Furthermore, measurement of the Cs-134/Cs-137 ratio in primary coolant at Indian Point Unit 1 yielded a value of 0.60, compared to 0.38 in water of lower activity which was sampled continuously from the condensor discharge canal. If the Cs-134/Cs-137 ratio were 0.60 at the release point, one could conclude that during 1969 approximately 75 per cent of the Cs-137 in fish from Indian Point was due to recent reactor releases, and approximately 25 per cent, or 14 pCi/kg wet, was due to other sources, presumably past weapons fallout. Cs-137 content of fish collected upstream during 1969 and 1970 amounted to 22 and 16 pCi/kg wet (Table 5), respectively. It would thus seem that radiocesium in fish can be attributed both to reactor releases of recent origin, as well as to residual sedimentary deposits from weapons fallout.

Among the radionuclides released in reactor wastes the largest contribution to the fraction of MPC is made by I-131 (Table 2). We have not been able to detect this radionuclide in any Hudson River samples. However, our detection limit for I-131 in biota is higher than for most other gamma emitters, 15 pCi/kg wet as compared to 5 pCi/kg wet for Cs-137. The higher detection limit arises from the necessity of switching to a different counting system with a less favorable geometry, an 8" x 4" NaI crystal, in order to measure large volume samples of unashed biota.

The concentration of naturally occurring K-40 (Table 8) has consistently exceeded the concentrations of artificial radionuclides, both of fallout and reactor origin, in all Hudson River samples, except for aquatic plants in which higher Mn-54 activities have been measured in the vicinity of Indian Point. This observation provides convincing evidence that non-specific radioactivity measurements such as gross-beta analysis yield little information about existing levels of artificial radionuclides in the Hudson River.

Relatively constant amounts of the naturally occurring radium isotopes, Ra-226 and Ra-228, have been observed in samples of bottom sediment and aquatic plants, while concentrations in water and fish have been more variable. Average concentrations in these samples are presented in Table 8. Both Ra-226 and Ra-228 have been found to be uniformly distributed spatially in the Hudson over an 80 mile length of river.

DOSIMETRIC EVALUATION

The exposure to man resulting from radioactivity in the Hudson River consists of a component from natural radioactivity and a component from artificial radioactivity. Neither dietary surveys nor bioassays of local populations are felt to be warranted by the low levels of artificial radionuclides in the Hudson. Edible shellfish are absent in the Hudson, and the abundant aquatic plants of the Hudson are not consumed by man. Accordingly, there is no opportunity for biological organisms of high concentrating ability to enter directly into human food supplies. Consumption of indigenous and migratory fishes caught both recreationally and commercially in the Hudson is apparently the most important pathway by which radionuclides can be recycled to man via the aquatic food chain. Based upon average concentrations of the radionuclides Cs-137, Cs-134, Co-58, Co-60, and Mn-54 in fish at Indian Point during 1969 (Table 5) we have calculated the yearly whole-body and gastrointestinal doses to man to be 0.04 mrem/year and 0.05 mrem/year respectively, assuming an average daily intake of 30 grams of fish taken solely from this location. Of the estimated 0.04 mrem/year whole-body dose, 0.02 mrem/year is due to Cs-134 and 0.02 mrem/year is due to Cs-137. Measurements of fish upstream from Indian Point during 1969 showed Cs-137 and Zr-Nb-95 to be the only gamma emitters present. The whole-body and G-I doses from consumption of such fish are estimated as 0.01 and 0.003 mrem/year, respectively. We thus conclude that during 1969 fallout Cs-137 in fish delivers a whole-body dose of 0.01

mrem/year and releases of radioactivity at Indian Point result in radionuclide levels in fish that deliver about 0.03 mrem/year to the whole body.

Concentrations of Ra-226 and Ra-228 in water (Table 8) amount to 1.6 and 0.4 per cent of permissible drinking water concentrations.[19] In addition, 0.7 and 0.2 per cent of the permissible intake of Ra-226 and Ra-228, respectively, would result from the consumption of 30 grams of whole fish per day.

Levels of fallout Sr-90 which were measured in whole fish during 1964, 1965, and 1966 would result in bone doses of 9, 20, and 7 mrem/year respectively, if 30 grams of whole fish were consumed each day. Fe-55, the major source of which is also fallout, as measured in Hudson River fish during 1968 contributes about 0.06 mrem/year to the spleen which is the critical organ, or 0.008 mrem/year to the whole body.

In spite of the fact that the Hudson River water is potentially potable in the freshwater areas, it is used to only a limited extent as a municipal drinking water supply, mainly because of inadequate treatment of introduced sewage. The water in the vicinity of Indian Point is sufficiently brackish throughout the summer, fall, and winter months to preclude its use for drinking purposes. The closest drinking water intake is approximately 23 miles upstream from Indian Point at Chelsea where a reserve pumping station for the New York City water supply is located, but which to date has not been used. In order for operational wastes discharged at Indian Point to be flushed by the tides upstream to Chelsea, evaporative losses in the Hudson have to approach freshwater discharge. This is a fairly common occurrence in the late summer months. When such conditions of flow prevail, the water salinity alone at Chelsea would prevent water use for drinking. Therefore, it is not conceivable that present reactor wastes could enter into a drinking water supply.

Based upon an estimated whole-body dose of 0.03 mrem/year from low-level releases at Indian Point in 1969, it is possible by a simple extrapolation to estimate the dose expected if discharges were at 100 per cent of the present MPC (mixture). During 1969 releases amounted to 4% of MPC. Discharge at 100 per cent MPC would then increase the 1969 dose estimates by about 25 times, to 0.8 mrem/year. Furthermore, assuming proportionality between electrical generation capacity, liquid radioactive waste composition, and available coolant dilution flows, the resultant dose from future multiple nuclear reactors can be estimated. For example, upon completion of the four new reactors on the Hudson, two at Indian Point and two directly downstream, the total generation capacity of

12,984 MWt would be about 21 times the present capacity at Indian Point Unit 1. The above assumptions then imply that 21 times the presently maximum permissible discharge of radionuclides would be possible, and the approximate dose from fish consumption would be about 21 x 0.8 mrem/year or 17 mrem/year. We consider this estimate to be more realistic than estimates based upon considerations of dilution and aquatic concentration factors.

SUMMARY

Measurements of radioactivity in samples of water, bottom sediment, and biota from the Hudson River have been performed over a seven year period from 1964 to 1970. Natural radioactivity levels generally exceed the levels of artificial radioactivity. The concentrations of most natural and artificial radionuclides are higher in bottom sediments than in water. These sediment-bound nuclides exist in physical states not available for direct uptake by consumable Hudson River biota. It appears, however, that recycling of at least one radionuclide, Cs-137, does occur from the sediments, a pathway not accounted for in the "concentration-factor" approach. Co-60, on the other hand, apparently has accumulated in bottom sediments at the Indian Point location on the Hudson, but appears to be effectively removed from biological availability by sediment sorption. Sr-90 has been found not to be as significantly bound by sediments as Cs-137, but the diminishing contribution of Sr-90 from weapons fallout and its near absence in reactor waste do not warrant continued assessment. Both Mn-54 and stable manganese seem to be leached from fresh-water sedimentary deposits during seasonal periods of salt water intrusion characteristic of the Hudson.

Aquatic plants have been found to concentrate Mn-54, Co-60, Co-58, Fe-55, Zr-95-Nb-95, Ce-144, and Ru-103, but are of no dosimetric consequence since they are not consumed by man, and since much lower concentrations of these nuclides are found in higher organisms of the aquatic food chain. These aquatic plants do serve, however, as good stationary integrators of radionuclide levels in the aqueous phase.

The critical nuclides with respect to human exposure from reactor releases at Indian Point Unit 1 have been Cs-137 and Cs-134. During 1969, the year of highest radiocesium discharges at Indian Point, a person consuming about 30 grams of fish a day, all taken from this limited portion of the river, would have received a whole-body dose from reactor-produced cesium isotopes of 0.03 mrem.

A whole-body dose from fish consumption of about 0.8 mrem/year would result from maximum permissible aqueous discharge at Indian Point Unit 1. Further extrapolation to hypothetical 100 per cent MPC release at all five Indian Point reactors

allows one to conclude that, the whole-body dose from fish consumption would be 17 mrem/year. Thus, it appears that present aqueous discharge standards as formulated by the USAEC are sufficient to insure exposure below the permissible 500 mrem/year whole-body limit, even as applied to releases from multiple adjacent power reactors, and to radionuclide transfers into human food supplies.

ACKNOWLEDGEMENTS

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TABLE 1

Annual deposition in Curies of selected weapons fallout radionuclides on the Hudson River drainage basin and river surface. The areas of the basin and surface were taken to be 34,700 km^2 and 155 km^2, respectively.

YEAR	^{90}Sr [2]		^{137}Cs [3]		^{144}Ce [3]		^{54}Mn [3]		^{3}H [4]	
	Basin	Surf.	Basin	Surf.	Basin	Surf.	Basin	Surf.	Basin	Surf.
1954	96	0.4	140	0.6	-	-	-	-	-	-
1955	120	0.6	180	0.8	-	-	-	-	-	-
1956	150	0.7	230	1.0	-	-	-	-	-	-
1957	150	0.7	230	1.0	-	-	-	-	-	-
1958	210	1.0	310	1.4	-	-	-	-	-	-
1959	300	1.3	440	2.0	-	-	-	-	-	-
1960	55	0.3	81	0.4	220	1	-	-	-	-
1961	84	0.4	124	0.6	1600	7	-	-	7700	34
1962	430	1.9	630	2.8	11000	47	200	0.9	97000	430
1963	830	3.7	1300	5.9	18000	78	1200	5.5	210000	920
1964	550	2.5	660	3.0	4500	20	360	1.6	110000	510
1965	190	0.9	280	1.3	760	3	57	0.3	44000	200
1966	84	0.4	120	0.6	140	1	-	-	-	-
1967	57	0.3	84	0.4	-	-	-	-	-	-
1968	46	0.2	67	0.3	-	-	-	-	-	-
1969	46	0.2	68	0.3	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-	-
Cumulative through 1969: (Decay corrected)	2860	12.8	4190	18.7	-	-	-	-	-	-

Table 2

Isotopic composition of liquid wastes at Indian Point Unit 1 during 1969. Average of undiluted monthly concentrations, C_i, and undiluted fractional MPC's.

Nuclide	C_i x 10^5 μCi/ml	MPC_i x 10^5 μCi/ml	$\frac{C_i}{MPC_i}$	$\frac{C_i}{\Sigma C_i}$ x MPC_i x 10^5 μCi/ml
^3H	2300	300	7.6	-
^{24}Na	0.29	20	0.015	0.052
^{54}Mn	19	10	1.9	1.7
^{58}Co	21	9	2.3	1.7
^{60}Co	15	3	5.0	0.41
^{89}Sr	0.14	0.3	0.47	0.00038
^{90}Sr	0.0066	0.03	0.22	2×10^{-6}
^{134}Cs	15	0.9	17	0.12
^{137}Cs	25	2	13	0.45
^{131}I	12	0.03	390	0.0031
^{132}I	0.14	0.8	0.18	0.0010
^{133}I	3.5	0.1	34	0.0031

Table 3

The quantities of natural, fallout, and reactor-produced radionuclides introduced into the Hudson either annually or during the year of maximum fallout or maximum reactor release, expressed both as Curies/year and Curies/year/MPC.[19]

Nuclide	Maximum Weapons Fallout (Ci/yr) *	Maximum Weapons Fallout (Ci/yr) †	Maximum Reactor Release (Ci/yr)	Natural Influx (Ci/yr)	Curies/year / MPC: Fallout *	Curies/year / MPC: Fallout †	Curies/year / MPC: Reactor	Curies/year / MPC: Natural
Sr-90	4	(830)	0.009	-	$4x10^6$	$(8x10^8)$	$9x10^3$	-
Cs-137	6	(1300)	6	-	$3x10^4$	$(7x10^6)$	$3x10^4$	-
Ce-114	80	(18000)	-	-	$8x10^5$	$(2x10^8)$	-	-
Mn-54	6	(1200)	14	-	$6x10^3$	$(1x10^6)$	$1x10^4$	-
H-3	920	(210000)	1100	-	$3x10^4$	$(7x10^6)$	$4x10^4$	-
Co-60	-		5	-	-		$1x10^4$	-
Ra-226	-		-	~3	-		-	$3x10^7$
Ra-228	-		-	~3	-		-	$1x10^7$
K-40	-		-	>>100	-		-	-

* Deposition on river surface.

† Deposition on entire drainage basin.

TABLE 4

^{90}Sr concentrations in various Hudson River Samples during 1964, 1965 and 1966.

YEAR		pCi/kg Wet
1964	Water	2.2
	Bottom Sediment (pCi/kg dry)	< 10
	Fish	130
	Aquatic Plants	300
	Crabs	900
1965	Water	1.5
	Bottom Seciment (pCi/kg dry)	180
	Fish	320
1966	Water	1.0
	Fish	100
	Aquatic Plants	50

TABLE 5

Comparison of the concentration of gamma-emitting radionuclides in fish collected near the Indian Point reactor with concentrations in fish collected upstream above salt water boundary.

pCi/kg Wet

	^{137}Cs		^{54}Mn		^{60}Co	
Year	Indian Point	Upstream	Indian Point	Upstream	Indian Point	Upstream
1964	39	32	19	18	N.D.	N.D.
1965	43	42	30	12	11	N.D.
1966	30	30	24	13	2	3
1967	20	-	4	-	3	-
1968	28	31	40	5	5	5
1969	56	22	32	N.D.	11	N.D.
1970	26	16	8	N.D.	3	N.D.

TABLE 6

Concentrations of the fallout radionuclides ^{95}Zr-^{95}Nb, ^{144}Ce, and ^{103}Ru in samples of Hudson River water, bottom sediments, aquatic plants, and fish collected during 1969 at Indian Point and at upstream control stations. pCi/kg wet.

	^{95}Zr-^{95}Nb		^{144}Ce		^{103}Ru	
	INDIAN POINT	UP-STREAM	INDIAN POINT	UP-STREAM	INDIAN POINT	UP-STREAM
WATER	0.06	0.09	ND	0.06	ND	0.05
BOTTOM SEDIMENTS (pCi/kg dry)	160	550	430	570	150	230
AQUATIC PLANTS	110	800	70	250	5	162
FISH	7.6	8.4	ND	ND	ND	ND

TABLE 7

Average concentrations of Co-58, Co-60 and Cs-134, Cs-137, and computed isotopic ratios in Hudson River samples at Indian Point during 1969.

	^{58}Co	^{60}Co	$^{58}Co/^{60}Co$	^{134}Cs	^{137}Cs	$^{134}Cs/^{137}Cs$
INDIAN POINT DISCHARGE CANAL WATER	1.9	2.3	0.83	0.46	1.2	0.38
BOTTOM SEDIMENTS	70	550	0.13	350	1820	0.19
FISH	7.8	11.4	0.68	25.6	55.8	0.46
AQUATIC PLANTS	305	404	0.76	24	57	0.42

TABLE 8

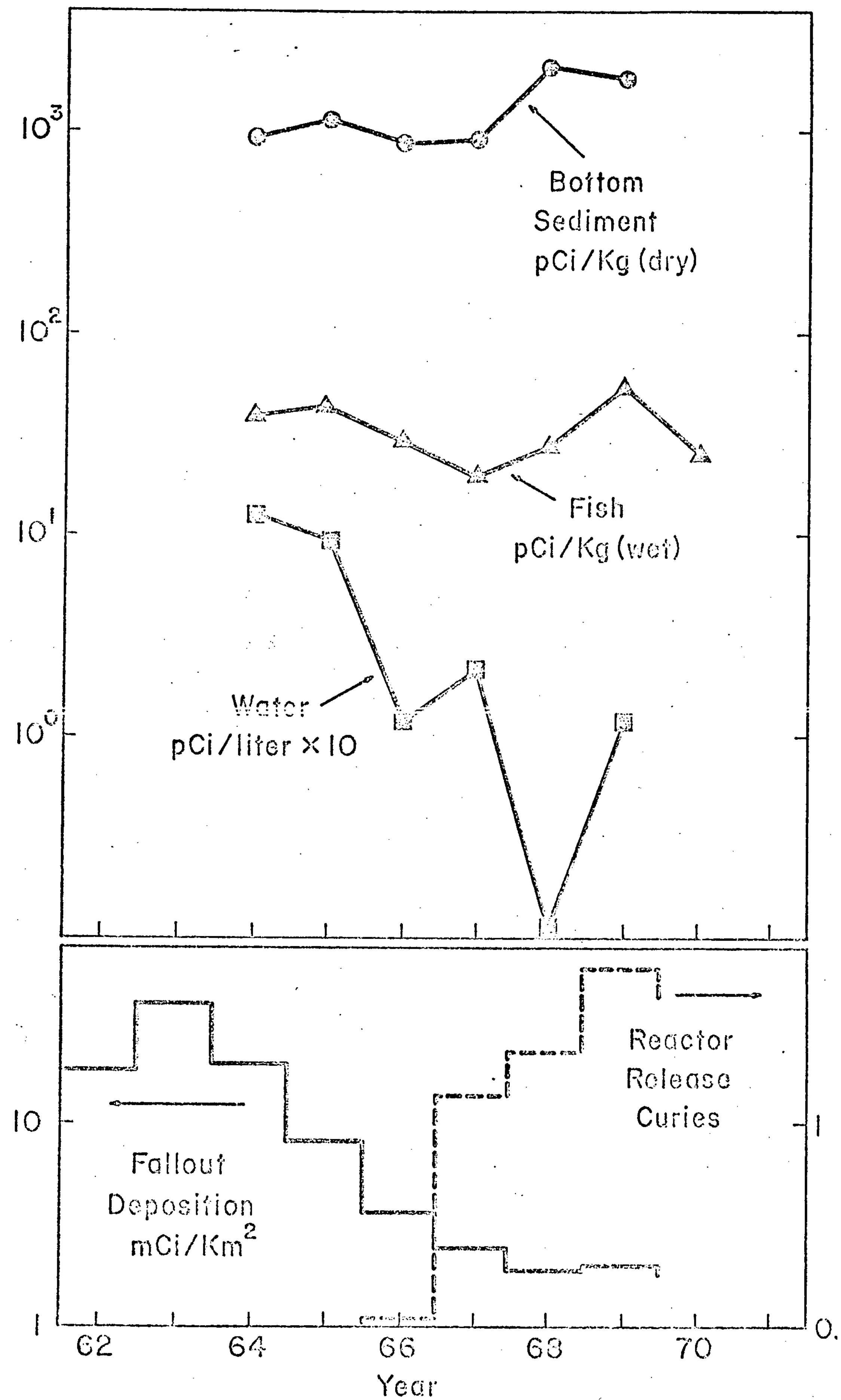
Average concentrations of the naturally occurring radionuclides ^{40}K, ^{226}Ra, and ^{228}Ra in samples of water, biota, and bottom sediments of the Hudson River

pCi/kg

	^{40}K	^{226}Ra	^{228}Ra
WATER	1 - 70	0.16	0.12
BOTTOM SEDIMENTS	14,000	810	940
FISH	1,300	5	4
AQUATIC PLANTS	2,000	150	50

FIGURE 1

Average concentrations of Cs-137 measured annually in Hudson River samples collected at Indian Point, annual fallout deposition of Cs-137, and annual release of Cs-137 at Indian Point Unit 1.

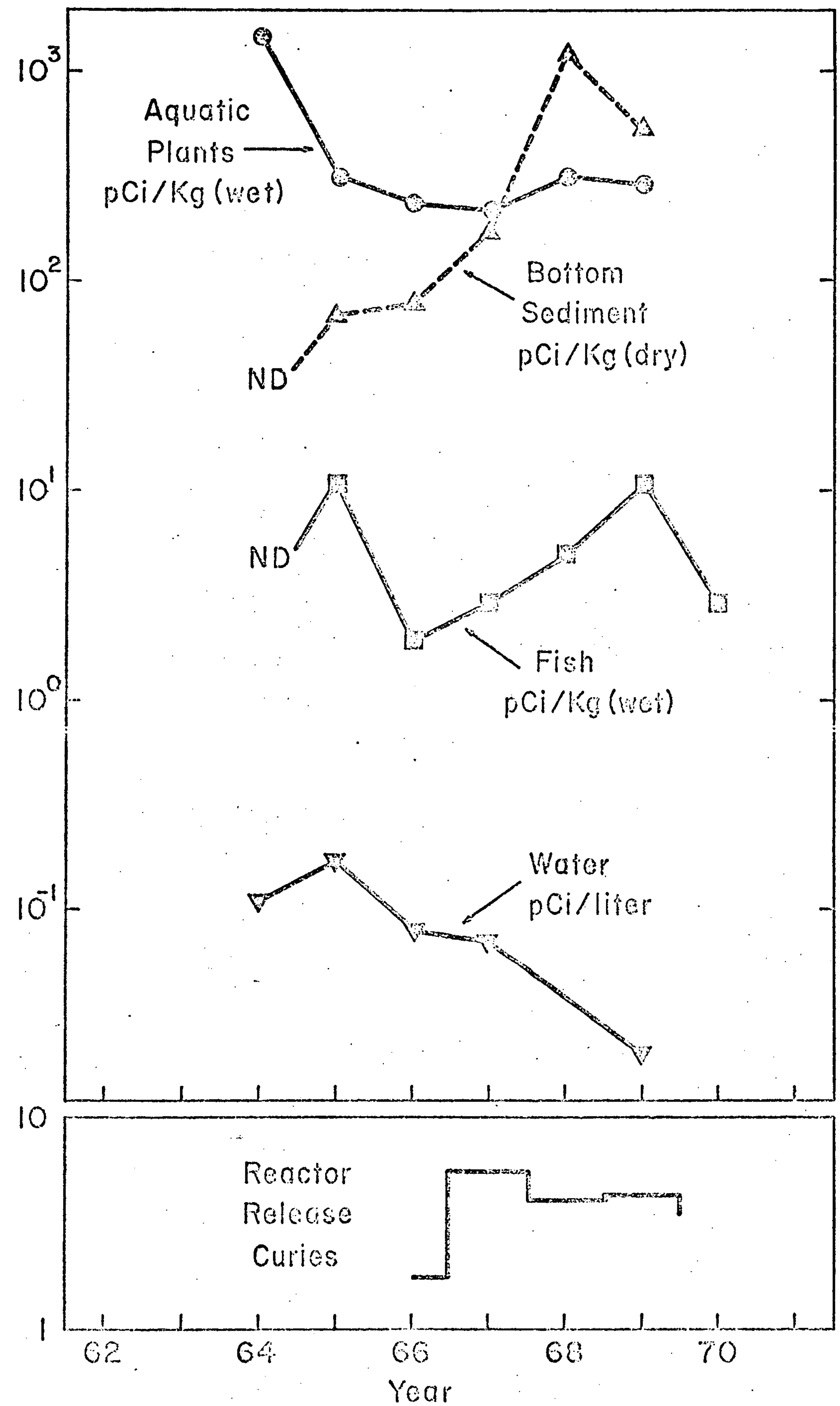


Bottom Sediment pCi/Kg (dry)
Fish pCi/Kg (wet)
Water pCi/liter × 10
Fallout Deposition mCi/Km^2
Reactor Release Curies
10^3
10^2
10^1
10^0
10
1
1
0.1
62
64
66
68
70
Year

FIG 1

FIGURE 2

Average concentrations of Co-60 measured annually in Hudson River samples collected at Indian Point, and annual release of Co-60 at Indian Point Unit 1.

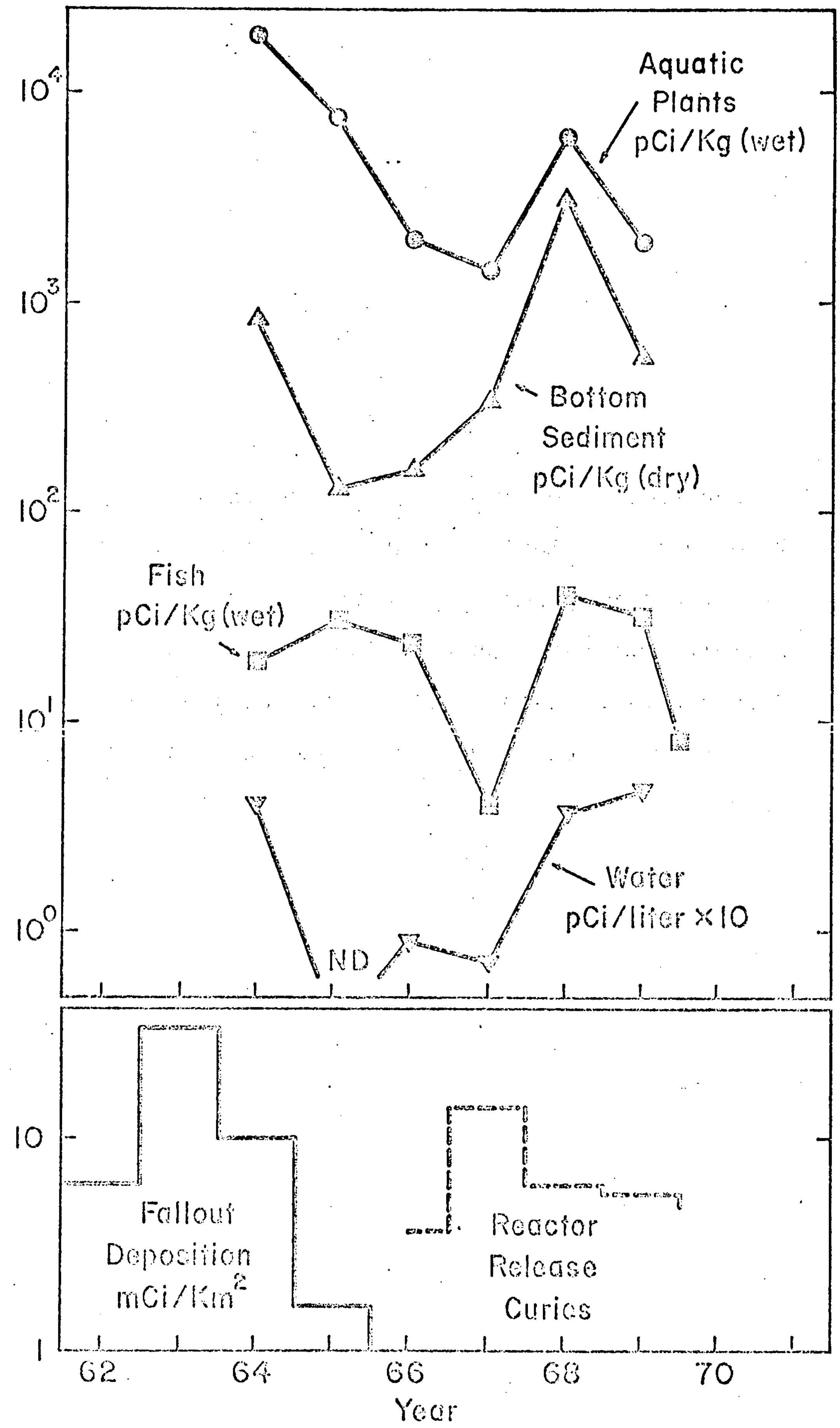


10³
10²
10¹
10⁰
10⁻¹
Aquatic
Plants
pCi/Kg (wet)
Bottom
Sediment
pCi/Kg (dry)
ND
ND
Fish
pCi/Kg (wet)
Water
pCi/liter
10
1
Reactor
Release
Curies
62
64
66
68
70
Year

F-2

FIGURE 3

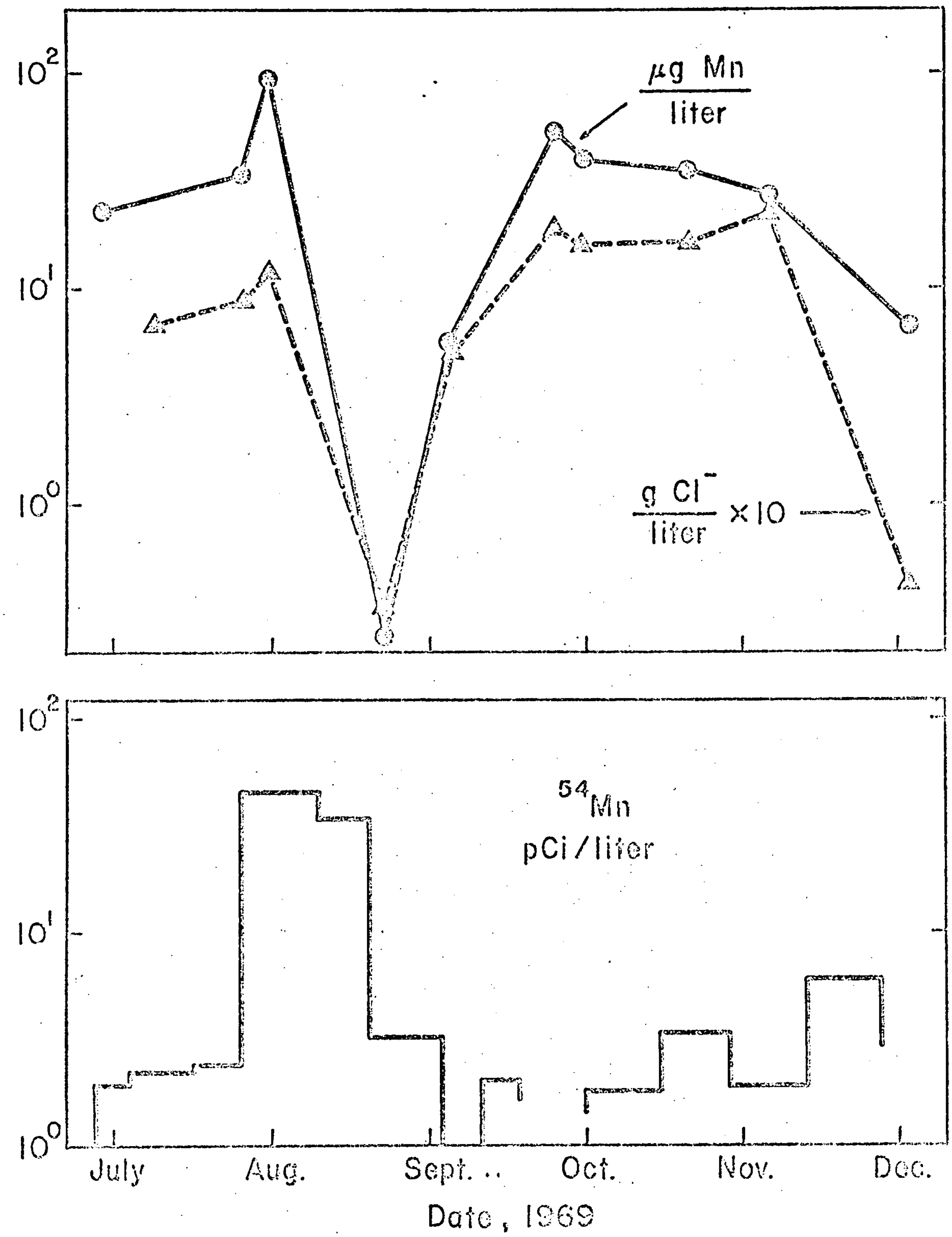
Average concentrations of Mn-54 measured annually in Hudson River samples collected at Indian Point, annual fallout deposition of Mn-54, and annual release of Mn-54 at Indian Point Unit 1.


Aquatic Plants pCi/Kg (wet)
Bottom Sediment pCi/Kg (dry)
Fish pCi/Kg (wet)
Water pCi/liter ×10
ND
Fallout Deposition mCi/Km²
Reactor Release Curies
Year
62
64
66
68
70
1
10
10⁰
10¹
10²
10³
10⁴

F-3

FIGURE 4

Concentrations of stable manganese in Hudson River water at Indian Point during 1969 illustrating the strong positive correllation with water salinity expressed as chloride concentration. Releases of Mn-54 at Indian Point as measured in continuous samples from the condensor discharge canal.

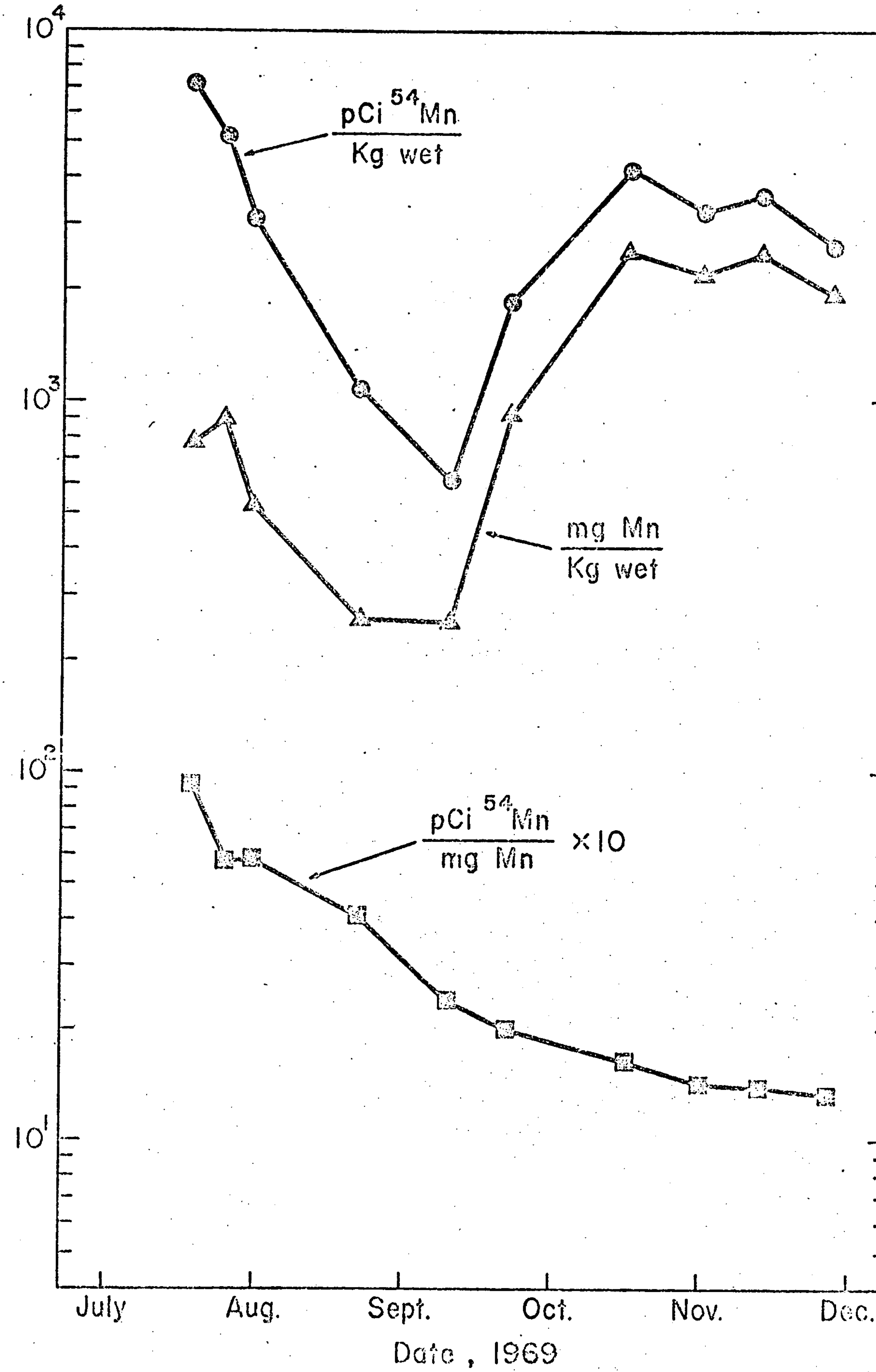


10^2
10^1
10^0
μg Mn / liter
g Cl⁻ / liter × 10
^{54}Mn
pCi / liter
July
Aug.
Sept.
Oct.
Nov.
Dec.
Date, 1969

FIG - 4

FIGURE 5

Stable manganese and Mn-54 content of the aquatic plant Potamogeton Perfoliatus, expresed both on a wet weight basis and as Mn-54 specific activity. 1969 measurements near Indian Point.



10^4
10^3
10^2
10^1
pCi ^{54}Mn / Kg wet
mg Mn / Kg wet
pCi ^{54}Mn / mg Mn ×10
July
Aug.
Sept.
Oct.
Nov.
Dec.
Date, 1969

F-5

THE BIOLOGICAL EFFECTS OF CHEMICAL DISCHARGES AT INDIAN POINT

Consolidated Edison Company of New York, Incorporated

New York

15 January 1973

I. ABSTRACT

The effect of the chemical discharges from Con Edison's Indian Point Power Plant Unit No. 3 on the biota of the Hudson River will be very minimal. Consideration of the discharges from all three units still gives discharges that are well below toxic levels. Dispersion of effluents contingent with models of the Hudson River in the Indian Point region indicates rapid dilutions to further minimize the possible effects of the chemical discharges on biota.

Data collected from discharge chemical bioassays performed by Environmental Analysts, Raytheon Co. and New York University for Con Edison indicate that the level of pollutants that will be discharged are below the 1/10 TLm values for the sensitive species *Menidia menida*, while data collected from bioassay work on thermal effects of metal poisoning indicated that the thermal effect on the Hudson River biota at river background concentrations of copper, zinc, nickel, cadmium, and chromium is minimal.

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TABLES

TABLES (Cont'd)

II. CHEMICAL DISCHARGES

Several routine discharges from Indian Point Unit No. 3 will contribute to the addition of chemical wastes to the environment: leakage from the primary coolant system, steam generator blowdown, regeneration of demineralizers, and prevention of organic fouling on condenser system surfaces. The different water treatment procedures 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, i.e. the concentrations of chemicals in the discharge waters are dependent upon flow rates, not power generation. With minor exceptions (such as system failure), the cooling water from the once-through condenser system and service water system serves to dilute any discharged chemicals. A list of chemicals utilized in the various plant systems, the amounts, and concentration limits at the confluence of the discharge canal with the Hudson River are given in Table I.

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. The Hudson River at Indian Point is classified "Class SB" (NYS Part CRR 701.4) (see Table II). All discharges are subject to regulation by the New York State Department of Environmental Conservation pursuant to section 1230 of the Public Health Law and to Federal regulations under Section 401 and 402 of the Federal Water Pollution Control Act of 1972. Since the regulations are

TABLE I

THE DISCHARGE OF CHEMICALS TO THE HUDSON RIVER FROM INDIAN POINT UNITS NO. 1, 2 & 3[a]

Chemical	Max. Sustained Releases, (lbs/day) Unit 1	Unit 2	Unit 3	Max. Sus. Conc. at Confluence with Hudson R. (ppm)[b] Unit 1	Unit 2	Unit 3	Max. Releases All Units (ppm)[c]	NYS Allowable[e] Concentrations (ppm)
Lithium hydroxide (Li)[d]	2.5	2.5	2.5	0.0002	0.0003	0.0003	0.006	---
Boric acid (Boron)[d]	600	600	600	0.2	0.06	0.06	1.8	---
Sodium hydroxide	156	12	12	1.2	0.015	0.015	4.1	---
Sulfuric acid (SO_4)	450	--	--	3	--	--	9.5	---
Sodium Phosphate (PO_4)	15	24	24	0.004	0.03	0.03	0.065	---
Hydrazine	24	5	5	0.006	0.0005	0.0005	0.03	---
Cyclohexylamine and/or	2.5	12	12	0.0007	0.001	0.001	0.02	---
Morpholine	2.5	12	12	0.0007	0.001	0.001	0.02	---
Sodium sulfate	Neutralization product of NaOH and H_2SO_4			2.5	--	--	7.9	---
Sodium carbonate[f]	1000			8.5			27.03	---
Chlorine				0 to 0.5[h]	0 to 0.5[i]	0 to 0.5	0.5	0.5
Potassium chromate (Cr VI)	Intermittent use	30	30				0.05	0.05
Detergent[g]	3.0		3	0.01	--	--	0.03	---

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

[b]Discharge during full power operation with 318,000gpm for Unit 1 and 870,000 gpm flow for Unit 2 and 870,000 gpm for Unit 3 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 1% solution for 8 hours to wash the Unit 1 flue gas passages of the superheaters, economizers and air pre-heaters, 4 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 1 shutdown.

[g]Alkyl benzene sulfonate.

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

[i]Intermittent discharge - 1 hour, 3 times per week for a 30 minute treatment of each water box of 3 condensers.

TABLE II

CLASS SB WATERS

Best usage of waters. Bathing and any other usages except shellfishing for market purposes.

Quality Standards for Class SB Waters

Items	Specifications
1. Floating solids; settleable solids; oil; sludge deposits	None attributable to sewage, industrial wastes or other wastes.
2. Garbage, cinders, ashes, oils, sludge, or other refuse	None in any waters of the marine district as defined in State Conservation Law.
3. Sewage or waste effluents	None which are not effectively disinfected.
4. Dissolved oxygen	Not less than 5.0 parts per million.
5. Toxic wastes, deleterious substances, colored or other wastes or heated liquids	None alone or in combination with other substances or wastes in sufficient amounts or at such temperatures as to be injurious to edible fish or shellfish or the culture or propagation thereof, or which in any manner shall adversely affect the flavor, color, odor, or sanitary condition 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.

phrased in terms of general criteria rather than specific numbers, certain discharge limits with respect to concentrations of various chemicals at the confluence with the Hudson River have been proposed by Con Edison which it believes will satisfy these criteria. These limits were obtained in part from bioassay work performed by Gift (1971), Renwoldt (1972), research of New York University (Lauer, 1972), and Cristin (1971).

During the operation of these nuclear power generating 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 as liquid effluents into the Hudson River through a common discharge canal for Units No. 1, No. 2, and No. 3. The chemical wastes will be diluted by the cooling water. During shutdown, 38,000 gpm of service water will be utilized in Unit No. 1, 30,000 gpm of service water in Unit No. 2, and 30,000 gpm in Unit No. 3 for dilution of chemical wastes. In full operation, a total of 318,000 gpm from Unit No. 1, 870,000 gpm from Unit No. 2, and 870,000 gpm for Unit No. 3 for a total of about 2.058 million gpm of water flow will be used to dilute the chemical wastes. For this analysis, a conservative approach was employed estimating chemical concentrations under adverse conditions, e.g. when dilution of the wastes would be less than those occurring during normal plant operations (see Table 1).

A. ORIGIN & TYPE

1. Releases During Construction and Testing

During various construction and testing phases of Indian Point Unit No. 3, various nonroutine releases of chemicals into the Hudson River will be required. At no time during this operation will the concentration at confluence with the Hudson River exceed the proposed limits discussed in Section II, B, 2.

a. Phosphate

Trisodium and disodium phosphate are used in the secondary system to control steam generator pH. Phosphate concentration (expressed as PO_4) will not exceed 10 ppm on a sustained basis. Intermittent and/or continuous releases are planned during plant testing as dictated by the steam generator chemistry. The maximum intermittent release concentration will not exceed 250 ppm. The expected maximum flow rate is 100 gpm, and the expected sustained release (expressed as PO_4) is 12 pounds per day. The phosphate will be released with hydrazine in the blowdown as described below.

b. Hydrazine

Hydrazine is used in the secondary system to control oxygen in the steam generators. The concentration will not exceed 20 ppm on a sustained basis or 100 ppm on an intermittent basis. Releases will be dictated by the need for oxygen control. The expected maximum flow rate is 100 gpm, and the expected sustained release is 24 pounds per day. As indicated, hydrazine will be combined with phosphate in the blowdown.

Hydrazine is also used in the primary system to control oxygen. Should the conduct of the testing program cause the hydrazine to be retained in the primary system for too long a period of time, a discharge of approximately 200,000 gallons of solution containing hydrazine might be required. The hydrazine concentrations would not exceed 100 ppm. This release would amount to approximately 170 pounds of hydrazine. The maximum discharge flow rate would be 300 gpm.

c. Lithium Hydroxide

Lithium hydroxide is used in the primary system for pH control. If it is necessary to discharge the previously mentioned 200,000 gallons of hydrazine solution, lithium hydroxide would also be released at a concentration of 10 ppm (as lithium), which would amount to 17 pounds of lithium. As before, the maximum discharge rate is 300 gpm.

d. Potassium Chromate

Potassium chromate is used in the closed cooling systems as a corrosion inhibitor. This solution will be discharged only on a contingency basis and would involve about 25,000 gallons, containing a maximum of 94 pounds of chromium at a concentration of 450 ppm. These batches would be discharged along with the 200,000 gallons mentioned earlier, and the concentration in the combined stream would be approximately 50 ppm chromium. It is proposed to discharge at such a rate that the diluted concentration at the confluence with the Hudson River would not exceed 0.05 ppm of hexavalent chromium.

e. Boric Acid

Boric acid is used in the primary system as a chemical shim. Small quantities of boric acid are accumulated in the waste hold-up system and discharged in the 200,000 gallon batch discussed earlier for hydrazine and lithium. The boron in this solution would not exceed 2000 ppm or approximately 3400 pounds of boron.

In the course of completing the construction of the plant, the need to discharge the boric acid tanks might arise. These tanks hold about 12,000 gallons of a solution containing about 2.3% boron by weight, or approximately 2,300 pounds. The boron release would be diluted in the refueling water storage tank to about 700 ppm and then discharged at flow rates not exceeding 300 gpm into the circulating water flow.

f. Sulfuric Acid

Sulfuric acid is used to control pH in the flash evaporator. The flash evaporator distills river water for use as make-up for various systems, and the concentrates are blown down to the discharge channel. The blowdown pH is between 7.0 and 8.5. Measurable amounts of H_2SO_4 in the circulating water are not anticipated.

g. Sodium Hydroxide

Sodium hydroxide is used in the primary system at the spray tank for system control and at the demineralizer for resin regeneration. It is also used in the waste disposal system for pH control at the waste evaporator. Although the caustic in the spray tank is not expected to be discharged to the river, the need might arise. The waste distillate would be discharged at 2.5 gpm at a concentration of 10 ppm for a total of 0.5 pounds per day of NaOH.

h. Sodium Hypochlorite

Chlorination of the main condenser is accomplished with sodium hypochlorite. One half of the condenser is chlorinated at a given time. The water from the chlorinated and unchlorinated sections mix within seconds after leaving the condenser resulting in a 1:1 dilution. The free chlorine residual dissipates quickly from exposure to sunlight and the chlorine demand of the river water so that discharge concentrations are usually 0.1 ppm or less. The overall time chlorine is added to the condenser is one hour. This procedure performed in daylight hours, is repeated on alternate days for a maximum of 3 times per week.

2. Releases During Normal Operation*

Because the nature of chemical discharges from Unit No. 1 differs from Units No. 2 and 3, and because of the use of a common discharge canal, any report on the environmental impact of Unit No. 3 with respect to chemical discharges must (a) identify separately the chemicals discharged from Unit No. 3 and (b) also report such discharges from Units No. 1 and 2.

a. Releases from Primary Systems

The standard chemicals utilized in the primary cooling systems to obtain the desired water chemistry includes lithium hydroxide, potassium chromate, sodium hydroxide, boric acid, and sulfuric acid.

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*Discussion of releases, usually referred to as occurring during evaporator breakdown, or on an intermittent basis, are included under this caption. Such releases should not be construed as occurring on any routine basis during normal operation. Moreover, at no time will discharge limits be exceeded.

1) Lithium Hydroxide

Lithium hydroxide is used in the primary systems for pH control. Waste water from these systems is processed by the respective waste disposal systems prior to discharge. There can be lithium hydroxide present in the effluent from this system if the evaporator malfunctions. If this happened, the maximum concentration expected would be 2.2 ppm (Li) with a maximum waste disposal flow rate of 25 gpm yielding a possible sustained release of 2.5 pounds per day or 7.5 pounds per day if all the evaporators failed simultaneously.

2) Boric Acid

Boric acid is used in the primary system as a chemical shim at a maximum concentration of 2000 ppm (as boron). Waste water from the primary system will be processed by the waste disposal system. In the event of an evaporator failure of one or all three units, the maximum discharge concentration of boron would be 2000 ppm for each unit. The maximum waste disposal flow rate would be 25 gpm resulting in a maximum sustained release of 600 pounds per day, per unit.

3) Potassium Chromate

Potassium chromate is used in the closed cooling water systems as a corrosion inhibtor in Units No. 2 and 3. No discharge of chromated cooling water is planned; however, some system leakage is assumed to occur leading to a maximum concentration of 100 ppm with a maximum discharge flow rate of 25 gpm. Under such conditions a maximum sustained release of 30 pounds per day per unit would result from Units 2 and 3.

4) Sulfuric Acid

Sources of chemical wastes during operation of Indian Point Unit No. 3 will include evaporator concentrates which are blown down to the discharge water to which has been added sulfuric acid to control the pH. 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 and 3.

Although no measurable releases of sulfuric acid are anticipated from Indian Point Units No. 3 and 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 four days. Although neutralized prior to discharge during mixed bed regeneration, the concentration of sulfuric acid during cation regeneration is 3% at a flow rate of 30 gpm, thereby yielding a maximum release of 450 pounds per day.

5) Sodium Hydroxide

Sodium hydroxide is used during normal operation for regeneration of the primary system demineralizers. Excess sodium hydroxide is drained to the waste disposal system where it is processed by the waste evaporator. Again assuming evaporator failure, either individual or simultaneously in Units 3 and 2, sodium hydroxide could be discharged at a maximum concentration of 500 ppm and a maximum discharge flow rate of 25 gpm. The projected frequency of demineralizer regeneration is once every four days for two hours. Under these adverse conditions the maximum release rate is 12 pounds per day, per unit.

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 release is expected to be 36 pounds per day from the boiler blowdown and evaporator blowdown. The regeneration of the mixed-bed ion exchangers scheduled to occur every four days would yield a total release of 120 pounds per day at a 4% solution.*

b. Releases from Secondary system

1) Phosphate

Trisodium and disodium phosphate are used in the secondary system to control steam generator pH and in combination with sodium hydroxide in the treatment of the house service boilers. Phosphate concentration (expressed as PO_4) for Unit No. 3 will not exceed 250 ppm at any time nor 10 ppm on a sustained basis. The expected maximum flow rate is 200 gpm and the expected sustained release (expressed as PO_4) is 24 pounds per day per unit for Units 3 and 2 and 15 pounds per day for Unit 1. The total for all three units is 63 pounds per day.

2) Hydrazine

Hydrazine is used in the secondary system to control oxygen in the steam generators. The concentration of hydrazine will not exceed 2.0 ppm during normal operation. The cold shutdown concentration will not exceed 100 ppm. A discharge at 100 ppm is not expected during normal operation, but may occur once per year at the end of the refueling outage. The expected

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* It should be noted that Unit 1 will have a maximum total release of sodium hydroxide of 120 pounds per day (4% at 6 gpm) and a sustained release of 36 pounds per day (75 ppm at 6 gpm).

maximum flow rate is 200 gpm and the expected sustained release is 5 pounds per day per unit during normal operation for Units 3 and 2. Hydrazine is discharged approximately once per year from Unit No. 1 during the refueling outage. The maximum concentration at this time will not exceed 50 ppm at a discharge flow rate of 40 gpm. The maximum possible release rate from Unit 1 would be 24 pounds per day.

3) Cyclohexylamine

Cyclohexylamine is used to adjust feedwater and steam pH. Concentrations of cyclohexylamine in the blowdown will not exceed 5 ppm on a continuous basis. The expected maximum flow rate is 200 gpm and the expected sustained release of the amine is 12 pounds per day per unit in Units 2 and 3. Cyclohexylamine is also used for similar reasons in Unit 1. The nuclear boilers are blowdown continuously at a maximum rate of 40 gpm containing a maximum concentration of 5 ppm cyclohexylamine. The maximum sustained release rate would be 2.5 pounds per day.

4) Soda Ash

Soda ash, used four times per year to wash flue-gas passages in the superheater of Indian Point Unit No. 1 could necessitate releases of 5 ppm at the discharge point. A 1% neutralized solution is discharged at a flow rate of 17 gpm for approximately 12 hours for a maximum release of 1000 pounds per day.

5) Sodium Hypochlorite

Chlorination of the main condenser is accomplished with sodium hypochlorite. One half of the condenser is chlorinated at a given time. The water from the chlorinated and unchlorinated sections mix within seconds after leaving the condenser resulting in a 1:1 dilution. The free chlorine residual dissipates quickly from exposure to sunlight and the chlorine demand of the river water so that discharge concentrations are usually 0.1 ppm or less. The overall time chlorine is added to the condenser is one hour. This procedure performed in daylight hours, is repeated on alternate days for a maximum of 3 times per week.

c. Detergent

"Colgate Low Foam" detergent is used in the plant laundry of Unit 1 at a rate of 3 pounds per day with a discharge flow rate of 25 gpm for approximately two hours per day. This detergent 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.

d. Sanitary Waste

There are three sewage treatment facilities at the Indian Point site, a main sewage treatment plant and two auxiliary systems which service the Gate House and Observation Building, respectively. The main sewage treatment plant treats all of the sanitary wastes from the nuclear and conventional portions of the site with the exception of the Gate House and Observation Building. Raw sewage enters the plant via comminutors located in the utility tunnel, where all coarse sewage material is cut into small settleable solids. After passing into a 6'-0" ejector basin, the sewage is pumped into dual septic tanks by 300 gpm pumps located on the top of this basin. Either one or both of these septic tanks may be selected by the use of manually operated sliding gates which are located in a distribution box immediately ahead of the tanks.

In the septic tanks, larger solids are removed and anaerobically decomposed; the process commonly referred to as sludge digestion. Sludge collected on the bottom of the septic tanks is removed and disposed of when it reaches a depth of 1/4 of the tank by a commercial contractor. Liquid separated from the sewage flows into a collecting pit at the south end of the septic tanks and is pumped into dosing tanks by means of 100 gpm pumps. Both the 300 gpm and the 100 gpm pumps are equipped with mechanical alternators which alternate the operation of the pumps. In addition, the alternator will cause both 300 gpm and 100 gpm pumps to operate simultaneously if the level in their respective pits rises too fast. Located in the dosing tanks are four siphons which alternately discharge the liquid sewage effluent to four 45-foot square sand filter beds.

After being discharged to the filter beds, the sewage effluent is filtered by passage through the sand in the beds. Below the beds are located underdrains whose normal function is to collect the filtered effluent and discharge it to the river. At the present time, however, the underdrains terminate at a capped header as the rate of percolation in the filter beds is so great that the use of the underdrains is not required. Therefore, no discharge of any type from the sewage facility is dumped into the river waters. In the future, should the load on the plant exceed the percolation capacity of the filter beds to any great extent, the underdrains will be connected to an automated chlorination station and the chlorinated effluent discharged to the river in accordance with state standards.

Separate sewage systems are provided for the sanitary wastes from the Gate House and Observation Building. The Gate House system is composed of a 512-gallon septic tank, a junction box and two 6'0" diameter leading pits. The sewage system which takes care of the sanitary waste from the Observation Building consists of a 545-gallon septic tank, a junction box, and five 60-foot long by 2-foot wide absorption trenches.

The design parameters utilized in the planning and construction of the overall sanitary waste system are summarized in Table III. These data clearly indicate the adequacy of the sanitary waste system for the Indian Point site. The system has been approved by New York State.

B. CONCENTRATIONS

1. State Criteria

New York State has water quality standards applicable to the Hudson River at Indian Point. This water body is classified as "Class SB" and a copy of the applicable criteria appears in Table II.

2. Proposed Concentrations

Although the New York State regulation is phrased in terms of general criteria rather than specific numbers, Con Edison is proposing to meet certain discharge limits with respect to concentrations of various chemicals at the confluence with the Hudson River which it believes will satisfy the "Class SB" criteria (see Table IV).

3. Permissible Concentrations

Since the criteria for these waters are general and the bioassay work gave certain confidence limits, the discharge water will be of a quality to satisfy the "Class SB: requirements at the levels prescribed in Table IV. Some of the chemical discharge levels have already received

TABLE III

SEWAGE DISPOSAL PLANT - INDIAN POINT GENERATING STATION

Type of Plant:	Intermittent Sand Filtration
Population:	Normal = 100; During Boiler Outage = 200; Ultimate = 300
Average Daily Flow:	30 gallons per person per day
Max. Cosign Hourly Flow:	6.25 gallons per minute x 200% = 12.5 gpm
Total Sewage Flow:	30 gpd x 300 = 9000 gpd = 6.25 gal. per minute
Elements of Plant:	Comminutor, Plain Sedimentation Tanks, Dosing Tanks with Automatic Siphons, Sand Filter Beds

Sedimentation Tanks:

Number of Units	Two
Required Capacity	1/2 day's flow = 4500 gallons per N.Y. State regulations ∴ each tank has a capacity of 2250 gallons.

Filter Beds:

Dosing Rate: 50,000 gallons/day/acre (average flow)

Size of Bed:

$$\frac{9{,}000 \text{ gpd}}{50{,}000 \text{ g/acre}} = 0.18 \text{ acres} \times \frac{43{,}560 \text{ sq. ft.}}{\text{acre}}$$

$$= 7{,}840 \text{ sq. ft.}$$

Four square beds (45'x45') = 8,100 sq. ft.

Dosing Tank:

Dimensions:	11.0' x 11.0'
Capacity:	Dose = 3" on one bed ∴ Capacity = 3,800 gallons
Siphon Flow (Max.)	15.62 gpm
Discharge (avg):	572.6 gpm
Cycle (Max Flow):	4.06 hours

TABLE IV

PROPOSED MAXIMUM CONCENTRATION OF CHEMICALS AT CONFLUENCE *

Chemical	Concentration (ppm)
Phosphate	1.54
Hydrazine	0.1
Cyclohexylamine	0.1
Lithium Hydroxide	0.01
Boric Acid	50.
Potassium Chromate	0.05 (hexavalent chromium)
Residual Chlorine	0.5
Sodium Hydroxide	10.
Sulfuric Acid	10.
Soda Ash	5.
Detergent	1.0

* Prior to dilution in the river.

state approval.

On February 10, 1971, the NYSDEC issued to Con Edison approval for nonroutine chemical discharges during construction of Unit 2 at stated concentrations of:

a. Hexavalent chromium, 0.05 ppm

b. Hydrazine, 0.1 ppm

c. Lithium hydroxide, 0.01 ppm

in the discharge canal with a minimum flow of 100,000 gpm of service and circulating water. The remainder of the discharge levels although not yet approved by the NYSDEC are believed adequate ("safe") as indicated by the bioassay tests performed by Gift, 1971; Renwoldt, 1972, and Lauer, 1972.

4. Accidental and Extreme Discharges

a. Normal Operation

The discharge concentrations will at no time exceed the limits of the proposed levels of discharge, and under no circumstances will discharge flow be less than 100,000 gpm.

1) Evaporator Failure

Predictions of possible concentrations (see II, A, 2) of lithium hydroxide, boric acid, and sodium hydroxide are considered in case of evaporator failure.

2) Potassium Chromate

There should be no release under normal operating conditions of potassium chromate; however, some leakage could occur (see II, A, 2:a:3) leading to a maximum of 100 ppm discharge to the effluent canal waters.

3) Hydrazine

Hydrazine will have a maximum release on the order of 100 ppm to the discharge canal once a year upon completion of refueling.

b. Construction and Testing

During construction and testing various nonroutine releases will occur; however, these releases will be at such a rate that the residual at the confluence with the river will not exceed the levels stated in Table III. Disodium and trisodium phosphate (250 ppm), hydrazine, (100 ppm), lithium hydroxide (10 ppm), potassium chromate (450 ppm), and boron (2000 ppm) could all be released in a batch quantity of 200,000 gallons into the discharge canal at a rate that would be dependent on both the flow volume of the discharge canal and the actual amount of hexavalent chromium in the batch release (the final concentration of chromium being a controlling factor in this instance).

5. Dilution Effects

Upon agreement between Con Edison and the NYSDEC the volume of 100,000 gpm is employed as the mixing volume in the effluent canal for the possible chemical discharges. If the plant operates at all, dilution water should exceed this amount since a minimum volume of 98,000 gpm is necessary just for service water in the three units.

a. Discharge Canal

If Unit 3 alone operates at 50% of normal cooling water capacity there would be approximately an additional 4.3:1 dilution factor involved, and at 100% operation there would be an 8.7:1 dilution factor. Considering the dilution values and the maximum possible amounts of materials to be discharged during normal operations the final concentrations in the canal would be as indicated in Table V.

Comparing Table IV and V it is evident that all of the discharges except hydrazine fall far below the proposed limits of Table III. The hydrazine value is twice that of the proposed concentration. However, this is for a cold shutdown as during refueling; the expected normal release is 2.0 ppm which would give a concentration on the order of 0.004 ppm which is again far below the limits proposed by both the State and Con Edison.

b. In River

Both Con Edison consultants and government agencies have studied the hydrology of the Hudson River near the Indian Point site and have indicated that water depths within 1,000 feet of the shore near the site are variable with an average of 65 feet, and at some points exceeding 85 feet with river width in front of the plant ranging from 4,500 to 5,000 feet. Flow in the Hudson River at Indian Point is controlled more by tides than by runoff from the tributary watershed. The Hudson River is tidal as far upstream as Troy, some 100 miles from Indian Point. The elevation of the water surface in the vicinity of the plant is so responsive to the tidal cycle that the average rate of flow has little effect on depth or velocity of flow. Tidal flow past the plant is more than 80,000,000 gpm,

TABLE V

DILUTION FACTORS OF DISCHARGES - Unit 3

Chemical Species	Max. Release[a] Concentration (ppm)	Release Volume (gpm)	Residuals in Effluent Canal (ppm)			Residuals in Hudson R. (11% of Tidal Flow)		
			100,000 gpm[b]	50% normal[c] operation (4.3:1)	100% normal[d] operation (8.7:1)	100,000 gpm	50% normal operation	100% normal operation
Lithium Hydroxide (Li)	2.2[e]	25	0.0006	0.00014	0.00007	0.000007	0.0000015	0.0000008
Boric Acid (B)	2000[e]	25	0.5	0.12	0.06	0.006	0.0014	0.0007
Sodium Hydroxide	500[e]	25	0.13	0.03	0.015	0.0015	0.00034	0.00017
Sulfuric Acid	nil	--	--	--	--	--	--	--
Sodium Phosphate	250[f]	200	0.5	0.12	0.06	0.006	0.00136	0.00068
Hydrazine	100[g]	200	0.2	0.05	0.02	0.002	0.00057	0.00023
Cyclohexylamine	5	200	0.01	0.002	0.001	0.0001	0.000023	0.000011
Morpholine	5	200	0.01	0.002	0.001	0.0001	0.000023	0.000011
Potassium Chromate	100[h]	25	0.025	0.006	0.003	0.0003	0.000068	0.000034
Sodium Hypochlorite	0 to 0.5	--	0 to 0.5	0 to 0.5	0 to 0.5	to 0.006	to 0.006	to 0.006

[a]These are maximum possible releases and are therefore not routine.

[b]Values normalized to a minimal flow of condenser coolant in the discharge canal.

[c]At 50% operation approximately 1/2 of maximum flow of 870,000 gpm will be used for a ratio factor of 4.3:1.

[d]At 100% operation 870,000 gpm will be utilized for a 8.7:1 dilution.

[e]Only discharged upon evaporator failure.

[f]Will not exceed 10 ppm on sustained basis.

[g]Will not exceed 2.0 ppm during normal operation.

[h]Not planned but leakage could occur.

80% of the time, and it has been estimated that this flow is at least 9,000,000 gallons per minute in a section 500 to 600 feet wide immediately in front of the facility. The net mean downstream flow due to runoff exceeds 11,700,000 gpm 20% of the time; 4,710,000 gpm 60% of the time; and 1,800,000 gpm 98% of the time.

Passing the 100,000 gpm suggested effluent flow into the river to be diluted by the 80% level of tidal flow suggests an additional maximum dilution factor of 800, or at the 20% level a maximum dilution factor of 47. If, however, it is assumed that only 11% * of this volume actually dilutes the effluent, then dilution factors would be on the order of 88 which would provide residual concentrations of such extremely small magnitudes that they would be insignificant (See Table V).

c. Extreme Conditions

It is estimated that 10% of the time the runoff value could be 1,800,000 gpm or less. However, due to the tremendous cross sectional area of the river, it is evident that even the lowest rates of flow will have a negligible influence on depth of flow in the vicinity of the plant. This is due to the relatively large available flow section and the width of the river. River depth is affected more by the tidal influence than it will be by any anticipated fresh water flows.

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* 9,000,000 gpm at 80% or 11% of estimated flow

6. Other Effluents

Within the immediate vicinity of Indian Point there are three other major industrial plants. Standard Brands has a plant located just north of the Con Edison facility and Georgia Pacific is located just south of the facility. The Lovett and Bowline Oil-fired power plants are located across the river from Indian Point, two and four miles, respectively, downstream. Discharges from these power plants are required to meet N.Y. State criteria for discharges to close SB waters, as shown on Page 9.

III. TOXICITY FISH BIOASSAYS

A. GIFT'S BIOASSAY WORK

1. Test Species

The toxicities of various individual and/or combined chemical discharges from a generating station on two ecologically important resident species of East River and Hudson River fish were determined using static, median tolerance limit (TLm) bioassay studies. Ninety-six hour static, bioassay determinations were conducted for four combinations of chemicals released as a result of normal plant operations. Fourty-eight hour static determinations were conducted using 11 different chemical combinations which will be used intermittently in plant cleaning processes.

a. Species Selected and Rational

The fish species selected for the study were the mummichog, *Fundulus heteroclitus*, and the Atlantic silverside, *Menidia menidia*. Both species are quite abundant in the plant receiving waters and they are important components of food chains. *Fundulus* was selected because it is a hardy, resistant species (Bigelow and Schroeder, 1953) which can be handled easily and maintains viable populations even in the poor water quality conditions prevalent in the East River. In contrast, Menidia was selected because it is a less resistent species which is more sensitive to toxic materials. It is thought that Menidia may be living near the limits of its tolerance due to the poor water quality conditions in the East River and, therefore, should be quite sensitive to further degradation in water quality. It is well known that Menidia is a difficult species to handle in the laboratory. These problems were compounded by the poor water quality under which Menidia were collected and held in the holding facility. Recognizing such limitations, it was felt that there was justification in using this fish. The final results would afford a comparison between the responses of two species, one resistant and one sensitive to environmental change.

b. Test Guidelines

The static bioassays were conducted following guidelines presented in Standard Methods for the Examination of Water and Wastewater, (1971). Water used in all bioassays was East River water pumped from the river in the vicinity of the Con Edison's site into an onsite laboratory. Using this water source allowed for any effects of pollutants either singly or synergetically from runoff, sewage, or industrial discharges.

2. Chemical Tested

The chemicals to be used in plant operation were tested on a combined basis with 15 different determinations made; however, only 6 of these are relavent to the Indian Point chemical discharges. The determinations were performed on a joint basis to account for any synergism that might occur.

All of the chemicals except chromate, boric acid and the Colgate Low Foam Detergent were tested during this series of assays. (Chromates were considered in thermal influence studies performanced by Renwoldt, 1972, see Section IV). The main portion of the chemicals were divided into three groups with one group run at two different pHs. The entire set of experiments were run as a static bioassay on a 96 or 48 hour basis.

Group one was a joint combined test on boiler blowdown chemicals at the proportions designated by Con Edison (see Table VI). Group two considered the combined discharge from the resin bed regeneration. It was run at both a pH of 8.0 and 6.0 (see Table VI). The third experiment considered chlorination. The two remaining tests of interest were 48 hour tests with soda ash and a mixture of hydrazine and ammonia (see Table VI).

3. Survival of Fishes

The 96 hour and 48 hour median lethal tolerance limits determined during the course of the bioassay study are presented in Table VII. Also included in the table are the estimated "Safe" concentrations of the various chemical combinations. The "Safe" concentration is determined from the recommendation for noncumulative toxicants as described in the Water Pollution Control Administration Report of the Committee on Water Quality

TABLE VI

BIOASSAY CHEMICAL COMBINATIONS

(after Gift, 1971)

Four static bioassays conducted on normal operating chemicals (96 hour tests).

1. One joint combined test on boiler blowdown chemicals including these chemicals in the following proportions designated by Consolidated Edison:

a.	Na_3PO_4	12 ppm PO_4
b.	NaCl	60 ppm Cl
c.	SiO_2	0.170 ppm SiO_2
d.	H_2SO_4	12 ppm SO_4
e.	Cyclohexylamine	1.0 ppm
f.	Hydrazine	1.0 ppm
g.	NaOH	adjust pH to 8.8

2. a,b Ion exchange regeneration wastes in the following proportions:

a.	Na_2SO_4	3050 ppm
b.	$CaSO_4$	626 ppm
c.	$MgSO_4$	250 ppm
d.	Na_2CO_3	300 ppm
e.	NaCl	150 ppm
f.	Na_2SiO_3	80 ppm
g.	adjust pH to 8.0 for one mixture and to 6.0 for the second mixture using NaOH and H_2SO_4	

3. Chlorination - NaOCl

4.	Na_2CO_3	10,000 ppm
5.	Hydrazine	200 ppm
	Ammonia	10 ppm

TABLE VII

The 96 hour and 48 hour median tolerance limits (TLm's) determined for Fundulus heteroclitus and Menidia menidia exposed to the various chemical combinations and estimated "safe" concentrations based on a 1/10 safety factor applied to the TLm determinations for Menidia menidia.

(Gift, 1971)

Normal Operating Chemicals - 96 hour TLm

1. Boiler Blowdown

Chemical	Fundulus heteroclitus 96 hr TLm ppm	Menidia menidia 96 hr TLm ppm	Estimated "safe" Concentration ppm
PO_4	28.32	9.62	0.96
Cl	140.60	48.12	4.81
SiO_2	0.40	0.14	0.01
SO_4	28.32	9.62	0.96
Hydrazine	2.36	0.80	0.08
Cyclohexylamine	2.36	0.80	0.08

2. Ion Exchange Regeneration Wastes

No toxicity related deaths for Fundulus heteroclitus or Menidia menidia at 3.77 times mixture concentrations.

3. Chlorination - Using NaOCl

Chemical	Fundulus heteroclitus 96 hr TLm ppm	Menidia menidia 24 hr TLm ppm	Estimated "safe" Concentration ppm
Chlorine residual	4.8	0.70	0.07

4.

Chemical	Fundulus heteroclitus 48 hr TLm ppm	Menidia menidia 48 hr TLm ppm	Estimated "safe" Concentration ppm
Na_2CO_3	2800.0	465.0	46.5

5.

Chemical	Fundulus heteroclitus 48 hr TLm ppm	Menidia menidia 48 hr TLm ppm	Estimated "safe" Concentration ppm
Hydrazine	13.3	7.40	0.74
Ammonia	0.57	0.37	0.04

Criteria, (1968) which suggests the use of a 1/10 safety factor (i.e., safe levels are estimated by taking 1/10 of the 48 or 96 hour TLm concentration). Since the chemicals present in these wastes have noncumulative effects, the use of the 1/10 factor should be permissible. To be further on the conservative side, the "Safe" concentrations were estimated by taking 1/10 of the TLm's determined for Menidia menidia, since this species was the more sensitive of the two species tested. The survivorship data were utilized to calculate the median tolerance limit by semilogarithmic graphical interpolation (see Table VII).

a. Test 1, Boiler Blowdown

The 96-hour TLm determined for Fundulus was more than two times the concentration of the undiluted boiler blowdown waste. The same TLm for for Menidia was, however, less than the concentration of the undiluted boiler waste, but the estimated "Safe" concentration of boiler blowdown based on 1/10 of the Menidia bioassay results should be appreciably higher than anticipated discharge concentrations in the effluent canal during normal operations (see Tables V and VII).

b. Test 2 a, b, Ion Exchange Regeneration Waste

Preliminary bioassays indicated that no fish deaths were expected at the stated concentration of the ion exchange regeneration wastes at either pH 6.0 or 8.0. Consequently, for the final bioassay determinations, a logarithmic series of dilutions were set with the highest concentration 3.77 times the stated operating level. It was felt that there was no reason to test still higher concentrations, since all of the higher concentrations tested were supersaturated and a portion of the salts remained undissolved.

No toxicity related deaths were observed for Fundulus or Menidia, even at the highest test concentration (3.77 x stock waste level). There were some mortalities noted in the tests with Menidia; however, mortalities at the highest concentrations were no higher than control mortalities. The experimental population of Menidia, as well as Menidia used throughout the study, showed evidence of tail rot and other fungal and bacterial diseases. In these studies with ion regeneration wastes, it is noteworthy that the Menidia in the higher concentrations appeared to be in much better condition than those in the controls and low concentrations. Apparently some component of the regeneration wastes acted as a prophylactic treatment, inhibiting the development of disease at the higher concentrations. Since no TLm concentration could be determined, no "Safe" concentration was estimated. However, since no toxicity related death occurred even at 3.77 times the stated operating level, no detrimental effects of the ion exchange regeneration wastes are anticipated at discharge concentrations (see Table VII).

c. Test 3, Chlorination

After the initial chlorine demand was satisfied, chlorine residuals continued to drop due to further oxidation of the remaining chlorine. Consequently, chlorine residuals were monitored in the chlorination bioassay studies until no further residual was detected. No detectable chlorine was present in either the study with Fundulus or in the study with Menidia after 24 hours. Consequently, the 96-hour TLm calculated for Fundulus was the same as a 24-hour TLm since no chlorine was present after 24-hours and no further Fundulus deaths occurred after this time. A 24-hour TLm is presented for Menidia, since again no chlorine was present after 24 hours. There were additional deaths in the controls and in the remaining fish population during the last three days of the test, but these were probably unrelated to the toxicity of chlorine.

The chlorine TLm's were calculated using the initial dose concentrations. This may prejudice the results since the fishes were only exposed to the initial concentrations for a short period of time. This is a limitation of static bioassay with chlorine. Complete evaluation would require continuous exposure in a flow-through apparatus. There is some justification for the static test since condenser circuit chlorination will only last for 30 minutes per condenser. Calculated "Safe" concentrations of chlorine indicate that if fishes are exposed to chlorine residuals of 0.5 ppm, some damage to the population might be expected.

d. Test 4, Soda Ash

The toxic effect of this salt is probably due to the effect of high pH on osmoregulation. Fundulus died when the pH reached 9.9 and above, whereas Menidia mortalities occurred at a pH of 9.12 and above. A 4.65×10^{-3} dilution of the waste is needed to reach estimated "Safe" concentrations.

e. Test 5, Hydrazine, Ammonia

Both hydrazine and ammonia are toxic chemicals. A 3.7×10^{-3} dilution of this cleaning chemical combination is needed to reach estimated "Safe" concentrations.

B. RENWOLDT'S BIOASSAY WORK

1. Test Species

The effect of increased temperature on the toxicity of six metal ions at various concentrations was determined for a range of temperatures from 15° C to 28° C. This range was chosen as an approximate representation if the temperatures in the thermal plume of power plants.

A cross section of fish from the Hudson River were used to reflect general trends not just specific tolerances. The test species chosen were representative of large populations in the river. They were:

a. Anquilla rostrata - American eel

b. Cyprinus carpio - carp

c. Fundulus diaphanus - banded killfish

d. Lepomis gibbosus - pumpkinseed

e. Morone americana - white perch

f. Morone saxatilis - striped bass

The bioassays were conducted as described by APHA (1971). To account for any effects due to existing pollutants, either singly or synergetically, all tanks were filled with river water and river water was used for all dilutions. The toxic metals were weighed as their nitrates, and the analytical concentrations were determined on water samples before and during an experiment. Atomic absorption spectroscopy was chosen as the analytical method.

Since toxicity will be a function of many water characteristics, the hardness, pH, and dissolved oxygen were maintained at the following constant levels:

Hardness	55 ppm
pH	8.0
D. O.	6.9 ppm

and the temperature was controlled over the desired range.

TLm for 24, 48, and 96 hour intervals were determined. Ten or more of each species were chosen for each experiment and an equal number for the control. The mortality-concentration data were analyzed by the average angle method with the aid of a computer. This method yielded both TLm values and confidence limits.

2. Chemicals Tested

The chemicals tested were six metals that are believed to be common discharges of industrial concerns on the Hudson River. The metals investigated were copper, zinc, nickel, cadmium, mercury, and chromium.

3. Survival of Fishes

Table VIII contains the results of the TLm experiments in terms of analytical concentration (ppm) of metal ion in the water.

Table IX relates the TLm values to the existing ambient background concentrations for the same metal ions measured in the river during the course of the investigation. This yields the magnitude of change that would have to occur to the receiving waters in order to produce a fish kill equal to the 96-hour TLm.

TABLE VIII

ANALYTICAL CONCENTRATIONS OF METAL IONS IN PPM
(after Renwoldt, 1972)

Species	Metal	TLm 24 hr	TLm 48 hr	TLm 96 hr
banded killifish	Cu++	1.3	0.98	0.84
(*Fundulus diaphanus*)	Zn++	23.0	20.4	19.2
	Ni++	63.1	50.0	46.1
	Cd++	0.30	0.21	0.11
	Hg++	0.27	0.16	0.11
	Cr+++	26.3	20.8	16.9
striped bass	Cu++	8.4	6.6	4.0
(*Morone saxatilis*)	Zn++	11.3	10.0	6.8
	Ni++	10.0	8.5	6.3
	Cd++	1.9	1.5	1.1
	Hg++	0.22	0.14	0.09
	Cr+++	19.3	18.8	17.7
pumpkinseed				
(*Lepomis gibbosus*)	Cu++	3.5	2.9	2.7
	Zn++	25.1	21.9	20.1
	Ni++	16.4	12.1	8.0
	Cd++	2.8	2.2	1.5
	Hg++	0.41	0.39	0.30
	Cr+++	19.1	17.8	17.0
white perch	Cu++	11.5	7.9	6.4
(*Morone americanus*)	Zn++	13.5	10.1	14.4
	Ni++	18.4	16.0	13.7
	Cd++	1.6	1.1	8.4
	Hg++	0.42	0.34	0.22
	Cr+++	17.5	16.0	14.4
American eel	Cu++	10.6	8.1	6.0
(*Anguilla rostrata*)	Zn++	21.4	20.1	14.5
	Ni++	14.1	13.1	13.0
	Cd++	1.5	1.1	0.82
	Hg++	0.25	0.19	0.14
	Cr+++	19.5	16.3	13.9
carp	Cu++	1.9	1.2	0.80
(*Cyprinus carpio*)	Zn++	14.4	9.2	7.8
	Ni++	38.3	28.9	10.4
	Cd++	0.45	0.3	0.24
	Hg++	0.33	0.21	0.18
	Cr+++	21.2	18.4	14.3

TABLE IX

RELATION OF TLM TO EXISTING BACKGROUND CONCENTRATIONS
(after Renwoldt, 1972)

Species	Metal	TLm 24 hr	TLm 48 hr	TLm * 96 hr
banded killifish	Cu++	54	32	31
(<u>Fundulus</u> <u>diaphanus</u>)	Zn++	10535	8640	7701
	Ni++	364	330	290
	Cd++	50	35	19
	Hg++	90	53	38
	Cr+++	6575	5020	4449
striped bass	Cu++	294	102	61
(<u>Morone</u> <u>saxatilis</u>)	Zn++	6001	1410	1031
	Ni++	180	161	108
	Cd++	315	250	190
	Hg++	74	63	30
	Cr+++	4870	4700	4667
pumpkinseed	Cu++	134	103	87
(<u>Lepomis</u> <u>gibbosus</u>)	Zn++	2730	1999	1350
	Ni++	405	351	324
	Cd++	466	350	250
	Hg++	140	130	100
	Cr+++	4868	4450	4250
white perch	Cu++	421	287	219
(<u>Morone</u> <u>americanus</u>)	Zn++	3067	2709	2260
	Ni++	219	166	230
	Cd++	266	190	66
	Hg++	140	120	74
	Cr+++	4351	4000	3601
American eel	Cu++	371	290	231
(<u>Anguilla</u> <u>rostrata</u>)	Zn++	2330	2185	2166
	Ni++	349	321	236
	Cd++	250	190	134
	Hg++	83	63	53
	Cr+++	4875	4075	3475
carp	Cu++	74	38	28
(<u>Cyprinus</u> <u>carpio</u>)	Zn++	6366	4855	1766
	Ni++	230	151	126
	Cd++	75	50	40
	Hg++	110	70	60
	Cr+++	5300	4600	3561

* ratio of toxic concentration to background concentration

Table X contains the overall ranges for TLm values up to 96 hours for each metal. The ranges are not presented by fish species since for some of the mercury, cadmium and chromium values it was necessary to use published data on fish other than the ones used in this investigation. While it could be argued that it is not valid to compare TLm data if the same test species were not used, it was felt by the investigators at Marist College that a comparison of ranges at two different temperatures is not useless, provided the water parameters such as hardness, pH and dissolved oxygen are nearly the same.

It can be seen that the TLm data at 28°C and 15°C are not significantly different for the ions studied with the exception of the mercurous ion. Computer significance analyses indicate for mercurous ion the difference in range is statistically meaningful. The 15°C data were obtained in soft water with the common goldfish, (Carassius auratus); and, therefore, it would appear reasonable to conclude that the toxicity of mercury is increased as the temperature increases, however, this may or may not apply to other fish of the Hudson River. For carp-like fish the toxicity increase is approximately three-fold for a 10° C increase in temperature.

TABLE X

OVERALL RANGES FOR TLM'S TO 96 HOURS IN PPM
(after Renwoldt, 1972)

Metal Ion	TLm range 15°C	TLm range 28°C
Cu++	.81 - 11.8	.80 - 11.5
Zn++	6.7 - 25.5	6.8 - 25.1
Ni++	6.2 - 63.2	6.3 - 63.1
Hg++	.37 - .74	.08 - .42
Cd++	0.3	0.11 - 2.8
Cr+++	10.3 - 31.6	13.9 - 26.3

C. LAUER'S BIOASSAY WORK

1. Test Species

The toxicities of various individual chemical discharges from Con Edison's Indian Point generating station on two ecologically important resident fish species of the Hudson River were determined using static, median tolerance limit (TLm) bioassay studies. Twenty-four and forty-eight hour static determinations were conducted on 8 different chemicals which will be used intermittently in plant processes.

a. Species Selected and Rational

The fish species selected for the study were the white perch, Morone americana and the striped bass, Morone saxatilis. Both species are quite abundant in the plant receiving waters and they are important components of food chains and sport fishing.

b. Test Guide Lines

The static bioassays were conducted following guidelines presented in Standard Methods for Examination of Water and Wastewater, (1971). Water used in all bioassays was Hudson River water pumped from the river in the vicinity of the plant site into an onsite laboratory. Thus the tests included any effects, either singly or synergistically, of pollutants from runoff, sewages, or industrial discharges.

2. Chemicals Tested

There were eight different determinations made utilizing chemicals that Con Edison discharges into the effluent waters (see Table XI for list of chemicals). Each chemical was tested at four concentrations.

TABLE XI

The 48 hour and 24 hour median tolerance limits (TLm's) determined for *Morone americana* and *Morone saxatilis* exposed to the various chemicals and estimated "safe" concentrations based on a 1/10 safety factor applied to the lowest TLm determination.

(after Lauer, 1972)

Normal Operating Chemicals (24 & 48 hour TLm in ppm)	*Morone americana*		*Morone saxatilis*		Estimated "safe" concentrations
	24 hr. TLm	48 hr.	24hr. TLm	48 hr.	
1. Boric Acid	10,040	6850	—	2100	210
2. Cyclohexylamine	40	40	64	64	4.0
3. Detergent	18.8	16.0	16.4	14.8	1.5
4. Soda Ash	705	620	340	198	19
5. Sodium Hydroxide	91	88	58	57	5.7
6. Sodium Hypochlorite[a]	2.8	2.8	2.8	2.8	.3
7. Sulfuric Acid	57	56	65	65	5.7
8. Trisodium Phosphate	510	510	388	385	38.5

a. Concentration expressed as total chlorine. Toxicity based on 3.0 hours due to small residency time of free chlorine; therefore, the TLm are for 2 hours.

3. Survival of Fishes

The 24-hour and 48-hour TLm concentrations of the various chemicals for striped bass and white perch are summarized in Table XI. The decrease in TLm concentration from the 24-hour to 48-hour exposure time for boric acid and soda ash indicate a continuing toxic effect by those two chemicals over the full 48-hour period of the test. The similar values for the 24-hour and 48-hour exposure times for the rest of the chemicals indicate that the toxic action of the chemicals has been fully exhibited by the 24-hour period of exposure. None of the individual chemical concentrations exceed the permissible concentrations, defined as the maximum concentrations tested in which mortality during 48-hour bioassays did not exceed mortality in the controls.

Neither a 24-hour nor a 48-hour TLm could be obtained for chlorine due to the fact that these were static tests and that after the test concentration was reached, rapid release of the chlorine decreased the total chlorine residual to unmeasureable levels before a 24-hour exposure period was reached. To make the tests more meaningful toward application with the Indian Point Nuclear Power Plant operational scheme, and in view of the decreasing chlorine residual, results are based on events observed during the first 2.5 to 3.0 hours.

In an initial (detectable) 0.3-ppm total chlorine residual both white perch and striped bass exhibited 100% survival after 3 hours of exposure while the total chlorine residual was undetectable after 0.5 hour. At an initial concentration of 0.60 ppm total chlorine residual for striped bass and 0.75 ppm for white perch both species had

100% survival for 3 hours while the chlorine residual was undetectable after 1.5 hours. At an initial concentration of 2.8 ppm total chlorine for white perch, a 50% survival was calculated to occur after 2 hours of exposure at which time the calculated remaining total chlorine residual was 0.89 ppm. With an initial concentration of 3.1 ppm total chlorine residual, striped bass exhibited 50% survival after 50 minutes of exposure when the calculated total chlorine residual was 1.56 ppm. At an initial concentration of 7.75 ppm total chlorine residual for white perch, 50% survival occurred at 40 minutes of exposure time and at a concentration of 6.2 ppm. At an initial concentration of 7.8 ppm total chlorine residual, striped bass exhibited 50% survival after an exposure time of 20 minutes when the remaining chlorine residual was about 7.0 ppm.

D. CRISTIN'S BIOASSAY WORK

1. Test Species

The toxicities of various individual chemical discharges from Con Edison's Indian Point generating station on two ecologically important resident fish species of the Hudson River were determined using static, median tolerance limit (TLm) bioassay studies. Twenty-four hour and fourty-eight hour static determinations were conducted on 2 different chemicals which will be used intermittently in plant processes.

a. Species Selected and Rationale

The fish species selected for the study were the white perch, Morone americana, and the striped bass, Morone saxatilis. Both species are quite abundant in the plant receiving waters and they are important components of food chains and the sport fishery.

b. Test Guide Lines

The static bioassays were conducted following guidelines presented in Standard Methods for the Examination of Water and Wastewater, (1971). Water used in all bioassays was Hudson River water pumped from the river in the vicinity of the plant site into an onsite laboratory. This procedure allowed for any additional effects due to pollutants from other sources acting singly or synergistically with the test chemicals.

2. Chemicals Tested

The two chemicals tested in this bioassay work were morpholine and hydrazine. Hydrazine as a blowdown product from the steam generator. Morpholine is no longer used at Indian Point; it has been replaced with cyclohexylamine. Tests results are presented here for purposes of indicating the general effects of amines. Hydrazine was tested at concentrations of 10, 1 and 0.1 ppm while morpholine was tested at concentrations of 1000,100, 10, and 1.0 ppm.

3. Survival of Fishes

Of the four morpholine concentrations tested, only the test tanks containing 1000 ppm produced noticeable differences in behavior and subsequent death of the experimental organisms. Upon introducing morpholine to the test tanks, an immediate reaction was noted for one striped bass specimen manifested by rapid swimming motions and sporadic twitching. The remaining specimens almost immediately increased their swimming speeds and swam erratically through all levels of the test tank. Upon introduction of the test solutions to the remaining test tanks, no noticeable change in activity was observed.

The contrast in behavior between the test tanks containing 1000 ppm and the remaining test containers was dramatic. In the tanks containing 1000 ppm morpholine, the specimens acted completely oblivious to any movements of the investigator. Swimming activity was continuous and random, opercle beats were rapid and irregular indicating severe stress for all specimens. After approximately 60 minutes, the first fish succumbed in the 1000 ppm solutions. Subsequent deaths occurred periodically. The behavior indicating final stress and death was similar for all specimens. In contrast, the specimens exposed to the lower concentrations of morpholine behaved quite normally. Motor activity was normal and apparently deliberate.

Upon completion of the 48-hour test period, all specimens in test tanks with 100 ppm or lower were in apparent good health and acted normally, or at least similar to the control specimens. At this point, the decision was made to retain the specimens in their respective test containers for an additional 48 hours. All specimens remained in apparent good health though the silhouette of the ventral surface of each specimen was concave reflecting the seven-day period without food.

The results of the bioassay indicate that concentrations of 100 ppm and below of morpholine do not cause a change in behavior, or death for juvenile white perch and striped bass. However, concentrations of 1000 ppm were definitely detrimental. Sufficient data was not available to indicate which of the two species is more sensitive to morpholine, if, in fact, a higher sensitivity does exist for either of the two species.

During the 48-hour test period for hydrazine, none of the striped bass and only one white perch specimen succumbed. This occurred 5 1/2 hours following introduction to the hydrazine. No other death took place in any of the test containers during the initial 48-hour experiment, though behavioral differences were noted for specimens of both species in test tanks containing 10 ppm as opposed to specimens in the control group or other test concentrations. The behavioral differences were noted immediately following the introduction of the chemical. Specimens in these tanks appeared to be "agitated". Swimming speed was increased and sporadic. Specimens in all other test containers remained relatively inactive, swimming slowly within the bottom half of the water depth and were very responsive to the movements of the investigator.

The single death of the white perch specimen in the 10 ppm test tank suggests this concentration may be harmful to this species; however, no conclusive evidence exists since no other deaths occurred. This specimen may have died from other causes since a specimen in the control tank also succumbed, though after 48 hours. It is significant to note that the sporadic abnormal behavior of the remaining specimens placed in the 10 ppm concentration represents a sublethal effect and such concentrations should be avoided in the natural environment. Based on the results of this bioassay, the extremely low concentrations of between 0.03 and 0.0006 ppm hydrazine planned for discharge should have no effect on the fish life of the Hudson River in the vicinity of Indian Point.

E. LAMONT-DOHERTY TOXICITY STUDIES

1. Test Species

Toxicity tests were conducted using sodium hypochlorite on axenic cultures of two typical estuarine phytoplankters, the flagellate *Monochrysis lutheri* and the diatom *Skeletonema costatum*. Stock cultures were maintained and experiments were conducted in an artificial growth medium with a salinity of 17.6%. Cultures were exposed to a 13-hour day, 11-hour night cycle at light intensities in the range of 500-800 foot-candles, at 20° C.

The composition of the medium used to grow the stock cultures was the following:

50% Sargasso Sea water (Millipore filtered, 0.45μ)

50% Double glass-distilled water

		mg/1
Add:	$NaH_2PO_4 \cdot H_2O$	2.5
	$NaNO_3$	37.5
Trace metals:		
	Na_2 EDTA complex	21.8
Chloride salts of:		
	Fe	3.25
	Cu	12.5
	Zn	25.0
	Mn	0.25
	Mo	12.5
Vitamin B_1		0.05
Vitamin B_{12}		0.25
Biotin		0.25

One-liter batches of stock culture were grown to densities of about 2 x 10^6 cells/ml and were then thoroughly mixed. 4.5 ml volumes of the stock culture were aseptically pipetted into culture tubes for testing. Test solutions of the chemical were prepared with sterile media and were arranged in such a way that the addition of 0.5 ml of test solution to 4.5 ml of culture would yield the desired test concentration. Control tubes were prepared in the same manner, and 0.5 ml of sterile medium was added at the same time instead of the test solutions. All test concentrations and controls were done in duplicate.

Test cultures and controls were incubated for 24 and 72 hours and then counted on a Bright Line Hemacytometer. Two counts were taken for each tube and the mean cell density was calculated.

2. Chemical Tested

Test concentrations of sodium hypochlorite ranged from ten times the maximum outfall concentration reported by Consolidated Edison to 1% of this concentration.

3. Survival of Planktons

<u>24-hour test</u>

Over a period of 24 hours, sodium hypochlorite at a concentration of 50 ppm was found to be 100% toxic to <u>Monochrysis</u>. <u>Skeletonema</u> was killed 100% by 5 ppm of sodium hypochlorite (see Table XII.).

Tabe XII

24-HOUR TOXICITY TEST

Cell densities of *Skeletonema costatum* (cells/ml)

Compound		Test Concentrations			
			Outfall Conc.		
NaOCl	Control	50 ppm	5 ppm	0.5 ppm	0.05 ppm
1	$2.5x10^6$	0	0	$2.2x10^6$	$2.6x10^6$
2	$2.60x10^6$	0	0	$1.88x10^6$	$2.15x10^6$

Cell densities of *Monochrysis lutheri* (cells/ml)

Compound		Test Concentrations			
			Outfall Conc.		
NaOCl	Control	50 ppm	5 ppm	0.5 ppm	0.05 ppm
1	$2.0x10^6$	0	$1.9x10^6$	$2.1x10^6$	$2.5x10^6$
2	$2.4x10^6$	0	$1.9x10^6$	$2.1x10^6$	$2.2x10^6$

Table XII continued

72-HOUR TOXICITY TEST

Cell densities of Skeletonema costatum (cells/ml)

Compound		Test Concentrations			
			Outfall Conc.		
NaOCl	Control	50 ppm	5 ppm	0.5 ppm	0.05 ppm
1	$2.7x10^6$	0	0	$2.8x10^6$	$2.9x10^6$
2	$2.8x10^6$	0	0	$2.6x10^6$	$2.7x10^6$

Cell densities of Monochrysis lutheri (cells/ml)

Compound		Test Concentrations			
			Outfall Conc.		
NaOCl	Control	50 ppm	5 ppm	0.5 ppm	0.05 ppm
1	$2.9x10^6$	0	$1.2x10^6$	$2.3x10^6$	$2.0x10^6$
2	$3.5x10^6$	0	$1.5x10^6$	$2.1x10^6$	$2.2x10^6$

These short-term toxicity tests were designed only to reveal which concentrations of the test chemicals were acutely toxic to the phytoplankters tested. Although the 72-hour test may show trends which reflect on the test organisms' ability to reproduce, long-term studies of organisms in the logarithmic growth phase (over several generations) are necessary to clarify this aspect.

IV. DISCUSSION

A. GENERAL CONSIDERATIONS

Trace element levels in fresh waters are important from the viewpoint of the suitability of the water for drinking purposes or industrial use, as well as of its potential toxicity to the natural fauna and flora either directly or as synergistic agents. In addition, the relation of trace element levels to primary productivity has been shown recently to be significant in the conversion of nutrient anions by photosynthesis, and some elements may play an enhancing or a limiting role. With these interests in mind, available information about the trace element levels in Hudson River waters should be considered together with some information about the concentrations of some elements in the muds and biota.

The Public Health Service has published a summary of the results of a sampling and analysis surveillance of the Hudson River at Poughkeepsie. The data provide estimates of the "normal" concentration of trace metals in the Hudson River for that period at a single point in the river. Additional data have been derived from the current research program of New York University, Institute of Environmental Medicine, (Eisenbud, 1969; Lauer and Howells, 1970). This study has demonstrated the considerable variability in the concentrations of trace metals at different locations along the river. Considerable variability also occurs on a seasonal basis due to the changes in fresh-water flow and the mixing influence of the tide.

In a tidal estuary such as the Lower Hudson River the degree of intrusion of salt water is important in defining the appropriate levels of trace element concentration. At Poughkeepsie, the chloride concentrations are usually <100 ppm so that the water is practically "fresh" and the appropriate standard of comparison is fresh water. At points south of this, the water is variably saline, following a pattern of maximum freshwater runoff following the spring thaw, and periods of low runoff during the summer with maximum salinities being recorded as the fall progresses into winter. Hence, at stations south of Poughkeepsie, variable levels of some trace elements are attributable to the sea water intrusion. Thus at Indian Point in 1968, salinity was <1 0/00 during spring and summer and increased during August to October to 6 0/00 or about 1/5 sea water, (Storet Retrival data). In Table XIII, the concentrations of trace elements in sea water and in fresh water typical of North America may be compared with concentrations in the Hudson watershed water and that of the river itself at Poughkeepsie and Indian Point.

The observed levels of concentration of a number of toxic metals are of particular interest in relation to those species of the biota resident in the Hudson. Many investigators have tested the effects of heavy metals, under varying environmental conditions, on aquatic organisms (Doudoroff and Katz, 1953). Sprague (1968) has demonstrated an avoidance reaction for salmonid fishes with as little as one hundredth (5 ppm) of the toxic level of zinc in fresh water. Pickering and Henderson (1968) investigated the acute toxicity of some heavy metals on various warm water species of fishes. These investigators concluded that each species reacted differently to a specific metal in the varying chemical and physical environment. Renwoldt (1972) found no connection between thermal changes in the water column and

TABLE XIII

SELECTED MINOR CONSTITUENTS OF SEA WATER[1], N. AMERICAN FRESH WATER [2], HUDSON WATERSHED[3] AND HUDSON RIVER WATER[4,5] (CONCENTRATIONS, mg/liter)

Element	Sea Water (Mean)	N. Amer. Water (Median)	Hudson Watershed (Del./Catskill) (Mean)	Hudson River at Indian Point (Annual Mean-1968)	Hudson River at Poughkeepsie (Mean for 1962-1969)
Lithium	0.2	0.0011			
Boron	4.6	0.01	0.009		0.034
Fluoride	1.3		0.86		
Magnesium	1350		1.8		
Aluminum	0.01	0.238	0.02		0.032
Silicon	3		0.46		
Phosphorus	0.07		0.062	0.118	0.023
Calcium	400		7.3		
Titanium	0.001	0.0086			
Vanadium	0.002	0			
Chromium	0.00005	0.0058	0		0.0070
Manganese	0.002	0.02	0.05	0.003	0.0026
Iron	0.01	0.3	0.05	0.012	0.044
Cobalt	0.0005	0		0.0011	
Nickel	0.002	0.01		0.0021	0.0056
Copper	0.003	0.0053	0.07	0.0041	0.025
Zinc	0.01	0	0.01	0.013	0.043
Arsenic	0.003		0.0008		0.032
Selenium	0.004		0.002		
Rubidium	0.12	0.0015			
Strontium	8	0.06			
Molybdenum	0.01	0.00035			0.009
Silver	0.0003	0.00009	0.0003		0.00064
Cadmium	0.00011		0	0.0011	0.0068
Iodine	0.06		0.003		
Barium	0.03	0.045	0.12		0.026
Lead	0.0001	0.004	0	0.019	0.014

References:
1. E.D. Goldberg, 1969
2. W.H. Durum and J. Hafety, 1963
3. Indian Point - Institute of Env. Med.
4. Storet Retrieval Data, USFWPCA
5. USPHS, 1965

metal toxicity. However, the TLm values observed under experimental conditions would be expected to cause fish mortality under most environmental conditions, even for short exposures.

It is difficult from a search of the literature to place specific toxic limits or ranges for each trace metal because of this variability between species response and other water quality characteristics in natural systems. The possible synergistic effects of two or more metals acting together to produce a toxic effect further complicates the picture (Brown, 1968; Doudoroff and Katz, 1953; Saunders and Sprague, 1967). It was for this reason that the bioassays were run with joint chemical complexes from the boiler blowdown and the ion resin regeneration waste. By using a mixture of the chemicals any synergistic effects will be taken into consideration.

The same rational supports the use of river water for a test media in that by so doing the effects of any trace pollutants already present would be accounted for.

B. Specific Considerations (Chlorination)

1. Introduction

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

In order to prevent reduced heat transfer and flow caused by this slime, chlorine is introduced into the cooling water on some periodic schedule. Although chlorination has previously been considered a panacea for all problems, recently environmental research has disclosed the possible adverse effects which chlorine may have on aquatic organisms. Among these are:

a. Direct Impacts

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

b. Indirect Impacts

- Effects of chloroamines
- Effects of chloro-organics

The potential effects of chlorination are based on two factors: concentration and time of exposure. By limiting either or both of these factors, the adverse effects associated with chlorine can be reduced or eliminated. It should be noted that there are several forms of chlorine of interest:

- hypochlorous acid (HOCL)
- hypochlorite ion
- chloramines NH_xCl_{3-x} and
- organic chlorine compounds.

Hypochlorous acid may be removed from the aquatic environment very rapidly, chlorinated compounds however may be more persistant. Formation of chlorinated compounds especially chloramines from hypochlorous acid depends on the concentrations of ammonia compounds and of hypochlorous acid as well as dissolved oxygen, pH, and temperature. Removal of hypochlorous acid may be accomplished by satisfaction of the"chlorine demand", which is a measure of the amount of substances in the water which can be oxidized by the chlorine present. In the process of satisfaction of this demand, the chlorine is reduced to chloride (Cl^-) ion, a biologically inactive form which occurs naturally in Hudson River water at Indian Point. In addition to the reduction of chlorine concentration resulting from chlorine demand, cooling water flows from other condensers and river mixing have diluting effects.

Studies with relevance to chlorination that have been undertaken by Quirk, Lawler & Matusky Engineers (1973) and others are:

- Laboratory studies of chlorine reactions
- Laboratory determinations of chlorine demand
- Field determinations of chlorine demand
- Laboratory studies on chlorine toxicity

Hudson River water from Indian Point and chlorine in the form used at Indian Point, sodium hypochlorite solution, were used in these studies. The data used, in conjunction with plant operating and design data, allow predictions of the concentration-exposure time at Indian Point and its effect on aquatic species to be made.

2. Reactions of Chlorine

In order to examine the discharge canal concentrations of chlorine species, it is necessary to develop the reactions which occur in chlorinated natural waters. For this purpose, the relevant reactions are:

1. Hydrolysis of sodium hypochlorite and dissociation of hypochlorous acid.
2. Immediate chlorine demand by alkalinity and organic and inorganic reducing substances
3. Formation of chlorinated ammonia compounds
4. Ultraviolet-catalyzed reduction of hypochlorous acid and hypochlorite ion (free chlorine)
5. Reduction of chlorinated ammonia species (combined chlorine) to chlorides and nitrogen compounds

Reactions in each of these groups, when taken together, control the relative and absolute concentrations of the various chlorinated species and their precursors.

Reactions in Group 1, hydrolysis and dissociation of sodium hypochlorite are:

$$NaOCL + H_2O \rightarrow NaOH + HOCL \quad \text{.....(1)}$$

$$HOCL \rightleftarrows H^+ + OCL^- \quad \text{.........(2)}$$

Reaction 1 is extremely rapid, and can be expected to be complete as soon as the hypochlorite is added to water. This is the exclusive reaction at pH 4 and hypochlorite $<$1,000 mg/l. Reaction 2 is a reversable pH-controlled reaction, and is of primary interest because the ionized form will not react with ammonium compounds.

Reactions of Group 2, reduction of immediate demand, are generally:

$$HOCL + RH \rightarrow ROH + H^{+} + CL^{-} \quad ......(3)$$

$$OCL^{-} + RH \rightarrow ROH + CL^{-} \quad ....(3a)$$

where RH is any oxidizable organic or inorganic form: Accoriding to several authors (Morris, 1967, and Strand, 1972) this demand is virtually instantaneous, and because of its rapidity, takes precedence over the reactions of chlorine with nitrogenous species. Taras (Feben, 1950) has presented a method for determination of this'instantaneous demand'.

After satisfaction of this 'instantaneous demand,' the long-term reduction of hypochlorous acid and hypochlorite ion (free chlorine) by reducing agents is rather slow, and will be assumed to be negligible (a conservative assumption).

Group 3 reactions, those of ammonia and chlorine, are of the following types:

$$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^- \quad ....(4)$$

$$NH_3 + HOCL \rightarrow NH_2Cl + H_2O \quad ....(5)$$

$$NH_2Cl + HOCL \rightarrow NHCl_2 + H_2O \quad ....(6)$$

$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O \quad ......(7)$$

These reactions control the so-called 'breakpoint' phenomenon. Their rates and equlibria are controlled generally by the pH of the medium, and compete with the slower chlorine reduction reactions. Reaction rates for these reactions have been experimentally determined, primarily by Morris and several coworkers (Morris, 1967).

The ultraviolet-catalyzed reduction of hypochlorous acid and hypochlorite ion (Group 4) has been studied by Hancil and Smith (1971). These reactions

$$HOCl \rightarrow H^+ + Cl^- + 1/2\ O_2 \qquad (8)$$

$$OCL^- \rightarrow Cl^- + 1/2\ O_2 \qquad (9)$$

have rates dependent on the absorption of UV by hypochlorite. In the absence of UV, rates are much slower than with UV, but the reaction does occur. [In modeling the reactions of chlorine, this reduction is assumed to be the sole means of free chlorine reduction to chloride (Cl^-) after the immediate demand (Group 2)] Several routes have been proposed for reduction of chlorinated ammonia species (Group 5) as follows:

$$NH_2 + NHCl_2 + H_2O \rightarrow N_2 + 3\ HCl + H_2O \qquad (10)$$

$$NH_2Cl + NHCl_2 + HOCl \rightarrow N_2O + 4\ HCl \qquad (11)$$

$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O \qquad (12)$$

of these routes, the most probable pathway is dependent on initial chlorine: ammonia mole ratios, pH, and concentration (Morris, 1967). Little work has actually been done on determining rate data for these reactions, therefore, for this investigation, results of batch studies conducted at the Federal Water Quality Laboratory in Duluth, Minnesota, were used to approximate the reduction of chloramines with time.

3. Summary

Now considering the above reaction equations, the known facts of the fate of chlorine and chlorine by-products, the dilution effects of the river and even considering a very low decay coefficient it is evident that discharges in the river resulting from chlorination will have minimal effects.

C. TRANSPORT FACTORS EFFECTING ENVIRONMENTAL IMPACT OF DISCHARGES

1. Exposure Factors

The tidal flow is cyclic but due to the fresh water flow, the flow versus time behavior is not symmetric. The duration of flood flow is somewhat shorter than that of ebb flow. Therefore a water particle released at Indian Point at slack before flood will travel a certain distance upstream, turn back downstream at slack before ebb and in its downstream movement pass by Indian Point. The distance downstream from Indian Point where it again turns upstream at slack before flood is the net downstream movement which varies mainly as a function of the rate of fresh water flow. The net downstream movement may be estimated at about 1100 feet at a minimum fresh water flow of 1,800,000 gpm and 11,000 feet at a high spring flood dependent fresh water flow of 18,000,000 gpm (see Appendix N).

2. Tidal Effects

A constant release of a substance at Indian Point would produce the following, somewhat simplified, but pertinent, picture. Starting at slack before flood, accumulation would occur in an area outside the outfall. The "parcel" of substance-containing water would start moving upstream and mix with the flood flow. The continuously released substance would immediately be carried with the flow in the upstream direction, occupying an area mainly determined by the flow pattern of the river. At slack before ebb the original "parcel" would have been formed at Indian Point and at slack a new "parcel" would form at Indian Point. Thus three "parcels" would be moving upstream during the second tide cycle, two of which were seperated by the distance of the net downstream movement. At slack before ebb, the third "parcel" would miss Indian Point by this distance. Theoretically, after a number of tide cycles a "necklace" of "parcels", chained together by substance-containing water of varying concentration and with equidistant spacing equal to the net downstream movement would occur in the river.

3. Longitudinal and Lateral Dispersion

Longitudinal and lateral dispersion would tend to change the initial boudaries and reduce the concentration of the parcels, producing a more uniform distribution of the substance over the entire estuary. Likewise contaminents from other sources along the river would be dispersed evenly in the water column. Longitudinal dispersion in the Hudson River also varies with fresh water flow, distance along the river's axis, and densitiy gradients. The upstream movement of salt during periods of low flow increases dispersion effect in the Indian Point area, and smoothes the otherwise strong influence of river flow. Values of the dispersion coefficient used in the model are given in Appendix B. Details of the effect of dispersion on contaminant intensity are given in Appendixes A and M.

D. LONG TERM EFFECTS

The long term effects of pollutants are affected by:

1. Their precipitation from the water column
2. Reactions that tie up or alter the pollutant
3. Sorption reactions

These three basic events are broken down into seven basic types that chemical species experience in the aquatic environment (Stumm and Morgan, 1970). They are:

1. Acid-base reactions
2. Redox reactions
3. Complex formation
4. Colloid formation
5. Precipitant formation
6. Sorption
7. Biochemical reactions

1. Complexation

Three of these reactions result in stabilized products that can remain in solution or can undergo the reactions of the remaining two groups (Gucker and Seifert, 1966). These three reactions are:

a. Acid-base reactions - the neutralization of an acid with a base to yield a salt complex that is usually soluble.

b. Redox (oxidation-reduction) reactions - the transfer of electrons between species or within a species to yield a more stable state.

c. Complex formation - union of metal and an organic compound to form a ligand which is usually soluble.

The acid-base reactions are the dominant reaction of all aquatic environments. The carbon dioxide, carbonate buffer system (acid-base buffer system) is the chief factor influencing pH of most waters. This system neutralizes the effects of acids or bases that are introduced to the aquatic environment from natural and man-made sources. The product of this reaction is a salt complex that is usually soluble, but not as reactive as the original species.

By definition the buffer system is extremely immense, yielding only at the extreme ends of the pH scale. Therefore, it is able to withstand a tremendous influx of a dilute or weak acid or base without the overall pH changing significantly. Strong acids or bases would cause a pH change in the immediate area of discharge but with dispersion and diffusion, the conditions of neutrality would quickly be restored.

The redox, or oxidation-reduction reactions involve the transfer of electrons between species or within species to achieve a more stable state. As generally thought of, these are the reactions of degradation and are usually associated with the breakdown of complex chemical species to simpler species which may then be used for nutrient sources. Degradation reactions are generally oxidation reactions. This tends to bind some of the available oxygen in the water and at extreme conditions enough could be bound to lower the dissolved oxygen level below that necessary to sustain aerobic life forms; however, this would require a larger load of organics than are presently available in the river.

The reactions of the aquatic environment are pretty much a steady state phenomenon. However, the actual rates of the reactions are temperature dependent. Since the discharged water from the Con Edison facility is at a higher thermal energy state than the receiving waters, the actual effect of the thermal energy difference should be considered.

The thermal influence on chemical rate constants is a direct proportionality. For general first-order reactions (most all aquatic reactions follow first orders kinetics (Stumm and Morgan, 1970), the rate of reaction will double for each 10°C rise in temperature or conversely be halved with each 10°C drop in temperature (Gucker and Seifert, 1966). Therefore, the rate of decay of the thermal plume is important. If the plume remains at a substantially higher temperature for extended lengths of time then some increase in the rates of reaction could occur. But for all practical purposes this will have little influence on the total chemical structure of the aquatic ecosystem; for, at the temperatures that are relavent to the water column, i.e., a maximum of 35°C and a minimum of about 4°C, the overall rates of reaction are so slow that even this threefold increase in rates will be negligible, if temperatures increased to a value of something on the order of 100°C such that a tenfold increase could be noticed then an appreciable rate increase would have occurred. At the initial and final temperatures reached here the rates are at such a low level that the three fold increase should not be considered significant.

The only reaction that actually could be significantly affected at these temperatures would be that of the oxidation of the organic compounds by the decomposers which increases approximately 4% with each 1°C rise in temperature (Baars, 1968). This would allow a small acceleration in the degradation of organics and therefore a possible decrease in the dissolved oxygen levels. However, due to the tremendous flow of the river and the dispersion factors exemplified by the thermal models (see Appendixes J, K, L, M) the actual thermal energy of the water column decays rapidly, and within a very short time the temperature has returned to within a few degrees of the ambient, e.g. within about 2°C of ambient.

2. Sedimentation

The second group of reactions result in products that remove reactants from the water column (Stumm and Morgan, 1970). These are the reations that form:

a. Precipitates - the formation of insoluble compounds that settle out

b. Colloids - the formation of stable products of an extremely small size that usually do not settle out

The formation of a precipitate usually implies a complex that has a very low solubility and therefore settles out readily and thus removes its constituents from the water column.

Colloids are like precipitates except they are particles of such small size that their weight does not permit settlement. The Brownian motion of the water molecules keeps them suspended. They do, however, eventually settle out as they are sorbed on the surface of and undergo co-precipitation with other particles.

Co-precipitation involves the trapping or a coalescence of another particle or species in a precipitating complex and subsequently removing it from the water column. Some of the species in (a) above and some of the complexes generated in (a) also undergo co-precipitation and are therefore settled out and become part of the bottom strata.

Precipitation is actually affected little by temperature. As mentioned above, reaction rates increase at elevated temperatures and likewise rates of precipitation increase. As temperature increases the density of water decreases giving a larger differential density between precipitate and water.

3. Assimilation/Sorption

The third type of reaction involves the interaction of the solvated species with a solid. These are sorption reactions (Stumm and Morgan, 1970) and are two general types:

- Inorganic - the interaction of a solute with a solid such as an ion being sorbed to a clay particle
- Biochemical - micro organisms act as sorption sites

a. Inorganic

Inorganic sorption reactions involve the absorption of chemical species or complexes onto active sites of particulate matter. Suspended clay particles are the chief constituents of these sorption reactions. Once sorbed, the sorbed species are essentially removed from further reactions in the water column. Thermal factors affect sorption reactions very little, if at all, at temperatures experienced in the normal water column.

b. Biochemical

In biochemical sorption reactions organisms act as the sorption site with bacteria, algae, and fungi being the principle constituents involved. However, filter feeders and some larger plants tend to concentrate certain ions in their systems (Bowen, 1966; Vinagradou).

The diversity of the biota in accumulating elements from the environment is indicated diagramatically in Table XIV, where reported notable accumulations are listed. In general, it is clear that algae and plants accumulate very many of the trace metals; and within the animal groups, filter feeders (sponges, ascidians and lamellibranch molluscs) are the prime concentrators (Brooks, 1965; Hamwi and Hasken, 1969; Polikarpo, 1966; Pringle, et. al., 1968; Vinagradou). Some exceptions can be seen, for instance the accumulation of iron and iodine in vertebrates where these elements perform a specific physiological function, and of arsenic in some crustaceans. In the lower Hudson River the most effective accumulators of metals seem likely to be the aquatic plants or phytoplankton, the lamellibranch molluscs, and perhaps shrimps and prawns.

Identification of the possible paths of entry into the biota is important when considerating the dynamic aspects of an accumulating system.

TABLE XIV.

NOTABLE AQUATIC ACCUMULATORS OF TRACE ELEMENTS

Element	Marine		Freshwater		Plankton		Sponges	Coelenterates	Crustacea	Mollusca Lamellibr.	Ascidians	Vertebrates
	algae	plants	algae	plants	Phyto-	Zoo-						
Aluminum		X			X							
Arsenic	X	X	X					X	X	X		
Cadmium	X								X	X		
Chromium		X									X	
Cobalt	X		X									
Copper		X			X	X	X		X	X		
Iodine	X				X		X	X			X (tunic)	X
Iron	X	X	X		X		X	X		X	X	X
Manganese	X	X	X	X	X		X		X	X	X	X
Nickel										X		
Niobium										X	X	
Silver										X		
Tin	X						X					
Titanium	X		X		X		X		X		X	
Vanadium											X	
Zinc	X	X			X			X		X		X

Allenby, 1969; Bowen, 1966; Brooks, 1965; Pickering, 1968; Powers & Robertson, 1966; Schmidt, 1971; Schroeder, 1962a, 1962b, 1963a, 1963b, 1964, 1966a, 1966b, 1966c; USPHS, 1965.

There appears to be a variety of ways in which the biota can accumulate trace metals.

- Direct absorption from the environment. This is regarded by some (Polikarpov, 1966) as the most important route for aquatic organisms, minimizing the role of accumulation by other routes, or alteration by physiological processes.
- Ingestion of living or non-living particulates suspended in the ambient medium
- Ingestion of preconcentrated elements in specific food materials
- Complexing of metals by coordinate linkage with organic molecules; this may be physiological (as in blood pigments) or physical (on to mucus sheets or body surface materials).

If the first pathway is the predominant one, then it can be expected that an organism would directly reflect the concentration levels of a contaminating pollutant in the medium. Although this has been claimed as the primary route of accumulation, the predominace of the "filter feeders" among accumulating animals suggests that this approach is more valid for aquatic plants and phytoplankton than it is for animals.

The second route appears to be the most predominant for trace metal accumulation in aquatic animals, since most of the obvious accumulators feed more or less continually on suspended particulate material which is consumed (though perhaps not digested) in a relatively unselective way. There is considerable variation, even within a single group of similar species, in the degree of accumulation; and of course, it will vary with the feeding rate. For instance, oysters appear to accumulate zinc much more efficiently than clams, but the soft shell clam is a better accumulator of iron (Powers and Robertson, 1966); the New Zealand scallop accumulates cadmium more efficiently than oysters or mussels. How variation reflects different metabolic rates, different filtering surface areas or efficiencies, or different environmental backgrounds of the individual species does not seem to have been explored adequately. The relation of the pumping rate of bivalves (and presumably of other filter feeders such as sponges or tunicates) to oxygen consumption demonstrates that accumulation factors obtained without reference to temperature and metabolic rate are of doubtful significance (Hamwi and Hasken, 1969).

The third route of accumulation, via concentrators in the food chain, is represented dramatically by the accumulation of pesticide residues (Biglane, 1967; Brown, 1968; Schmidt, 1971). This route is predominant in terrestrial organisms, but it is also demonstrated in the aquatic environment. In addition to pesticides, it can be exemplified in the accumulation of iron and iodine in mammals and zinc in fishes, however, no studies have as yet been performed on a wide variety of organisms in the Hudson River to determine what if any, the major concentrators are.

The final route of accumulation, that of the complexing of materials either physiologically (internally) or on external surfaces, may be important, especially for aquatic plants, diatoms or for mucus producing animals. It seems possible that some of the manganese sequestered by plants from the ambient water, may be accumulated, apparently irreversibly, in this way (Allenby, 1969).

c. Thermal Influence

Thermal influences of the assimilation of chemicals is related to the increase or decrease in metabolic activities of the aquatic organisms. The amount of dissolved oxygen available also affects the activity of the poikilothermic organisms, the sensitivity of certain organisms to metal poisoning increases as dissolved oxygen decreases (Pickering, 1968). As metabolic rates increase the demand for oxygen increases and therefore more water is pumped to obtain it. A side effect of this increased pumping is the rate at which pollutants pass through or come into contact with the organism.

If the thermal delta over ambient does not cause lower dissolved oxygen levels, due to either the decrease in solubility of the gas at elevated temperatures or depletions due to degradation of organic loads, then the poikilotherms will experience contact with a larger amount of pollutants than normal. If the thermal delta alone affects the organism, then a slight increase in metabolic rate will occur. If, however, both the dissolved oxygen level and the thermal level have an effect then the organism may experience some stress and metabolic rates would increase significantly, pumping rates would increase and contact with the chemicals would also increase.

There is some drop of dissolved oxygen across the plant but not a value that can be related directly to thermal degassing (Quirk, Lawler & Matusky Engineer's, 1972). Therefore, the possibilities of lowered dissolved oxygen values due to thermal influence of the Indian Point discharge are minimal. Consequently, the chief influence on the poikilotherms is thermal.

The work of Renwoldt (1972) shows that increased toxicity due to thermal influence of background metals in the river is minimal. This study indicated that an increase in water temperature from 15°C to 28°C does not increase the mortality rate of fish exposed to copper, zinc, nickel, cadmium, or chromium, but does slightly increase the mortality rate of fish exposed to mercury.

4. Percent of Resources to be Affected

Some 11% of the total flow of the Hudson River passes in front of the Indian Point plant and into this flow is discharged the chemical effluents. At the confluence of the effluents with the river the concentration will be extremely small (see Table V). Comparing, for example, the yearly average chromium values (see Table XV) with the quantities to be discharged, the concentrations to be released to 100,000 gpm flow would be 0.015% for the minimal value of 1962 or 0.0015% for the maximum value of 1965.

Based on the results of the model studies (Appendix N) small water masses develop in the river at each of the tidal cycles that contain a large portion of the thermal energy and the chemical discharges. These water masses are transported down the river the distance of the net flow some 1100 feet at a minimum fresh water flow of 1,800,000 gpm and 11,000 feet at a spring flow of 18,000,000 gpm. The water masses then diffuse into the surrounding waters until they no longer exist due to dispersion and dilution. At this point in time the models predict (Appendixes A and B) that the concentrations of effluent will be part of the background of the river. However, at the point of discharge, the concentrations are real entities and will be dispersed first of all in the flow right in front of the plant and then to the remainder of the river with time. The fact that

TABLE XV

TRACE METALS OF HUDSON RIVER AT POUGHKEEPSIE, N.Y.

		ppb									
Mile	Year	Iron	Manganese	Zinc	Copper	Cadmium	Chromium	Nickel	Lead	Arsenic	Silver
70	1962	154.0	0.8	75.0	20.0	2.0	2.0	2.0	15.0	15.0	0.3
--	1963	63.0	3.6	47.0	10.0	1.0	6.0	1.0	3.0	10.0	0.3
--	1964	7.7	1.3	53.5	7.0	9.5	5.5	5.0	10.0	32.0	0.8
--	1965	58.5	2.8	34.0	13.0	16.0	20.0	12.0	23.0	50.0	1.2
--	1966	14.0	4.5	60.3	12.3	8.3	7.0	8.3	18.3	48.6	0.8
--	1967	7.0	2.6	8.0	72.0	5.0	3.0	5.0	10.0	26.0	0.5
--	1968	15.0	2.5	23.0	48.0	5.0	4.0	5.0	10.0	40.0	0.5
--	1969	37.6	2.8	46.2	20.6	8.0	7.9	6.6	14.4	36.4	0.7

United States Federal Water Pollution Control Administration, Storet retrieval data.

the effluent is discharged primarily into the 11% of the river flow right in front of the plant, to be further diluted eventually by the 80,000,000 gpm tidal flow, and therefore the actual percentage of the river that experiences the high concentrations of chemicals is small.

V. CONCLUSIONS ON THE BIOLOGICAL EFFECTS OF CHEMICAL DISCHARGES

A. CONCENTRATIONS

The final concentrations at confluence with the river using 100,000 gpm criteria will give concentrations that will fall below the concentrations Con Edison sets as its maximum discharge limits under normal operating conditions (Table I). As stated before the service water flow is 98,000 gpm with the plant operating at any percentage of capacity, the dilution factor will increase and therefore concentration will decrease further. At 50% of cooling water flow there will be an additional 4.3:1 dilution factor, at 100% normal operation the dilution factor becomes 8.7:1 which yields concentrations of contaminants that are of minute significance (Table V). There is then further dilution due to dispersion from river and tidal flow.

Since the chemicals used in the operation of the plant are noncumulative, a small but constant concentration could be endured by the organisms. If the concentrations are significantly below the TLm values (as they are during normal operation) then the actual conditions and length of exposure should be of little consequence.

During evaporator failure or refueling, if an extreme concentration of potential pollutant were released, it is doubtful that discharge values to the river would exceed to any appreciable extent the values shown in Tables I and V, since these values were actually determined for maximum conditions. If, however, something did occur and these limits were exceeded, dispersion of the contaminant would follow the modeled criteria of Appendix A. There would be a cushion of 80,000,000 gpm of tidal water to absorb and/or dilute this extreme discharge and therefore a one time point discharge would have little overall general effect on the water quality of the estuary.

Another point of consideration is the actual fate of chemicals discharged into the river by the other 4 power plants in the Indian Point region for although these plants are fossil fueled, the actual released chemicals are very similar to those of Indian Point. The actual residency and/or fate of these substances in the water column are essentially unknown but if the contaminants undergo chemical reactions especially inorganic sorption reactions then perhaps a great portion of them are actually removed from the water. If this removal action does not take place then perhaps an accumulation of these chemicals occurs but in all likelihood this would represent an exception to the usually occurring phenomena of aquatic systems.

B. TOXICITY

Comparing the proposed discharge limits with the results of the bioassay studies it can be seen that the actual release concentrations under normal operating conditions will be below the 1/10 TLm values. At these concentrations the toxicity of any of the components should be very minimal.

The Renwoldt studies (1972) proved that the thermal effects of the power plant discharge have little to no effect on the toxicity of metals in the river. The same report also finds that the concentrations of the metals investigated required to produce 50% mortality within 96 hours are very much higher than concentrations actually found in the Hudson River. It can be concluded that thermal discharges from power plants have no practical effects on the toxicity of metal ions to fish for the concentrations actually found in the Hudson River.

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The Biological Effects of Entrainment

at Indian Point

Consolidated Edison Company of New York, Incorporated

New York

April, 1973

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ABSTRACT

Entrainment through Indian Point Unit 3, whether operating singly or in conjunction with Units 1 and 2, will result in limited moralities of certain species as a function of their tolerances to abrupt pressure changes, mechanical abrasion, temperature and chlorine. Little or no morality due to entrainment could be expected during four months of the year when temperatures are low, because temperature tolerances of organisms are not exceeded by the discharge temperature, no chlorination occurs, and most species of pressure-abrasion sensitive fish larvae are absent from the ecosystem. Temperatures in excess of the tolerance limits will result in limited mortalities of some species entrained during three of the remaining eight months, and only the effects of chlorination, pressure and mechanical abrasion would be experienced during the other five months.

Only 2.5% of the tidal flow passing Indian Point is entrained. This fact, combined with distributional patterns of the fauna indicates that percentages of a total population which might be entrained will be quite low. The total effect of entrainment at Indian Point Unit 3 then becomes the product of low percentages of total populations entrained and limited mortalities to certain species during portions of the year.

From this, it seems reasonable to conclude that no irreversible damage to the Hudson River ecosystem will result from the operation of Indian Point Unit 3 either alone or in conjunction with Units 1 and 2 in the duration of the current environmental studies which are scheduled for completion in 1977.

INTRODUCTION

The entrainment of aquatic organisms in once through cooling processes has been considered as a potential source of modification to the aquatic ecosystem from which the water is drawn. This report is directed toward the evaluation of entrainment effects resulting from normal operation of Indian Point Unit 3, both alone and in conjunction with Units 1 and 2. Account is also taken of the combined effects of all power plants expected to be in operation on the river in 1975. This report will discuss the types of organisms subject to entrainment by the plant and the effects of such entrainment, both short and long term, on individual organisms, populations and the ecosystem. The projections are based on latest available data and the current state of the art in evaluating data. Study programs under way at Indian Point for purposes of validation of these projections are outlined.

Climatic Conditions at Indian Point

The daily water temperature regime at Indian Point ranges from 32± F during winter, to 78-79± F during summer in an average year. These extremes occur primarily during the late winter months (January through early March) when the river is intermittently covered with ice and at the end of summer, usually August (Figure 1). Salinity at Indian Point varied from essentially fresh to 9 0/00 saline during 1969 and 1970 as a function of freshwater runoff. Normal saline values may be expected to be very low during the spring when melting ice and snow add significantly to available freshwater, and to increase through the summer when freshwater input is reduced (Figure 2). Precipitation produces periodic lowering of salinity at Indian Point throughout the summer and a general decrease during fall and winter. With the advent of sub-freezing temperatures in the late winter, freshwater flows decline and a second high salinity period follows until dispelled by spring thaws.

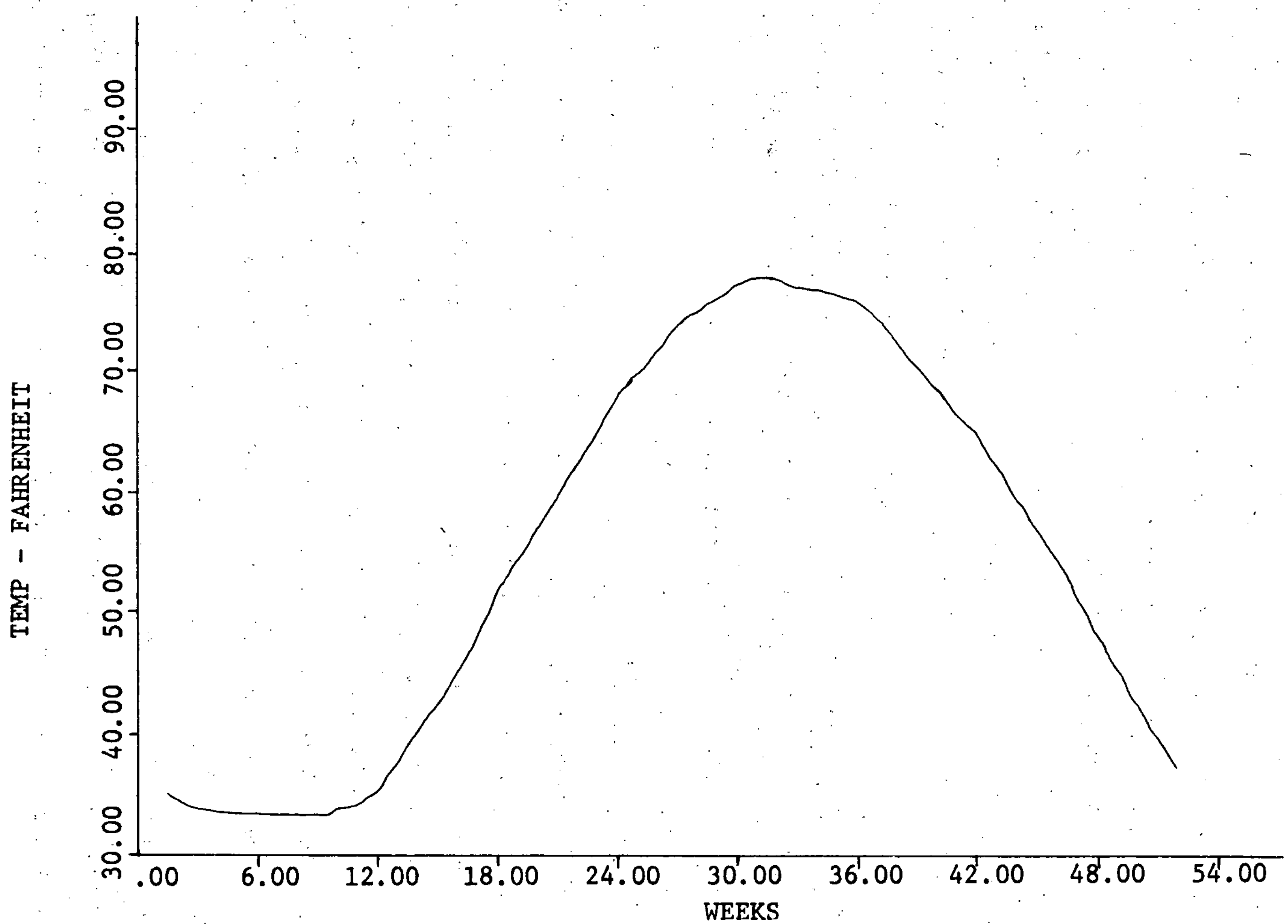

Figure 1: Mean water temperature regime at Indian Point: calculated from U.S. Geological Survey data for Peekskill, 1959-1969.

Indian Point Facility

The Indian Point nuclear power stations is designed to utilize Hudson River Water in once-through condenser cooling. The facility is composed of three reactors with a combined generating capacity of 2103 MW(e). Unit 1, which was initially placed in operation in October of 1962, uses 318,000 gallons of cooling water per minute at maximum flow. Operating a full cooling water flow, Units 2 and 3 will require 870,000 gpm each for a maximum operational demand of 2,058,000 gpm (4586 cfs). Water will be removed from the Hudson at Indian Point, passed through the facility and returned to the river channel through submerged effluent ports at a distance between 700 and 1400 feet downriver (Figure 3).

Total elasped time from intake to release from Unit 3 operating alone is estimated at 8.71 minutes at full operational flow and 14.52 minutes at reduced flow (60%). Total elapsed time from intake to discharge for Unit 3 with Units 1 and 2 also in operation is estimated at 5.91 minutes at full operational flow and 9.84 minutes at reduced flow (60%). Figure 4 shows the ΔT/time relationship for Unit 3 at full and reduced flow, with and without Units 1 and 2 in operation. Entrainment times and temperature change encountered in each of the three units operating individually and in combination at full and reduced flow are given in Table 1.

The exact degree of temperature elevation is dependent upon rate of flow and amount of recirculation occuring at any given time. The average water temperatures encountered at the confluence of the discharge canal with the river are expected to vary between $55.8^{o}F$ in winter (32^{o} ambient plus ΔT of 23.8^{o}) and 92.5^{o} in summer (77.5^{o} ambient plus ΔT of 15^{o}).

Operational plans for Units 1, and 2 and 3 propose a reduction in rate of flow from approximately November through March of each year as a means of reducing

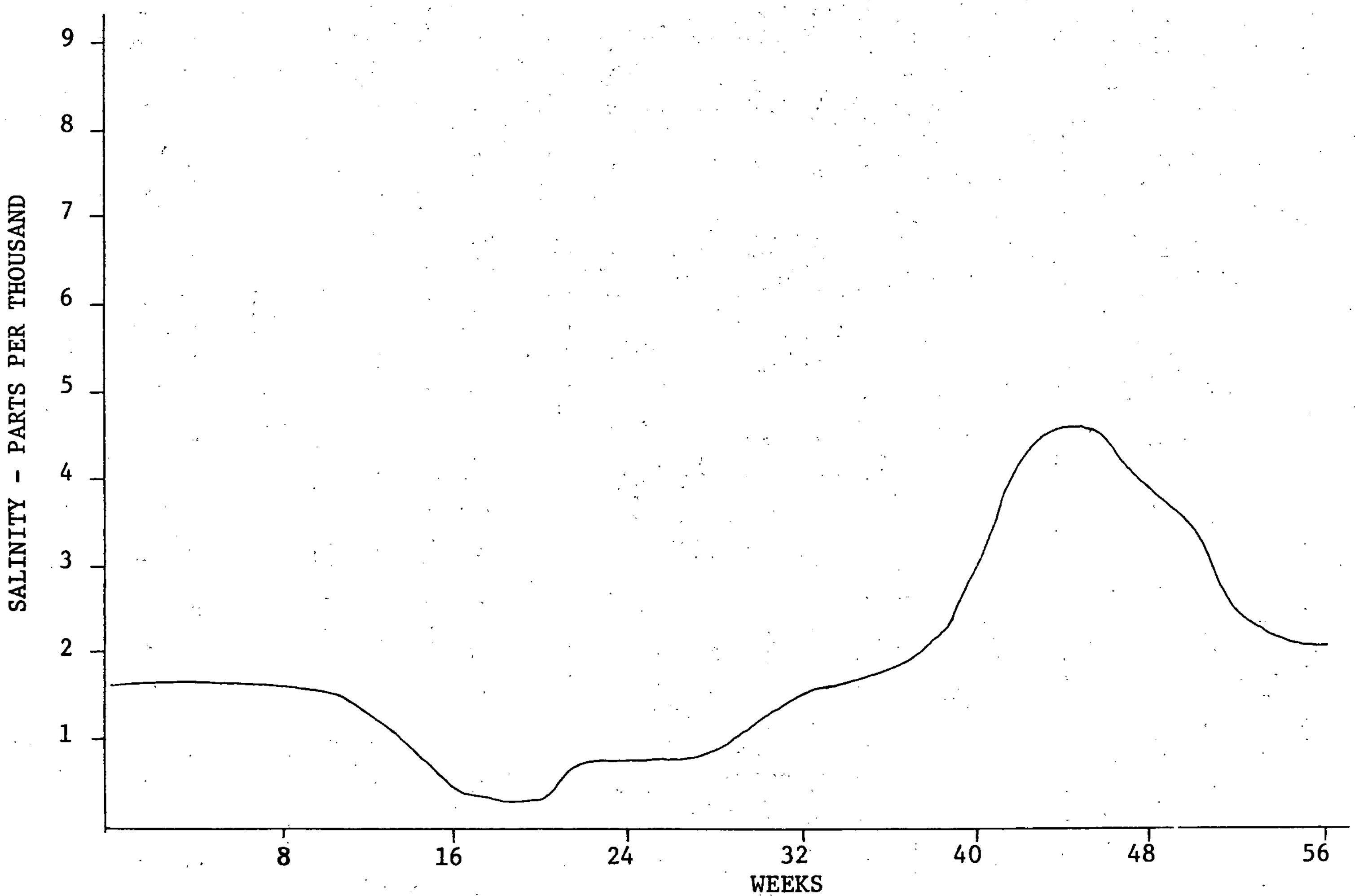

Figure 2. Indian Point salinity regime. Calculated from U. S. Geological Survey data for Peekskill 1966-1969.

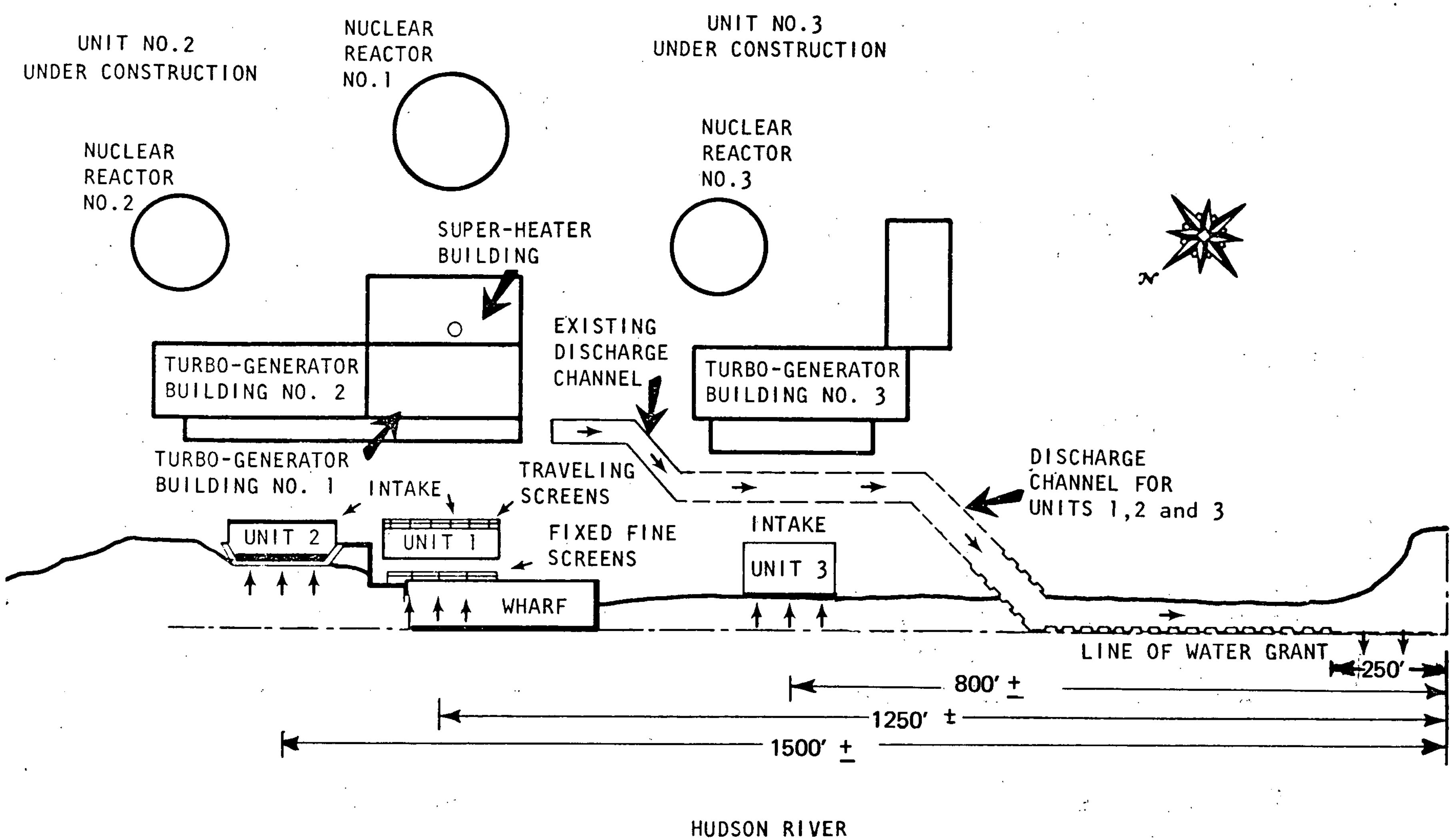

Figure 3. Schematic diagram of Indian Point nuclear facility.

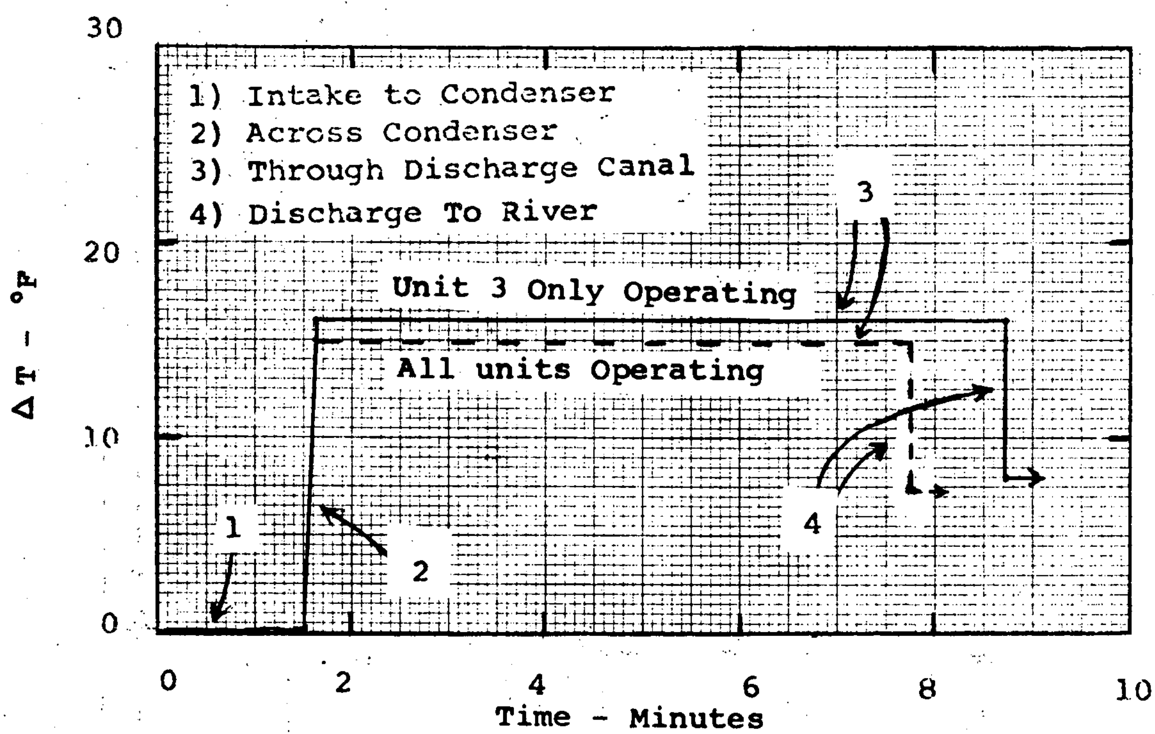

Figure 4a. ΔT vs. Time for Unit 3 at Full Flow.

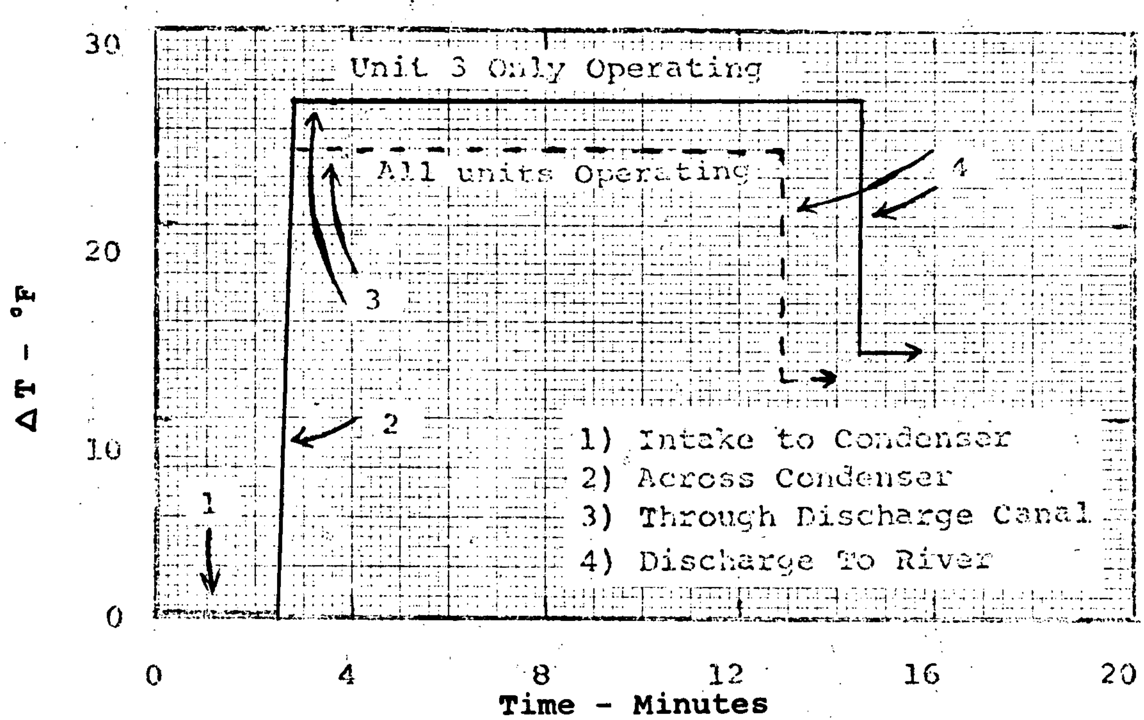

Figure 4b. ΔT vs. Time for Unit 3 at Reduced Flow (60%).

		TIME - MINUTES						
		INDIVUDUAL UNITS- Single Operation			INDIVIDUAL UNITS- Simultaneous Operation			
	FULL FLOW	1	2	3	1	2	3	MEAN
TIME - MINUTES	INTAKE TO CONDENSER	1.16	1.52	1.52	1.16	1.52	1.52	1.51
	CONDENSER TRANSIT	0.08	0.14	0.14	0.08	0.14	0.14	0.13
	CONDENSER TO EFFLUENT	32.08	13.52	7.05	6.12	7.90	4.25	6.07
	TOTAL	33.32	15.17	8.71	7.36	9.55	5.91	7.71
ΔT- °F	CONDENSER RISE	12.6°	14.9°	16.3°	12.6	14.9	16.3	15.1°
	CONDENSER + SERVICE WATER	12.0°	14.6	16.0				14.8°
	REDUCED FLOW							
TIME - MINUTES	INTAKE TO CONDENSER	1.93	2.53	2.53	1.93	2.53	2.53	2.52
	CONDENSER TRANSIT	0.14	0.23	0.23	0.14	0.23	0.23	0.22
	CONDENSER TO EFFLUENT	53.47	22.53	11.75	10.18	13.17	7.08	10.12
	TOTAL	55.54	25.30	14.52	12.25	15.93	9.84	12.86
ΔT- °F	CONDENSER RISE	21.0°	24.8°	27.1°	21.0	24.8	27.1	25.2°
	CONDENSER + SERVICE WATER	18.6°	23.8°	26.5°				23.8°

Table 1. Average transit times and T for cooling water during full and reduced (60%) flow operation of Indian Point Units 1, 2 and 3 operating alone and together.

impingement mortalities on the intake screens. An overall ΔT value of approximately 23-28° F and exposure of 20-25 minutes is anticipated during this operating mode.

Chlorination of the main condenser is accomplished with sodium hypochlorite, with only one-half of a single condenser chlorinated at any given time. The water from the chlorinated and unchlorinated sections mixes within seconds after leaving the condenser, resulting in at least 1:1 dilution. Total dilution in the cooling system may be as high as 11.94 parts unchlorinated water to one part chlorinated dependent upon the combination of units in operation at the time (Table 2). Free chlorine residual is dissipated quickly as a result of the chlorine demand of the river water, vaporization and exposure to sunlight. Discharge concentrations to the river are usually 0.1 ppm or less. The overall time chlorine is added to each condenser is one hour. This procedure, performed in daylight hours, is repeated on alternate days for a maximum of three times per week.

The frequency at which chlorine will be employed will be determined by ambient river water temperature. It is expected that when river water temperatures are below 45°F (winter) no chlorination will occur. Further reductions to twice weekly chlorination during spring and fall may also be possible provided heat transfer rates in the condensers are not impaired by this action. Thus, chlorine would be employed approximately 8 months/year and approximately 5 months of this period it may occur only twice weekly. Table 2 shows the chlorination schedule employed at Indian Point Unit 1 during 1972.

A. 1972 chlorination schedule at Indian Point Unit 1

SCHEDULE

Time Period	Chlorination Cycles/week
Jan. 1 - Apr. 15	0
Apr. 16 - Jun. 30	2
Jul. 1 - Sep. 30	3
Oct. 1 - Dec. 15	2
Dec. 16 - Dec. 31	0

B. Dilution experienced upon leaving condensers at Indian Point.

DILUTION

Combination of Units on Flow	Unit Experiencing Chlorination	Ratio Chlorinated/ Unchlorinated
Single Unit		1:1
Units 1 & 2	Unit 1	1:6.47
or 1 & 3	Unit 2 or 3	1:1.73
Units 2 & 3	Either	1:3
All Units	Unit 1	1:11.94
	Units 2 or 3	1:3.73

Table 2

LITERATURE REVIEW

The entrainment of aquatic organisms in cooling water may be expected to affect all varieties of minute holoplankton, both animal and plant, and the eggs and larvae of fish and invertebrates. Its effect may, however, be beneficial, detrimental or negligible dependent upon the extent and severity of its application, the species involved, and the proportion of any population entrained. Thus, all trophic levels within the Indian Point ecosystem are subject to its effects in varying degrees.

Primary Producers

Studies of the effects of entrainment upon planktonic forms from the Indian Point area under winter conditions evaluated survival of phytoplankton following entrainment in the condensers of Unit 1 of the nuclear facility (N. Y. U., 1971). The results indicate that exposure to thermal shock in the proposed operational range at Indian Point has no recognizable effect upon the organisms tested. Tests of physical damage due to entrainment indicated no difference between intake or effluent samples. These studies have been supplemented by temperature tolerance and survival data for the summer months (Lauer, 1972). The results confirm those from the previous study.

Measurements of C^{14} uptake by mixed phytoplankton populations collected from both intake and effluent areas at Indian Point by N. Y. U. (Lauer, 1972) indicate that photosynthetic rate is stimulated by brief exposure to elevated temperatures up to 88° F. Above this temperature, results become variable with a tendency toward inhibition of photosynthesis increasing as temperature increases (Table 3). Similar results have been reported by Morgan and Stross (1969) and Warinner and Brehmer (1966). While such an inhibition may be indicative of damage to the organisms involved, Savage (1969) reports it is generally reversible if temperature increase experienced was not too extreme.

Attempts to measure changes in phytoplankton populations have indicated no neasurable change in the vicinity of Indian Point during the period of operation of Unit 1 (Lauer, 1972). Similar results have been reported for the Patuxent River estuary (Flemer, et. al., 1970).

Decomposers

Research conducted by New York University Medical Center's Laboratory of Environmental Studies (1971) has shown no adverse affects to the decomposer level of the ecosystem due to passage through the condensers at Indian Point. Water samples were collected at both the intake and effluent portals of the Indian Point plant and cultured according to Public Health Service procedures. Total coliform colonies and total colonies were counted. The results of tests conducted under winter conditions indicate no chage at ΔT values comparable to the maximum operational increase at Indian Point and only slight reductions in numbers until ΔT reached 80° F. Additional research conducted during the following summer (Lauer, 1972), produced similar results and indicated that no discernable deterioration of the bacterial population occurs until a maximum temperature of 104° F - 106° F (ΔT 30° F + 74° F - 76° F ambient) was applied for periods of 15 minutes or longer. Maximum temperatures of 94° F - 96° F for exposure times up to 45 minutes caused no adverse effects. Studies of ATP concentrations indicate that bacterial populations do undergo adverse effects during chlorination. However, because of the low frequency of chlorination to be used at Indian Point no adverse effect is expected upon the total bacterial population in the Indian Point area.

Consumers

The consumer level of the trophic system at Indian Point is rich and varied. It includes representatives of most of the invertebrate phyla, many fish, and the larvae of both groups. Data from Lauer (1972), Beer (1969) and Nauman and Cory (1969) indicate that little or no detriment to plankton, species composition, or fish populations occurs as a result of use of natural waters for cooling. Due to the diversity of

Date	Ambient Temp.	Temperature °F WB	D1	D2	Plume1	Plume2	Elevated Temperature only, % change in ^{14}C uptake compared to Intake WB	D1	D2	Plume1	Plume2	Elevated Temperature plus chlorine, % change in ^{14}C uptake compared to Intake WB	D1	D2	Plume1	Plume2	Total Chlorine Residual (ppm) WB	D1	D2	Plume1	Plume2
							1972														
1/11*	36	56	43				+13					-100	-66				.8	.1	.1		
5/24*	59	68	68	68				+34	+38			-100	-92	-99			.6	.1	.1		
5/30*	63	70	68	68				+59	+15			-89	-87	-92			.6	.1	.1		
6/5*	66	77	77	77				+21	+37			+2	+9	+7			.6	<.1	<.1		
6/6*	68	78	78	78				+15	+13			+26	+28	+5			.5	<.1	<.1		
6/15*	68	75	73	73								-70	+2	-64			.7	.1	.1		
6/20*	69	69	69	69								-51	-50	-37			.3	<.1	<.1		
6/29*	68	68	68	68								-54	-61	-100			.15	<.1	<.1		
7/10*	71	76	76	76								-24	-55	+11			.6	.1	.1		
7/20	76	87	86	86			+19	+65	+31												
8/1	78	93	92	91			-7	-59	-53			-79	-39	-100			.45[1]	.21[1]	.13[1]		
8/3	78	88	88	88			+53					-69	-76	-58			.35	.12			
8/8	78	85	88	85			+11	+1	+16			-74		-30			.3	.09	.075		
8/10	76	90	90	90	84	82	-11	-3	-11	+6		-66	-48	-25	+45	-53	.24	.08	.045	0	0
8/15	76	91	88	88			-16	-30	-10			-64	-51	-21			.28	.1	.07		
8/17	76	92	91	91			+61	+52	+51			-93	-55	-42			.2	.06	.09		
8/29	77	89	88	88			-35	+17	-32												
	77	93	91	91			+47					-98	-76	-42			.22	.08	.11		
9/5	78	93	92				+9	+23													
	78	93	93	92	85	80						-82	-100	+16	-13	-15	.26	.12	.01	0	0
9/12	75	89	86	86	80	78	-15	+23	-5	+26	+19										
	75	88	81	81	80	78						-100	-65	-16	-2	-20	.23	.06	.11	0	0

Table 3. C^{14} uptake following entrainment at Indian Point. From: Lauer, 1972

of this trophic assemblage, effects upon specific representatives will be treated in the Thermal Tolerance and Discussion sections of this report.

Thermal Tolerance

Thermal tolerance limits have been compiled in tabular forms to facilitate examination*. They have been arranged to show species, acclimation temperature, test temperature, exposure time, percentage of survival and the literature cited. The data indicate that within the temperate zone, little or no mortality occurs below 85°F regardless of the organisms considered. This hypothesis is supported in the literature by several authors. Coutant (1962) reports that normal population structures of freshwater invertebrates are maintained up to 89.6°F, but that losses of numbers and diversity occur above this temperature.

Mihursky, McErlean and Kennedy (1970) have developed a thermal predictive model for estuarine systems which is based upon summer temperature conditions and general, prolonged temperature elevations within the ecosystem. This model proposes that in temperate estuarine systems with temperatures as high as 80° F, all species are within their optimal temperature range and subject to little or no thermal stress. Approximately 10 percent of the species present could be expected to be subjected to stress at 85° F but only one percent might be expected to be unable to tolerate the modified conditions. With an increase to 90° F, stress conditions would be extended over approximate 70 percent of the species present. Exclusion from the ecosystem would approximate 10 percent. Beyond this point, approximately 70 percent of the species normally found in the area might be lost. This model which is based upon prolonged temperature elevations, while useful as an index of the degree of stress experienced by an ecosystem, cannot be considered as totally applicable to the effects of entrainment at Indian Point, where temperature elevations are of very short duration followed by a return to ambient conditions.

*Appendix 1 of this report

Mechanical Effects

In a paper describing survival of larval fish (clupeids), Marly (1971) reported 100% mortality following passage through the Connecticut Yankee nuclear power plant. Additional research reported at Johns Hopkins Entrainment and Impingement Workshop (February 5 - 12, 1973) indicated that 80% of this mortality was the result of mechanical damage and 20% resulted from temperature shock. This study involved maximum temperatures of 105.8° F, ΔT's of 22.5° F and retention time of 93 seconds in the condensers and up to 100 minutes in the discharge coral.

In testimony before the AEC, Lauer (1973) stated that only occasional mangled larvae were observed from either intake or discharge samples at Indian Point during experiments with entrainment without added heat. This was attributed to collection damage. The average concentration of larvae per unit volume of water filtered did not differ significantly in pooled intake or discharge samples. He also reported that survival of larvae at the discharges differed 7 to 30% from those collected at the intakes. While these values indicated that some larvae are killed by mechanical effects experienced during entrainment at Indian Point, the effects are considerably lower than the 80% reported by Marcy.

Chlorination

The use of chlorine to prevent fouling of condenser tubes can be a potential hazard to entrained organisms. The specific effects of chlorination at Indian Point have been investigated by N.Y.U. (Lauer, 1972). Phytoplankton samples collected at the condenser outfall during chlorination consistently showed inhibition of C^{14} uptake (Table 3). The inhibition is reported to decrease, however, as initial concentrations decrease following dilution in the effluent canal.

Micro and macro-invertebrate plankton exposed to chlorination at Indian Point exhibited mean survival rates of 32% to 98% (Lauer, 1972). Hirayama and Hirano (1970) have shown that ten minute exposures to levels of approximately 1.0 ppm were not 100% lethal to cultures of Chlamydomonas sp., and the cultures were able to reproduce within three days following the treatment. Exposures of five minutes at 1.0 ppm yielded similar results with reproduction during the first day following treatment. Similar experiments indicated that Skeletonema costatus cultures were able to reproduce after 20 days and three days following the same treatments. While these results indicate considerable variation in tolerance to chlorine, they also clearly show that the detrimental effect is a function of duration of exposure.

Sub-lethal Temperatures

It has been reported that the entrainment of organisms in cooling water at sub-lethal temperatures may result in side effects which are deleterious. Coutant (1970) explains that heat death in poikilotherms follows a predictable sequence which progresses from loss of equilibrium to coma and finally death. Insipient lethal temperature (TLm), in its usual connotation, is taken as that temperature at which 50 percent of a population would be killed by prolonged exposure to a given temperature. The early responses of organisms to a temperature at this level could then be expected to be those of the early stages of heat death and might be expected to render those individuals affected more susceptible to both pathogens (Mihursky, McErlean and Kennedy, 1970) and predators.

Coutant (1972) has proposed on the basis of reported temperature responses of various organisms that a reduction in temperature of 2° C (3.6° F) below upper critical limits for a particular species is sufficient to insure total survival. He further reports that 80 to 85% reduction in exposure time has moderating effects equivalent to a temperature reduction of 2° C. Thus, the appearance of sub-lethal conditions could be expected only at levels of temperature equal to or less than 2° C below the TLm of a particular species.

Species Composition

Species composition shift within an area subjected to thermal stress from heated effluents is a major consideration in the evaluation of overall effects of entrainment or thermal discharge. Several authors have reported that species composition was not affected at or near the effluent canals of power generating stations. Flemer, et. al. (1970) reported no measurable effects of either heat or chlorination upon entrained organisms in open river conditions near a generating station. Similar results have been published (Beer, 1969; Templeton and Coutant, 1970; Naumann and Cory, 1969; Philbin and Phillipp, 1970), indicating little or no effect on relative abundance or species composition of benthic organisms, plankton, epifauna or salmonids as a result of entrainment or heated effluents. Earlier appearances of spring blooms (Foerster, 1969) and shifts to dominance of warm tolerant forms (Kinne, 1963) have been reported at specific locations, however.

Lauer (1973) has concluded on the basis of research conducted at Indian Point that no significant changes in species composition or populations can be expected for bacteria, phytoplankton, or zooplankton in the Hudson River as a result of the operation of Indian Point Units 1 and 2.

Entrainment Modeling

Entrainment models have been developed by the Hudson River Fishermen's Association, the U.S. Atomic Energy Commission and the firm of Quirk, Lawler and Matusky Engineers. Past examination of the Hudson River Fishermen's Associations' model has shown it to be inadequate to describe the complex interrelationship between the Indian Point plant, the striped bass population and the rest of the ecosystem.

The U.S. Atomic Energy Commission presents a mathematical model for probability of entrainment at Indian Point Units 1 and 2 in their Final Environmental Statement for Indian Point 2 (1972). The calculations yield mean entrainment mortality probabilities of 17% based on average annual flow rates and projects 30% extreme annual probability and 45% extreme monthly probability. These figures are based upon the following assumptions: 1) random distribution of all entrainable organisms; 2) no effect of diurnal migrations; 3) larvae are subject to entrainment for the first 8 weeks of their life during which time they drift passively with the current; 4) the tidal cycle at Indian Point causes high repeated exposure of these larvae to entrainment while they drift passively back and forth past the plant; 5) no compensation; and 6) 100% entrainment mortality. From this model, the AEC staff predicted significant reduction of Hudson River striped bass populations. Con Edison disagrees with these assumptions and conclusions. (See Lawler and McFadden, 1972 and 1973.)

A mathematical model more applicable to Hudson River fish populations has been developed by Quirk, Lawler & Matusky, Engineers for striped bass (Lawler, 1973). This is a transport model which relates river hydrodynamics to the life cycle of striped bass in the Hudson River. Major parameters of the model are life cycle predicts a decrease in striped bass population from the operation of Unit 1 and 2, of 5.0% after 10 years. For Indian Point Units 1 and 2 plus Bowline and Roseton the decrease will be approximately 13.0%. He further states in his testimony to the AEC on February 20, 1973 that the AEC staff has not verified the ability of its model to estimate the effects on Indian Point Units 1 and 2 entrainment on the Hudson River striped bass population. These results show clearly that operation of Units 1 and 2 should not be expected to cause a substantial or irreversible adverse impact on the river's striped bass population, particularly during the first 10 years of operation. These reductions are expected to stabilize at the above values after approximately 10 years.

A study using the QLM model was also performed to predict the impact of Indian Point Units 2 and 3. This study predicted reductions of 6% after 10 years from the operation of Indian Point Units 2 and 3 and 16% after 10 years from the operation of Indian Point Units 2, 3, Bowline and Roseton. These results indicate that operation of Units 2 and 3 should not be expected to cause a substantial or irreversible adverse impact on the river's striped bass population, particularly during the first 10 years of operation. These reductions are expected to stabilize at the above values after approximately 10 years.

Raytheon Studies*

Plankton studies conducted in the Indian Point region during 1969 and 1970 by Raytheon Company indicate a rich and diverse planktonic community which varies seasonally. Species collected and their relative abundance were reported as was community overlap. Meroplanktonic forms, determined from the deployment of succession panels, and their relative abundance are also reported.

Striped bass eggs were initially observed in the Peekskill segment during early May, when river water temperature had reached approximately 52°F and reached maximum densities at 57° F. Eggs were more numerous in bottom and mid-depth (minus 20-80 ft.) collections as a result of their slightly negative buoyancy and were obtained frequently at the northern transect (mile points 35-47). Yolksac larvae were present in greatest numbers during late June and early July. Yolksac larvae were more abundant, particularly in bottom collections. Larvae were more frequently collected in surface samples at Roa Hook, in mid-depth samples at Stony Point and in bottom samples at Indian Point. Prejuvenile specimens were present only at the Indian Point transect in mid-depth collections. Channel stations accounted for the greatest number of specimens collected while stations located on the east side of the river accounted for the least specimens. A majority of the surface and bottom collections at all stations contained more specimens than mid-depth samples. During July, the numbers of striped bass larvae collected in the vicinity of Indian Point had decreased at all depths.

Yolksac and larval stages of the white perch were collected most frequently at northern stations, particularly in bottom collections. The total absence of prejuvenile speciments may be related to their benthic habitat, thus, they remain out of reach of "bottom" plankton nets that were fished approximately five feet above the substrate. Peak concentrations occurred during May and June, followed by a substantial decline in numbers during July. The presence of yolksac larvae from early May through late June suggests a prolonged spawning period that was also indicated for the striped bass, a closely related species. Larval stages were more concentrated generally at deep channel stations.

* Appendices Pond Q describe these studies in greater detail.

Clupeids (alewife and blueback herring combined) were collected more frequently at the central and northern transects during their yolksac and larval stages. Prejuvenile specimens were not obtained at the northern transect, while yolksac larvae were rare at the southern transect. These observations reflect the downstream migration of these species following hatching and initial development in freshwater. Unlike most species collected, greatest numbers were obtained in surface samples. Their cross-stream distribution reflects a pelagic habit, suggesting no particular preference for deep or shallow water. Their initial presence in the study area was noted during early May. Although the species were not separable during their larval stages, their bimodal distribution suggests overlapping spawning periods.

Substantial diurnal differences in vertical distribution were evident from an analysis of zooplankton samples obtained during periods of daylight and darkness. Amphipods (Gammarus, Leptocheirus and Monoculoides) were consistently more abundant in samples obtained during darkness and generally at the bottom. A vertical night migration was indicated for each species, although greater concentrations remained near the bottom. The opossum shrimp, Neomysis americana, was concentrated near the bottom during daylight. The sand shrimp, Crangon septemspinosus, represented the most abundant invertebrate species collected in trawls and seines during both years but was only rarely present in either spring or monthly planktonic samples in 1969 or 1970 indicating an association with salinity.

Clupeid larvae were significantly more numerous in surface collections from both day and night sampling. This preference of a pelagic habitat is characteristic of their behavior as juveniles and adults and is probably not related to light conditions as appears to be the case in striped bass, Neomysis, etc. Bay anchovy larvae collections generally were greater at night, particularly at Roa Hook and Indian Point. Greatest concentrations were at the surface and bottom. Atlantic tomcod were most abundant during the day at the bottom. Some vertical migration did occur during the day and night. White perch were caught primarily during the day at Roa Hook and Indian Point transects with largest catches at the bottom. At Stony Point, largest catches were made during the night at mid-depth and surface. A vertical migration occured at night with larger catches at the surface at night than during the day at all transects. Striped bass larvae were represented only in bottom and mid-depth collections during daylight. Largest catches were generally at the surface at night. These data suggest a negative phototaxis resulting in vertical migrations to the bottom during daylight. The closely related white perch did not display such a distinct migratory behavior.

Northeastern Biologists studies (Jensen, 1969) reports that the entrainable stages of the striped bass life cycle include the eggs which appear in the river for a period of 1.5 to 3 days before hatching or dying by natural means, the larval stage which progresses through a series of steps for approximately 21 days, during which the fish passes from the planktonic to the swimming stage and at the end of which the young fish has reached a size of about 18 mm, and the very early juvenile stage lasting for four to seven weeks beyond the larval stage during which time they migrate to the shoals and after which the fishes have reached a length of about two inches. At this point, the fish is no longer subject to entrainment by Indian Point.

N Y U Studies

Laboratory temperature tolerance studies initiated by N. Y. U. Medical Center were designed to cover the full range of ΔT's and exposure times that could be produced during various seasons of the year by all possible combinations of power level operation at Indian Point Unit 1 and 2. The results from these studies support earlier data indicating that the temperature tolerances of bacteria, phytoplankton and representative species of micro- and macro-invertebrate zooplankton will not be exceeded by the Δ T's expected in the dischage canal water during the fall, winter and spring. The data indicate that a 15° F ΔT in the summer would not exceed the temperature tolerance of the bacteria, phytoplankton and macro-invertebrate species studied except for Neomysis which is present when salinites exceed 0.5 0/00.

Laboratory studies indicate that Neomysis americana may experience appreciable mortality when entrainment temperatures exceed 90° F. This would include a period of approximately three months a year. The total extent of mortality is dependent upon total temperature encountered and duration of exposure of the organisms entrained. This mortality has not, however, been observed for Gammarus fasciatus, the primary food source of young-of-the-year striped bass and white perch. Laboratory and field studies of the tolerance limits of Gammarus indicate that little or no mortalities occur at 96°F for 30 minute exposure of this species. This temperature exceeds the maximum entrainment temperature which might be experienced at Indian Point.

Discharge temperatures below 90° F have been shown to stimulate carbon uptake by phytoplankton. At discharge temperatures above 90° F, the frequency of inhibition of C^{14} uptake in samples from the intake and discharge canal at discharge temperatures up to 93° F have been observed. 93° F was the highest temperature observed during the study. Temperatures in this range would not be reached during a normal year at Indian Point.

Comparisons of the ratios of live to dead micro-invertebrate zooplankton in Unit 1 intake and discharge water (net and pumped samples) during the summers of 1971-72 indicated no significant mortality at temperatures up to 93° F and ΔT's up to 11° F, which agree with projections from laboratory studies. Projected entrainment mortalities of organisms such as copepods, which have relatively short generation times, appear to have little potential for affecting populations in the Hudson River.

Laboratory thermal shock studies on the survival and reproduction of Daphnia pulex and ostracods shows that Daphnia pulex can survive and reproduce after a ΔT as high as 39° F above an ambient temperature of 72° F if the exposure time is less than one minute, but that lower ΔT's can have deleterious results if the exposure time is from 4.5 to 6 minutes. The ostracod study has shown them to be more hardy and able to survive at ΔT of 29° F above an ambient temperature of 75° F for an exposure time of 30 minutes, but that a ΔT of 32°F for an exposure time of 30 minutes had only 53% and 20% survival. While the results of the Daphnia pulex and ostracod studies do not lend themselves to cold winter months, they can be applied to warm weather months of plant operations (N.Y.U., 1970).

Studies in Progress

An extensive survey of fish and benthic population dynamics at Indian Point was initiated by Consolidated Edison on April 1, 1972. This survey has been designed to complement previous ecological base line studies for the area and provide a more thorough delineation of the importance of each facet of the biome. Additionally, it will incorporate the data derived from previous studies to provide a more complete view of conditions in the area and determine the effects on the ecosystem of specific plant operations.

Studies in progress by New York University will supplement our knowledge of the effects of entrainment gained in previous research. These include additional experimentation into temperature tolerances, evaluation of mortality and sub-lethal detriment as a result of passage through the facility, determination of the effects of chlorination, physiological responses to heat shock, percent of population entrained and overall effect on the ecosystem. Similar studies are soon to be underway at other new plants on the river.

DISCUSSION

The use of natural waters for once-through cooling systems imposes varying degrees of physical buffeting, rapid changes in pressure and temperature, and periodic exposures to chemical discharges upon organisms that are contained within the water source and taken into the plant. Evaluation of the effects of these processes upon the aquatic ecosystem must consider the cumulative of these factors in arriving at the final assessment. The present state of our knowledge of these effects is admittedly limited, but has reached a degree of refinement with regard to particular species which allows certain generalizations and preliminary estimates of their upon the ecosystem at Indian Point.

Striped Bass (Morone saxatilis)

Extensive studies of striped bass indicate that limited mortalities could be expected to occur as a result of the operation of Indian Point Unit 3, but these mortalities would represent a small percentage of the population and result in no permanent and irreversible damage to Hudson River population levels. This contention is supported by data on thermal tolerance, distribution of eggs and larvae, and the effects of pressure, mechanical abrasion and chlorine upon those life stages of striped bass which are subject to entrainment.

Distribution:

Studies conducted by Raytheon Company, Carlson and McCann, Ratbjen and Miller, QLM, and Lauer have identified several significant facts concerning the behavior of striped bass eggs and larvae.

Primarily these are:

1. Striped bass eggs are semi-bouyant and tend to be moved by river currents and settle in quiet water. The average spawner produces about 300,000 to 1,000,000 eggs of which about 1-10% can be expected to hatch.

2. Yolksac larvae of striped bass tend to be concentrated on or near the bottom. This stage lasts about 28 days and 0.5-1% can be expected to survive to the next stage.

3. The strength of a year class can be independent of the number of spawners.

4. Juvenile striped bass exhibit diurnal vertical migrations, apparently in response to light, concentrating on or near the bottom during daylight hours and achieving more random depth distribution at night.

5. Very early juvenile stripers migrate into shoal area nursery grounds where they remain until they reach a length of approximately two inches.

6. Larvae or juvenile striped bass above 18 mm (0.8 inches) in length have good swimming ability and are not taken in intake and discharge canal samples at Indian Point Units 1 and 2, indicating that they are either able to completely avoid entrainment or pass through in sufficiently good health to avoid capture. 18 mm and longer larvae are found in shoal areas.

Hydrographic modeling of the Indian Point area has shown that little or no water is taken into the plant from depths below 30 feet (Lawler, 1972). The river bottom drops rapidly from this depth at the Indian Point intake structures to approximately 60 feet at a distance of one hundred yards, thus limiting entrainment to those forms found in the upper water column. The average net downstream flow of the Hudson between May and July varies between 2.55 and 0.66 miles per day.

When these facts are considered jointly with the small percentage (2.5%) of total river flow withdrawn by the Indian Point facility, it seems unlikely that a significant percentage of the annual spawn of striped bass would be subjected to entrainment at Indian Point.

Thermal Tolerance:

Thermal tolerance of the several life stages of striped bass varies from a maximum safe temperature (100% survival) following 60 minute exposure of 73° F for newly hatched larvae (Lauer, 1973) to juvenile forms which can withstand indefinite periods of exposure to 95° F (Meldrim and Gift, 1971). Within these extremes, the response of a particular stage to thermal shock is a function of the life stage, acclimation temperature, Δ T, total temperature encountered, and duration of exposure.

Lauer has reported the thermal tolerance of striped bass egg and larvel developmental stages in testimony before the AEC regarding Indian Point Unit 2. Within the developmental cycle, two stages, the early gastrula and newly hatched yolksac larvae show greatest sensitivity to temperature. Entrainment temperatures at Indian Point would exceed the 60 minute safe temperature of these stages only during the latter portion of the reproductive season and could be expected to produce some degree of mortality in those organisms entrained during these phases of development (Figures 5 and 6). Temperatures in excess of this safe temperature do not imply 100% mortality. Actual percent mortality would be a factor of both degree to which the level was exceeded and duration of exposure.

Effects of Pressure:

Lauer (1972) has reported that striped bass eggs exposed to abrupt changes in pressure ranging from 5 to 100 psia showed no increased mortality or abnormal development either in the egg stage or resulting larvae. Striped bass larvae up to 30 days old fed immediately following exposure to the same elevations and suffered no mortality or behavioral aberration following the treatment. Older larvae and juveniles showed identical responses to abrupt pressure increases up to 500 psi and maintenance at these pressures for up to two hours before instantaneous return to ambient pressure.

It seems evident from these results that striped bass would experience no detriment from abrupt pressure change alone.

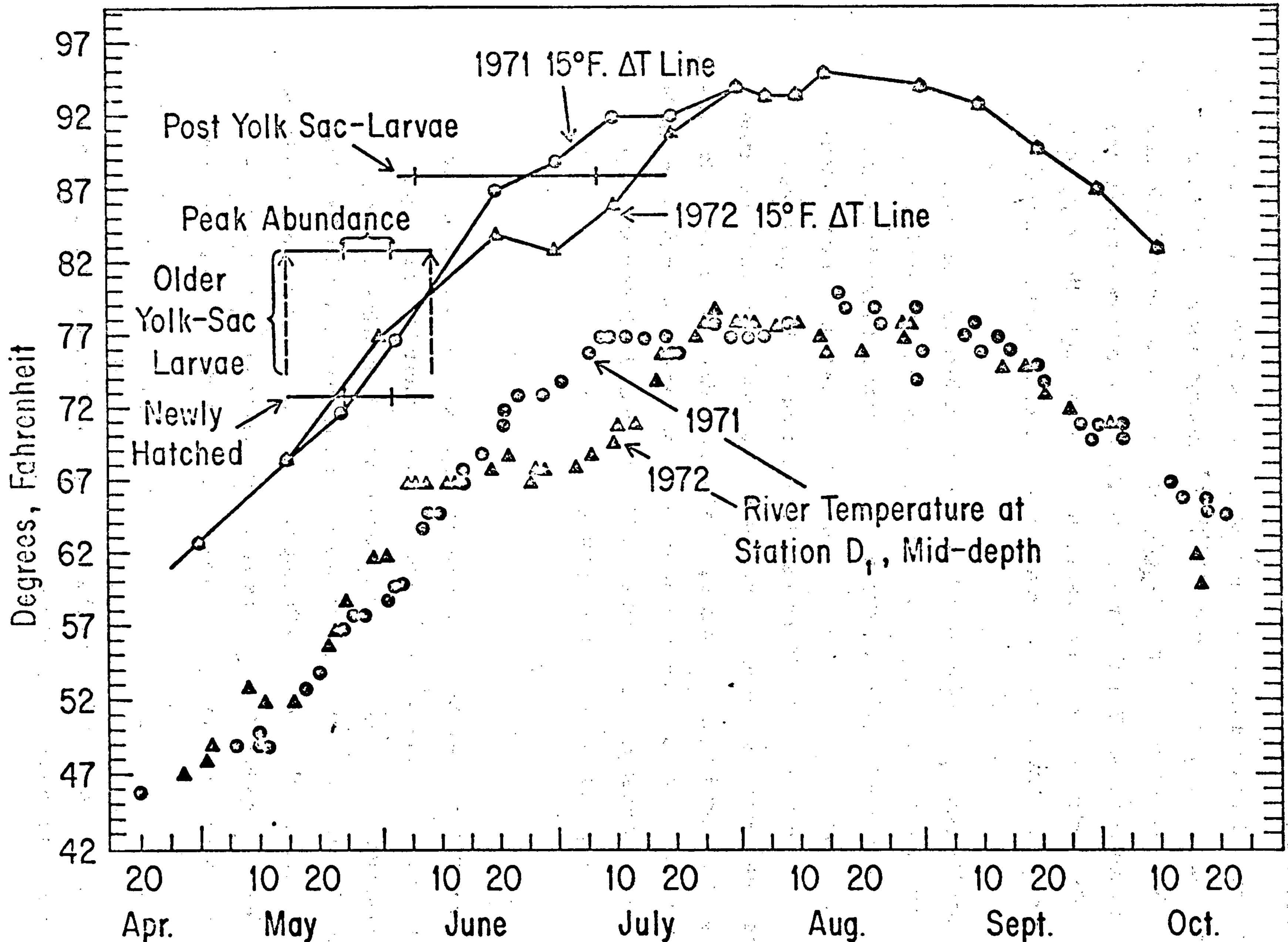

Figure 5. Striped bass eggs, 1971. Seasonal occurrence in the Hudson River at Indian Point relative to the upper 60-minute safe temperature for various developmental stages, and to the projected Indian Point Plant discharge canal temperatures at full design capacity (15°F ΔT) operation. From: Lauer, 1973.

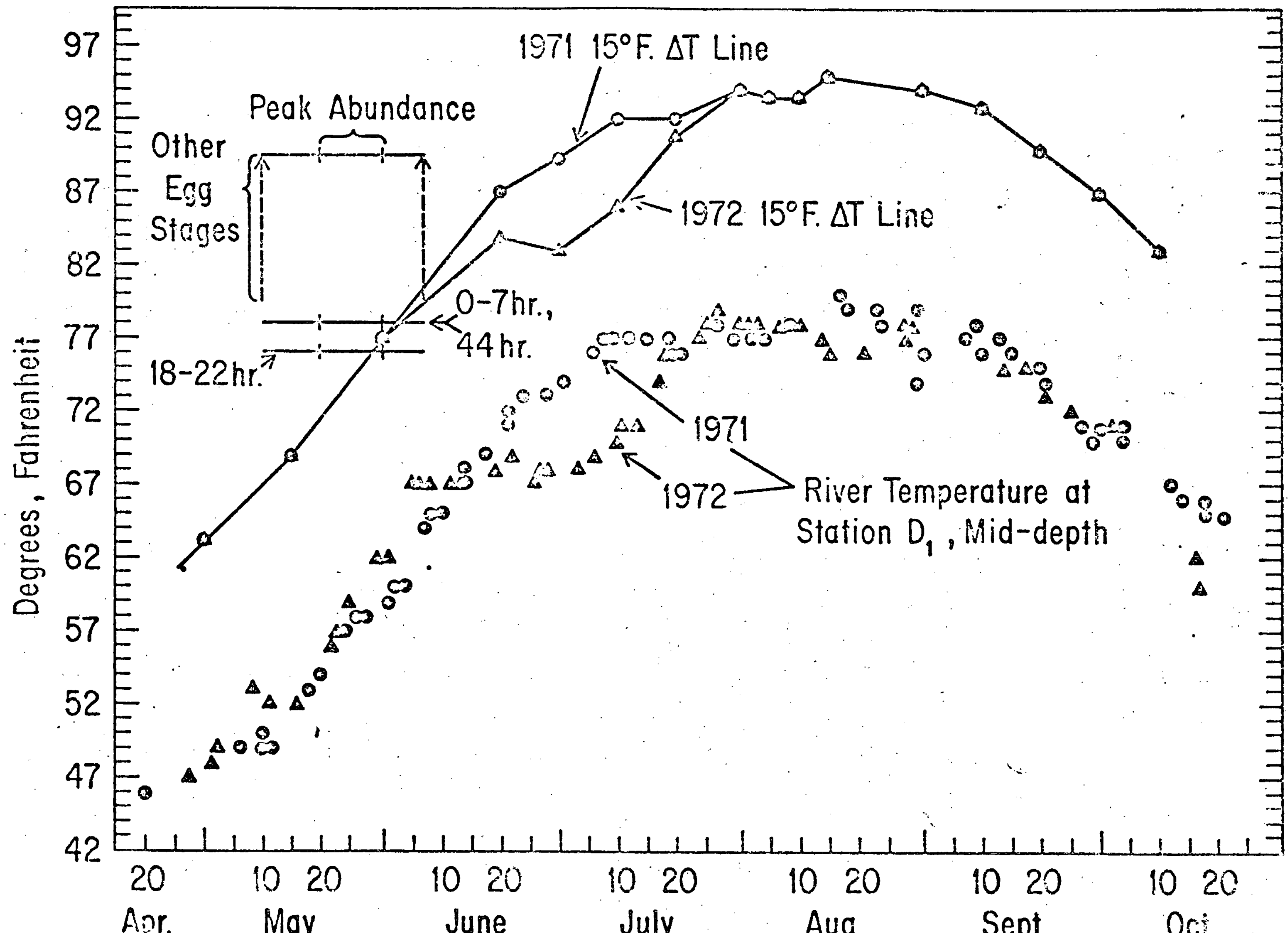

Figure 6. Striped bass larvae, 1971. Seasonal occurrence in the Hudson River at Indian Point relative to the upper 60-minute safe temperature for various developmental stages, and to the projected Indian Point Plant discharge canal temperatures at full design capacity (15°F ΔT) operation. From: Lauer, 1973.

Effects of Mechanical Abrasion During Entrainment

Pre- and post-entrainment sampling of Morone sp. (striped bass and white perch) larvae at Indian Point indicate 61 to 93% survival of larvae entrained with no temperature change. This is considerably higher than the 20% value suggested by Marcy (1973) and the 0% suggested by the AEC Staff.

Effects of Chlorination

Data presented in Lauer's February 5, 1973 testimony before the AEC indicate that mortalities of Morone sp. larvae attributable to chlorine fall into the range of 13-41% of those entrained. When considered on a weekly basis, however, a maximum of 1.78% of the water entrained at Indian Point Unit 3 would be subjected to chlorination and this only during daylight hours. Thus, if entrainment rate were constant, the weekly % mortality of entrained Morone larvae due to chlorination would not be expected to exceed 0.73%. Since a "daytime only" pattern of chlorination is used at Indian Point, the vertical migration behavior of these larvae could be expected to further reduce the potential for chlorine damage to these forms.

White Perch (Morone americanus)

While data specific to white perch are not so readily available as those for striped bass, it has been assumed in the past that their population response to the effects of entrainment in Indian Point Unit 3 will not appreciably differ from those of the striped bass. Past work has treated both species together (Lauer, 1973).

Distribution:

The distribution patterns of white perch eggs are different from those of striped bass in that white perch eggs are adhesive and less bouyant than those of striped bass. It is expected that there characteristics will substantially reduce if not eliminate the susceptibility of white perch eggs to entrainment. Yolksac and larval stages of white perch concentrate on or near the bottom as do comparable stages of the striped bass while prejuvenile specimens appear almost exclusively within the lower few feet of the water column. All larval stages are more concentrated in deep water areas.

Temperature Tolerance:

Meldrim and Gift (1971) have reported that juvenile white perch (80-150 mm in length) are able to withstand 15 minute exposure to 95° F with no ill effects. Since this temperature and duration of exposure exceeds the highest average temperatures at Indian Point Unit 3, it is reasonable to conclude that some degree of thermal shock mortalities of white perch larvae might occur but that these would be limited and occur infrequently. This assumes that thermal tolerances of white perch larvae are similar to those of juveniles.

Pressure, Mechanical Abrasion and Chlorination:

Since the results of research on the response of Morone sp. to pressure, mechanical abrasion and chlorine include white perch larvae as well as those of striped bass, the expected effect of entrainment can not be distinguished as being different for the two species.

Gammarus fasciatus

Gammarus fasciatus, an estuarine amphipod, is the major food source of many Hudson River fish including white perch and one to two year old striped bass. Research has shown that these organisms experience limited mortalities when entrained during chlorination but pass through the facility virtually unaffected at all other times. Due to the low frequency and short duration of chlorination, this mortality could not be expected to result in any appreciable detriment to populations of Gammarus in the Hudson River.

Distribution:

Gammarus is a common epibenthic form in the Indian Point region which exhibits diurnal vertical migration. Populations of Gammarus are consistently highest on or near the bottom during daylight hours and become more evenly distributed through the water column at night (Lauer, 1972; Raytheon, 1971). In addition, they tend to be more abundant in areas such as shallow grass beds which provide greater protection from predation (Texas Instruments, 1972). As in the case of striped bass larvae, the negatively phototactic diurnal migration pattern of this species serves to reduce its likelihood of entrainment at Indian Point, particularly during chlorination periods.

Temperature Tolerance:

Temperature tolerance studies of Gammarus have shown that it experiences no mortality following 30 minute exposure to 96° F (ambient 77° + ΔT 19°). This tolerance level is in excess of any conditions which might occur at Indian Point.

Pressure and Mechanical Abrasion Response:

Survival data from intake and discharge canal collections show no increase in mortality of Gammarus following entrainment either with or without change in temperature. From these results, it can be concluded that no detrimental lethal effects to Gammarus result from the pressure changes or mechanical abrasion incurred during passage through the Indian Point facility.

Effects of Chlorination:

Lauer (1972) reports the presence of dead and stunned Gammarus in discharge samples during chlorination. The percentages of dead and stunned specimens ranged from 5.2 to 18% dead and 9 to 24% stunned. Approximately 68% of the stunned specimens subsequently died. The total expected mortality as a result of chlorination would then fall between 11.4% and 34.3% of those organisms entrained during chlorination periods.

If these values are compensated for the percent of water chlorinated in Unit 3, at the maximum application rate of 1.78%, the loss of Gammarus passing through the plant in an extended period of time would be reduced to 0.2% - 0.6% of those entrained. No appreciable damage to Hudson River populations could result from mortalities at this level.

Neomysis americana

Neomysis has been reported as a common member of the plankton community at Indian Point during those portions of the year when salinity exceeds 0.5 0/00.

Such periods could be expected in mid-winter and summer when freshwater runoff is reduced.

Post entrainment data for Neomysis indicate that no decrease in percentage survival occurs when temperature is lower than 90° F, but that sizeable mortalities could be expected above this temperature and during chlorination. The significance of this thermal shock sensitivity is reduced, however, by the dramatic diurnal vertical migrations of Neomysis which reduces their susceptibility to entrainment during daylight hours. Lauer (1972) reports that entrainment at Indian Point will not significantly reduce populations of Neomysis in the Hudson River. Further studies of the population dynamics of Neomysis are now in progress to more completely evaluate the effects of entrainment mortalities on Hudson River populations. The stomach analyses of fish in higher trophic levels indicate Neomysis is not a critical element of the food chain of key species.

Indian Point Temperature Regime

Figure 7 illustrates the water temperature regime at Indian Point (Figure 1, Introduction) together with the elevated temperatures which would occur in the condensers of the generating facility with the imposition of ΔT values of 15° F during the summer and 23.8° F during the winter months. Late summer maxima during an average year would not exceed 94° F. These temperatures could be expected to persist for relatively short periods at the extreme.

Thermal Tolerance

Thermal tolerance data as reported in the literature are a staggering assemblage of mortality levels, exposure intervals and acclimation temperatures which are seldom directly comparable to the conditions experienced at a specific generating station. There are, however, indications that tolerance to thermal shock is a function of both total temperature encountered and duration of exposure. Coutant (1972) reports that no mortality results from exposure to temperatures 3.6° F (2° C) below upper

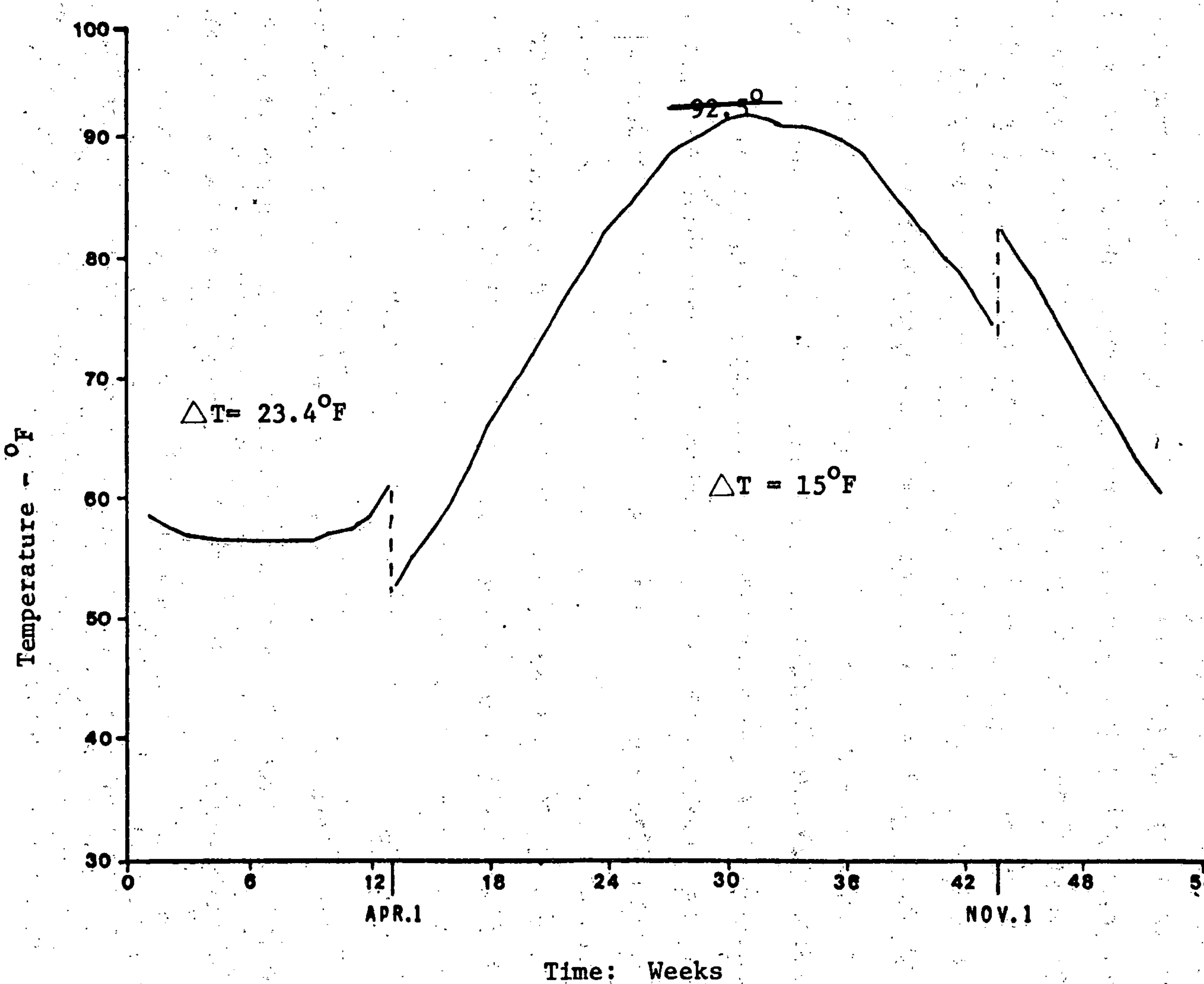

Figure 7. Temperatures encountered at Indian Point condensers at proposes operational levels.

stress temperatures. He further states that 80 - 85% reduction in exposure time produces an effect equivalent to that of a 3.6° F decrease in temperature. These values then provide a convenient means of estimating the effects of entrainment at a particular generating facility in terms of tolerance limit data as they appear in the literature.

If a 3.6° F reduction in temperatures from the TLm values for a given exposure time results in 100% survival, it is reasonable to assume that an increase of 3.6° F above a temperature at which 100% survival occurs will result in no more than 50% mortality. Further, we may assume that exposure times which do not exceed 15-20% of those reported for a particular temperature will elevate the effective tolerance of the species cited by 3.6° F. With these values, reported tolerance levels for species found in a particular area and the operational regime of a particular facility, it is possible to predict the levels of survival which might be expected following entrainment in once-through cooling systems. Table 4 contains such an evaluation for 15 species which are common to the Indian Point area. The species fall into five groups according to their expected responses to entrainment at temperature maxima for average years and have been ranked in descending order of thermal resistance.

In addition to these species, NYU (1971) research indicates that the decomposer level of the ecosystem will experience no detriment as a result of any level of exposure in the ranges encountered at Indian Point. Lauer (1971) reports actual stimulation of carbon uptake by the phytoplankton community by temperatures in the range of the cool year maximum although some inhibition is indicated at higher levels.

Egg and larval stages of common organisms which may be less tolerant than the adult forms and thus more sensitive to the effects of entrainment are subjected to interpretation only on the basis of responses of the individual species. The presence of freshly settled barnacles at the effluent gates of the Indian Point facility during the summer indicates that the larvae have survived entrainment in viable condition prior to attachment. Similar conclusions may be drawn for several benthic

Table 4: Temperature tolerances and expected percent survival of Indian Point species following entrainment at Indian Point Unit 3 in an average year.

TAXON	Temperature °F	Exposure Minutes	Reported Survival %	Expected Survival at IP3 %
Callinectes sapidus	104	sev. hours	100	100
Ostracoda	104	3-3.5	100	100
Melosira varians	96.8	---	100	100
Nitzschia amphibia	96.8	---	100	100
Gammarus fasciatus	96.8	30	100	100
Palaemonetes pugio	95-100.9	1440	100	100
Morone saxatilis juv.	95	---	100	100
Morone americanus juv.	95	15	100	100
Eurytemora affinis	93	30	100	100
Halicyclops sp.	93	30	100	100
Daphnia pulex	94	30	50	100
Crangon septemspinosa	87.8-91.4	1440	50	50
Acartia tonsa	86	1440	100	50
Neomysis americana	88	30	85-90	50
Cyclops bicuspidatus	83	30	98	50

and epi-benthic invertebrate species common to the effluent canal (hydroids, ectoprocts, decapods).

It would seem likely that the tolerance of meroplanktonic larval forms would not greatly differ from the mean of the population as a whole and that relatively high levels of survival of entrained organisms might be expected under any conditions which occur at Indian Point as a strict function of thermal tolerance of the fauna.

Effects of Pressure and Physical Abrasion

Studies at Indian Point with no ΔT indicate that no significant difference in numbers of organisms or percentages of survival can be determined for samples of bacteria, phytoplankton, microzooplankton and macrozooplankton taken at intakes and effluents. This indicates that entrainment at Indian Point results in no appreciable damage due to physical abrasion and that the pressure differentials encountered during passage produce no recognizable detriment to these groups. Some disorientation has been observed in post-entrainment studies of larval and juvenile fish (tomcod) but this reaction seems to be at least partially reversible.

Marcy (1973) has reported 80% mortality of clupeid larvae as a result of mechanical damage during entrainment through a nuclear generating facility. Research at Indian Point (Lauer, 1973) has reported that 7-39% mortality occurred in Morone sp. following entrainment at Indian Point. It is apparent from these conflicting reports, that no generalizations from station to station are possible concerning the possibility of mechanical damage. In any event, entrainment at Indian Point will not cause 100% mortality of striped bass larvae as predicted by the AEC but are expected to more closely approximate the 7-39% values reported by Lauer.

Non-Random Distribution

By classic definition holoplankton are passively drifting organisms which move only through the movement of the water mass in which they are borne. To a large extent this is true, but certain notable exceptions occur.

Certainly, horizontal movements of any magnitude are accomplished only as a function of net movement of the water mass but many, if not all, planktonic forms are subject to vertical translocation either in response to physical stimuli or changes in physiological activity with age or season. This may be seen in the diurnal vertical migrations of many species in the Indian Point area (Gammarus fasciatus, Leptocheirus pinguis, Monoculodes sp., Neomysis americana, striped bass juveniles, white perch juveniles). These migrations are apparently performed in response to light (N.Y.U., 1972). This then indicates that highest concentrations of all species exhibiting such responses will remain at or near the bottom during the light hours and become more randomized and thus subject to entrainment at night. Short night length during those months when critical temperatures occur in the Indian Point condensers would then greatly reduce the possibility of entrainment and resulting detriment to the vertically migrating forms which make up at least 90% of the macrozooplankton collected in the area.

Other species remain on or near the bottom during portions of the life cycle (striped bass eggs, early larvae). This phenomenon produces the same net result of reducing entrainment as vertical migration, but could be expected to result in a much higher reduction since no daily increased susceptibility period occurs as in diurnally migrating forms.

Chlorination

Several factors support the conclusion that chlorination as employed at Indian Point Unit 3 will have no significant biological effect on populations in the river. Chlorine, as sodium hypochlorite, will first be introduced into one-half of the condenser (3 sections) for one-half hour. The chlorine will then similarly be introduced into the remaining three sections. It is proposed that this procedure will be used at a maximum frequency of three times per week during those months when river water temperatures exceed 45° F. Depending on operating conditions, this frequency may be reduced to two applications per week for the majority of this period. This would result in the treatment of 1.78% and 1.19% of the water entrained during the summer and spring-fall regimes, respectively, and no treatment whatsoever during the remainder of the year. This fact in itself would seem to negate any extensive detriment to the ecosystem. Additionally, the "daytime only" pattern of chlorination employed at Indian Point could be expected to reduce the potential for chlorine damage to negatively phototaxic diurnally migrating forms.

Research has further shown that chlorine tolerance like thermal tolerance is a dose response (Hirayama and Hirano, 1970; Brook and Baker, 1972; Lauer, 1972). At Indian Point, the short term (8-12 seconds) exposure experienced by entrained organisms prior to reduction of concentration should thus further reduce the percentage of entrained organisms killed during chlorination. Additional studies of the effects of chlorination at Indian Point are currently being conducted by New York University. The possible effects of chloramines produced as a result of chlorine added to the ecosystem have been discussed in Appendix Z.

Chlorination as it is applied to Indian Point Unit 3 could not affect more than 1.78% of the organisms entrained as a strict function of the duration of application. This fraction of the community could be expected to experience mortality and inhibition of photosynthesis as a function of its exposure, but the short duration of entrainment and relatively low chlorine concentrations encountered should reduce these effects to a low level. Overall effect to the community would be further reduced by the removal of diurnally migrating forms from any contact with chlorine. Total river flow at Indian Point has been estimated at 80,000,000 gpm. Full flow operation of all Indian Point units is estimated at slightly over 2,000,000 gpm. This represents only 2.5% of the total flow and thus indicates that the fraction of the plankton community passing Indian Point which might be entrained would also be extremely low.

When these factors are considered simultaneously, it becomes apparent that no significant effect of chlorination can be projected for the operation of Indian Point Unit 3 either alone or in conjunction with Units 1 and 2.

Sub-lethal Effects

Thermal shock at sub-lethal levels may result in temporary debility, rendering the subject more susceptible to predation or infection. It must be recognized that normal predator-prey relationships are based upon selective harvest of sick, injured or weak individuals of the prey. If competition does occur at this stage, the removal of these organisms from the population would reduce competitive pressures on the more fit representatives and enhances their survival and reproductive potential. Assuming a finite range of tolerance limits within any given species, minor debilitation of organisms with lower resistance to termperatures, chlorination or pathogenicity may be considered to be a selective force for higher resistance within the species and result in population stabilization at a more resistant level. This effect of thermal shock thus seems to be subject to the normal compensatory mechanisms of the ecosystem and of limited significance at best.

Assessment of Total Effects of Indian Point Unit 3

If the expected survival values which were presented in Table 4 can be assumed to be representative of the population at Indian Point as a whole, we can calculate that in an average year, thermal shock will cause no detriment whatsoever 9.5 months of the year. During the remaining 2.5 months, 73% of the species entrained would experience no detriment in their passage through the condensers.

Cumulative Effects of Existing and Proposed Utilities

Temperature elevations at the condensers of existing and proposed plants approximate those proposed for the Indian Point facility. The critical temperature periods projected for Indian Point are then generally comparable throughout the region. This indicates that no appreciable entrainment mortalities, due to thermal shock, either individual or cumulative, will occur between mid-September and mid-July of the following year if all contributing units operate as predicted (Table 5).

During the remainder of each year, temperatures encountered in passage through the various cooling systems could be expected to produce limited mortalities in certain species. These mortalities would be experienced by only those members of a population which were entrained, however, and are not expected to produce significant deterioration of the ecosystem. When the various moderating factors are considered, it seems reasonable to conclude that no irreversible damage to the Hudson River estuary will occur during the period necessary to complete research programs presently underway at Indian Point.

Table 5. Operational levels at capacity operation of existing and propose power facilities on the lower Hudson River.

FACILITY	River Mile	Mw	Rate of Flow gpm	T °F	Projected Operational Date
Danskammer	66	508	308,000	14.5	In operation
Roseton					
Unit 1	65	600	325,000	17	Dec., 1972
Unit 2	65	600	325,000	17	Spring 1973
Indian Point					
Unit 1	43	285	318,000	12	In operation
Unit 2	43	873	870,000	14.6	Spring, 1973
Unit 3	43	965	870,000	16	1974
Lovett	42	503	323,000	14.8	In operation
Bowline					
Unit 1	37.5	620	384,000	15	In operation
Unit 2	37.5	620	384,000	15	1975

CONCLUSIONS

Expected Mortalities

Entrainment through Indian Point Unit 3, whether operating singly or in conjunction with Units 1 and 2, will result in limited mortalities of certain species as a function of their tolerances to abrupt pressure changes, mechanical abrasion, temperature and chlorine. Research indicates that only larval fish show any appreciable degree of mortality as a result of the combined effects of pressure and mechanical abrasion encountered during entrainment. This effect would then be significant only during the spawning periods and one to two months following. Temperatures in the detrimental range would occur during only three months of the year and even then would affect only a small percentage of the faunal assemblage at Indian Point. Chlorine is added to a maximum of 1.78% of the water entrained and during four months of the year no chlorination whatsoever occurs.

Little or no mortality due to entrainment could be expected during four months of the year when temperatures are low, no chlorination occurs and most of the pressure -abrasion sensitive fish larvae are absent from the ecosystem. Temperatures in excess of the tolerance limits will result in limited mortalities of some species entrained during three of the remaining eight months while only the effects of chlorination, pressure and mechanical abrasion should occur during the other five months.

Effects upon the Ecosystem

Based upon tidal flow, only 2.5% of the water passing Indian Point is entrained. This fact, with the distributional patterns, both vertical and horizontal, of the holoplankton and meroplankton of the region indicates that percentages of a total population which might be entrained will be quite low. The total effect of entrainment at Indian Point Unit 3 then becomes the product of low percentages of total populations entrained and limited mortalities to certain species during portions of the year. From this, it seems reasonable to conclude that no irreversible damage to the Hudson River ecosystem will result from the operation of Indian Point Unit 3 either alone or in conjunction with Units 1 and 2 before environmental studies are completed in 1977. Any significant increase in mortality of young of the year striped bass, such as that suggested by the AEC to be plant induced would be readily detected by Con Edison's Ecological Study. Both short term and long term alternate mitigating measures are available to prevent irreversible damage.

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APPENDIX 1

TEMPERATURE TOLERANCE DATA

SPECIES	ACCLIMATION TEMP.	TEMPERATURE C°	TEMPERATURE F°	EXPOSURE TIME	% SURV.	REFERENCE
Blue Green Algae						
**Oscillatoria sp*	--------	46.2	115		0	Biol. Probs in H_2O Poll. US Dept. Hew, 1962
Diatoms						
Cymbella tumida	--------	29	84.2		100	Fogg, 1962
**Melosira varians*	--------	36	96.8		100	"
Navicula confervacea	--------	36	96.8		100	"
**Nitzschia amphibia*	--------	36	96.8		100	"
Coelenterata						
Chrysaora quinquecirrha	--------	34	93.7	1440	50	Heinle, 1969
Crustacea						
**Acartia tonsa*	(5-10°C)	30	86	1440	100	Heinle, 1969
"	(20-25°C)	32.5	90	180	0	"
"	----------	33	91.4	5760	0	Mihursky, 1969
Apeltes quadracus	----------	31-33	87.8-91.4	1440	50	"
Assellus intermedius	----------	34.5	94.3	1440	0	Parker & Krenkel, 1969
"	(30°C)	34.6	94.3	1440	0	Sprague, 1963

* Reported at Indian Point

APPENDIX 1 (con't)

SPECIES	ACCLIMATION TEMP.	TEMPERATURE C°	TEMPERATURE F°	EXPOSURE TIME	% SURV.	REFERENCE
Crustacea (cont'd.)						
*Callinectes sapidus	------	30	86	Indef.	100	Tagatz, 1969
"	------	30	86	Indef.	100	Holland, Aldrich & Strawn
"	------	40	104	Several hrs.	100	Galloway & Strawn, 1972
*Crangon septemspinosa	-------	31-33	87.8-91.4	1440	50	Mihursky, 1969
*Cyclops bicuspidatus	-------	15	59	60	100	N Y U - MC, 1971
"	-------	21.1	70	60	100	"
"	-------	24.3	76	50	100	"
"	-------	24.3	76	60	89	"
"	-------	28.3	83	30	98	"
"	-------	32.1	90	30	0	"
*Daphnia pulex	68-79°F	23.7	75	30	90	"
"	68-79°F	26.8	80	30	70-80	"
"	68-79°F	36.3	97	25	78	"
"	68-79°F	34.7	94	30	50	"
"	68-79°F	40.5	105	1	0	"
*Eurytemora affinis	(20-25 C)	30	86	240	100	Heinle, 1969
"	(20-25 C)	30	86	1440	0	"
"	--------	34	93	30	100	Lauer, 1972

*Reported at Indian Point

APPENDIX 1 (con't)

SPECIES	ACCLIMATION TEMP.	TEMPERATURE C°	F°	EXPOSURE TIME	% SURV.	REFERENCE
Crustacea (cont'd)						
**Hyalella azteca*	(20°C)	33.2	91.8	1440	0	Sprague, 1963
**Neomysis americana*	---------	31-33	87.8-91.4	1440	50	Mihursky, 1969
"	---------	31.7	83-88	30	85-93	Lauer, 1972
*Ostracods	75°F	40	104	3-3.5	100	N Y U -MC, 1971
"	75°F	41.7	107	12	53	"
**Palaemonetes pugio*	---------	35-38	95-100.9	1440	50	Mihursky, 1969
**Rhithropanopeus harrisi*	---------	35-38	95-100.9	1440	50	"
Mollusca						
**Crassostrea virginica*	---------	27-32	80.6-89.6	60-480	-100	Kennedy, 1969
" egg & larvae	---------	33	91.4	480	Sig. Red	"
" " "	---------	34	93.2	60-480	0	"
Insecta						
Midge larvae A	---------	29	84.2	1320	50	Wurtz, 1969
" B	---------	30	86	1320	50	"
" C	---------	37.6	86.9	1320	50	"
" D	--------	34.5	94.1	1320	50	"
" E	--------	35	95	1320	50	"
" F	--------	35.5	95.9	1320	50	"
" G	--------	38.2	101.8	1320	50	"

*Reported at Indian Point

APPENDIX 1 (con't)

SPECIES	ACCLIMATION TEMP.	TEMPERATURE C°	F°	EXPOSURE TIME	% SURV.	REFERENCE
Mollusca (cont'd)						
Gemma gemma	(25°)	35.6	114	2880	50	Kennedy & Mihursky, 1971
*Macoma balthica	(26°)	33.3	91.3	1440	50	"
*Mya arenaria	(25°)	32.1	89.6	1440	50	"
Modiolus demissus	-----	38.42-40.18	101.5-	1440	50	Waugh & Garside, 1971
Mulinia lateralis	(25°C)	33.5	91.3	1440	50	Kennedy & Mihursky, 1971
Thais haemastoma	------	34	93.2	indef.	100	Mc Ritchie, 1969
Fish						
*Carassius auratus	------	34	93.2	840	50	Mackenthun, 1967
Gillichthys mirabilis	(27°)	39.62	103.28	60	0	De Vlaming, 1970
*Ictalurus catus	(20°)	31.2	88.16	---	0	Kendall & Schwartz, 1968
"	-------	31.	89	---	100	Texas Instruments, 1972
*Lepomis macrochirus	-------	36	96.9	1440	50	Mackenthun, 1967
Lucania parva	-------	35-38	95-100.9	1440	50	Mihursky, 1969
*Micropterus salmoides	-------	32	89.6	4320	50	Mackenthun, 1967
*Morone americanus	-------	27.5	82	480	50	Meldrim & Gift, 1971
" juveniles	-------	35	95	15	100	"
*Morone saxatilis	-------	32	89.6		100	"
" juveniles	-------	35	95		100	"
*Perca flavescens	-------	32	89.6	540	50	Mackenthun, 1967

*Reported at Indian Point

THE BIOLOGICAL EFFECTS OF FISH IMPINGEMENT
ON THE INTAKE SCREENS AT INDIAN POINT

Consolidated Edison Company of New York, Incorporated
New York

15 January 1973

ABSTRACT

Since Indian Point Unit 1 began operation in 1962, fish have been impinged on the cooling water intake screens. Fish collections have indicated that the largest impingement occurs during the winter months; and small white perch, 2-4 inches in length, constitute about 70 percent of the total number of fish collected. Tomcod, striped bass, herrings, and bay anchovy are collected frequently on the screens. Efforts to reduce impingement have been partially successful with fine mesh fixed screens, air curtains, and reduced intake flows showing the most promise to date. Current operating procedure includes reduced intake flows (60 percent of full flow) from October through March of each year to reduce fish impingement below previous levels.

The effects of impingement mortality on fish populations in the Hudson estuary are being investigated. A comparison of mortality induced by impingement and the commercial fishery suggest that white perch have sustained much higher levels of mortality due to fishing with apparently no adverse effects on abundance. The extent to which fish populations are able to compensate for additional mortality through increased survival, growth, reproduction, and recruitment suggest that any incremental increase in mortality due to plant operation will be mitigated by a significant compensatory response. Current studies of population dynamics will allow a quantitative prediction of the effects of impingement mortality on fish abundance before Unit 3 becomes operative in the second part of 1974. On the basis of the information available it is concluded that full power operation of all units at Indian Point would not cause irreversible damage to the fish populations before noticeable change in their population parameters could be determined through the current monitoring program.

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INTRODUCTION

The Indian Point plant began operation in October 1962. Like all steam-electric generating plants, whether nuclear or conventional, it utilizes water to condense the steam that produces electricity and discharges the waste heat to the environment. This cooling process requires large volumes of water which are drawn directly from the Hudson River and returned as a heated effluent after "once-through" cooling.

Since Indian Point Unit 1 began full operation in 1963, large numbers of fish have been collected on the screens at the cooling water intake. This problem has been a concern to Consolidated Edison, State and Federal agencies, sports enthusiasts, and conservationists. During the past ten years various methods of reducing this impingement mortality have been tested. Studies related to the cause of impingement, its solution and its effect on the natural abundance of fishes, are still in progress and provide the basis for predicting the biological effects of impingement at Indian Point Units 1,2 and 3.

This report reviews the history of fish impingement, protective measures, fisheries data, and related topics as they apply to the operation of the Indian Point plant. Data on fish collections, seasonal variations in numbers and species composition, are presented and discussed. The effects of various protective measures such as fine meshed fixed screens, circulator flow reduction, and air curtains are considered. The results of swim speed experiments and the condition of impinged fish are described. Hudson River fishery data are summarized, and the effects of additional mortality on fish populations are discussed. The activities of the Fish Advisory Board and other expert consultants are presented as an indication of Con Edison's continuing efforts to reduce fish impingement to the lowest practical levels while producing electricity at Indian Point.

LITERATURE REVIEW

Fish Impingement and Protection at Unit 1

The history of fish impingement and protection at Indian Point from 1962 until the present has been well documented (Consolidated Edison, 1970; Division of Compliance, 1971; Atomic Energy Commission, 1972). The configuration of the Unit 1 intake structure and discharge channel has contributed to the fish impingement problem at Indian Point. The cooling water enters the intake forebays and passes through fixed screens, a trash rack, traveling screens, circulator pump, condenser, and the discharge canal (Figures 1 and 2). The trash rack is constructed of widely spaced heavy bars and prevents large debris, logs and floating ice from entering the plant. The fine mesh (0.375 $in.^2$) traveling screens consist of a continuous belt of screen panels which move vertically through the inflowing water, removing small debris which could clog the narrow passages of the cooling system. The traveling screens are cleaned by a spray system. The intake forebays are preceded by a long wharf, supported by many pilings.

During March 1963, fish congregated in the intake forebays and were subsequently collected on the traveling screens. Striped bass, tomcod, and white perch dominated the collections. The quest for effective fish barriers began in 1963. Air curtains installed in front of the forebays in April 1963 were completely ineffective. In July 1963, foxwire netting was placed across openings in the sheet piling around the wharf, but the large collections of debris and resultant water pressure constantly removed the netting. The experimental barriers having failed, the fish were netted from

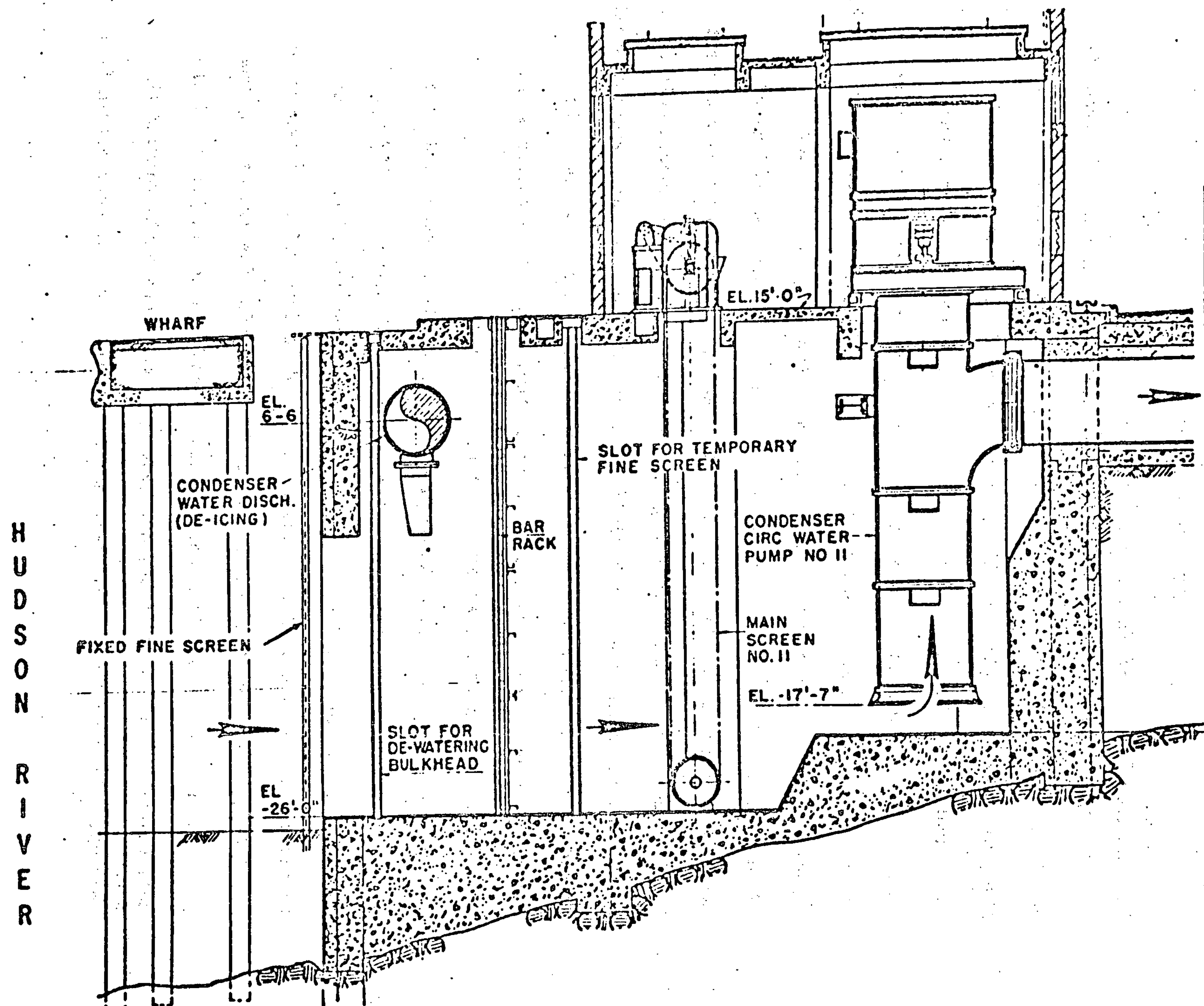

Figure 1. Indian Point No. 1 section of intake.

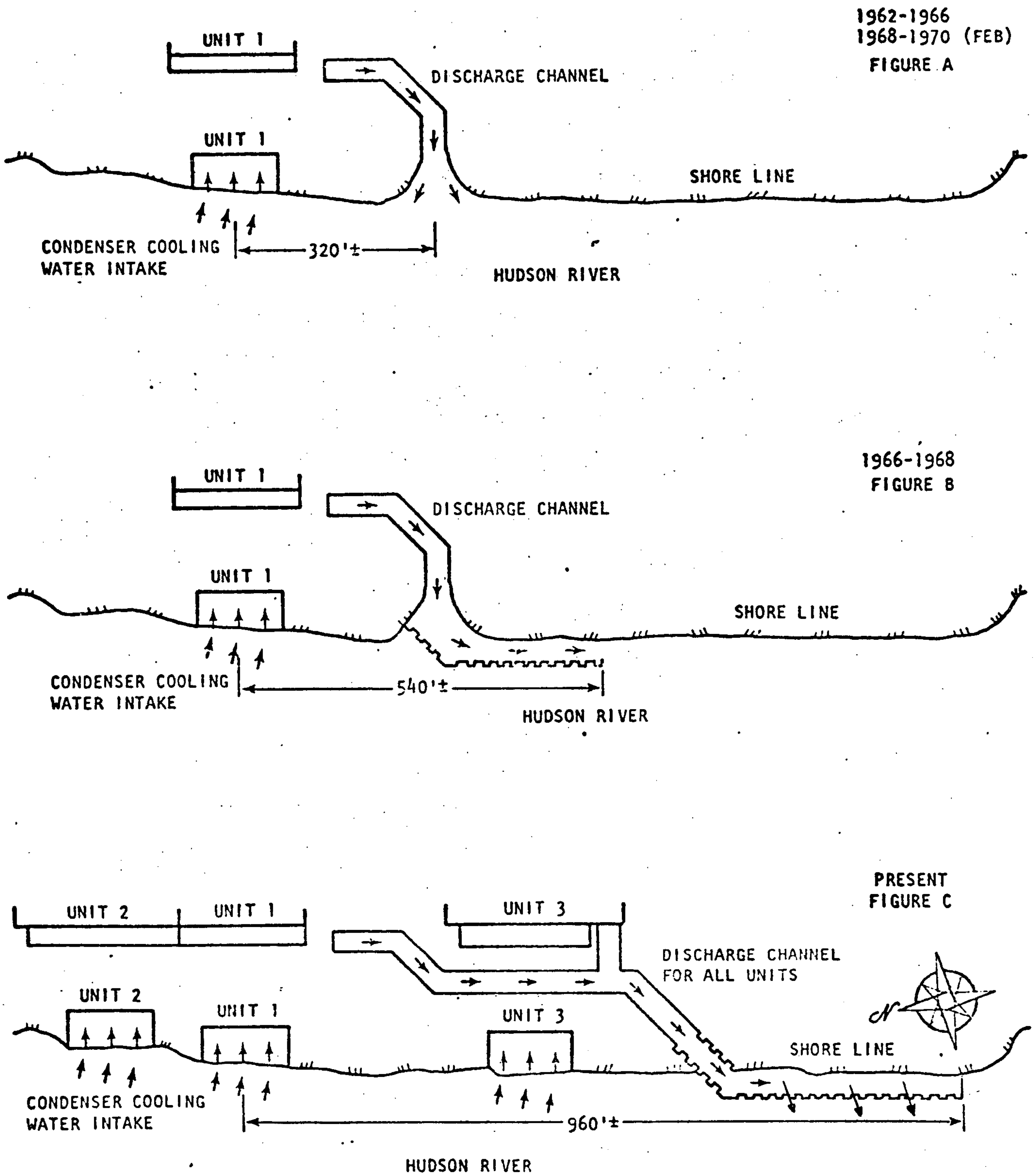

Figure 2. The evolution of the Indian Point intake-discharge structure.

the forebays and released to the river (Consolidated Edison, 1970).

In February 1964, Dr. Alfred Perlmutter (New York University) suggested that fish were being attracted to the intakes by the sanctuary of the wharf and warm discharge water carried upstream by the tide. The results of hydraulic model studies by Alden Hydraulic Laboratory confirmed that warm water from the discharge was being recirculated through the intakes. The discharge channel was modified to direct the flow south along the river bank (Figure 2) and this reduced recirculation and the temperature rise from 10° F to 6° F in the thermal model. The outfall structure was again modified in 1972 to utilize controlled submerged discharge ports for releasing the effluent, and reduce even further recirculation to the intake forebays.

Other attempts to repel fish at Indian Point have met with limited success. A pneumatic sound source was employed during 1965 with inconclusive results. Fish were initially repelled, but the method gradually lost its effectiveness. Two of the trash racks were modified to 1 x 2 in. bar mesh, but fish became gilled in the screens, rendering them unacceptable. It was recognized in June 1965 that fish collections on the traveling screens increased when sodium hypochlorite was added to the intake forebays. The point of introduction was relocated behind the traveling screens, and large fish were no longer collected on the screens. Many small fish were still collected, and some were alive when washed from the screens. The sluice was extended to carry the live fish to the river, but this was not entirely satisfactory because the dead fish were returned to the intakes by the tide and during winter they were deposited on the ice cover of the river. Sheet piling sections were removed from the ends of the wharf in an effort to reduce the sanctuary effect, but small fish continued to be impinged on the screens. During 1966 the area beneath the wharf was illuminated by floodlights in an unsuccessful attempt to repel fish. The forebay entrances were enlarged, reducing the average intake velocity from approximately 1.3 to 0.8 ft. per second. Tests at Indian Point (1965, 1970) have demonstrated that there is a direct relationship between intake velocity and impingement rates.

The installation of fine mesh fixed screens (0.375 square inch opening) at the mouth of the intake forebays during 1967 resulted in a substantial reduction in the numbers of fish collected. Tests of the fixed screens indicated that they were a very effective barrier to fish entering the forebays. Since the fixed screens were placed at the mouth of the intakes, fish could move to either side to avoid the intake flow. The design approach velocity to these screens was less than one foot per second when the screens were clean.

Sparcity of fish collection records makes it impossible to evaluate the fish impingement problem for 1968 to the fall of 1969. In the fall of 1969, the fixed screens were removed because of the large volume of leaves collected on the traveling screens and the threat of losing condenser cooling water due to screen blockage by frazzle ice. In January 1970, the fixed screens were returned to service, but from time to time abnormal numbers of fish were still collected on the traveling screens. An inspection of the intakes revealed large holes under some of the fixed screens, and these were subsequently filled. Repair of the screens reduced fish impingement from an average of more than 38,000 per day on 2-3 February to sustained counts of less than 5000 per day after 6 February (Consolidated Edison, 1970). This change in impingement rate indicated that the fixed screens were effective in reducing the total numbers of fish collected at the Unit 1 intake.

During early March 1970, large numbers of fish were collected on the fixed screens. By 5 March, 69,000 small fish had been collected from the fixed screens. On 7 March, the screens were raised and cleaned; 120,000 fish were collected as a result of leaving the screens in place during the preceding weeks. The debris fouling the screens was anlayzed and found to contain a high percentage of nylon fibers. The source of the nylon fibers is unknown. As the screens become fouled with various debris, the intake velocity of the water is apparently increased, resulting in greater impingement rates. Attempts to maintain clean screens during periods of heavy fouling have been generally successful.

The modifications in plant design and operational procedure which have been implemented to reduce fish impingement are summarized as follows:

DATE	MAJOR CHANGE
June 1965	moved point of injection of sodium hypochlorite at intake
August 1965	removed sheet piling around warf
April 1966	intake openings enlarged (reducing intake approach velocities)
Spring 1966	discharge extended to 540 feet from intake as opposed to original 320 feet
November 1967	removed discharge extension because of construction of Unit No. 3, returning discharge to 320 feet from intake
December 1967	completed installation of fixed fine screens on all intakes
Fall 1969	fixed fine screens blocked in fully open position
December 1969	fixed fine screens partially lowered
January 28, 1970	fixed fine screens fully lowered and back-up screens installed

February 1970	holes under screen plugged
February 6, 1970	discharge moved 960 feet from intake
April 1970	changed procedure for disposal of dead fish to minimize recirculation
April 1970	tested reduced flow operation
December 29, 1970	discharge moved 1,155 feet from intake
January 1971	commenced operation with flow at 60% of normal flow and continued until April and thereafter reduced flow on days when the numbers of fish collected appeared unusual
June 1972	ports completed for submerged discharge, with adjustable gates designed for an exit velocity of approximately 10 fps.

Indian Point Fish Advisory Board

The magnitude of fish impingement during the winter of 1969-70 resulted in additional investigations of fish protection measures by Consolidated Edison. To assist the Company the Fish Advisory Board was formed. The Board consists of expert biologists and engineers from the United States and Great Britain, and its function is planning and implementing studies to achieve fish protection at Indian Point. It has met frequently since May 1970 to provide technical assistance to Consolidated Edison's fish impingement studies.

The Indian Point Fish Advisory Board has also considered the fish impingement problem in some detail (Consolidated Edison, 1972). The Board concluded that intake velocities of 0.5 ft./sec. in summer and 0.3 ft./sec. in winter would protect the fish populations of the area. Field observations and laboratory experiments on the swimming ability of local species supports these conclusions (Tatham, 1970). The design of new intake structures and modifications to the existing ones have been reviewed. The Board has recognized that the most effective intake design must provide low intake velocity, self-cleaning capability for traveling screens, elimination of sanctuary areas near intakes, or effective fish transfer facilities. In conclusion, the Board has recommended the following measures to achieve fish protection at Indian Point:

- Provide for low intake velocities until a long-range solution is achieved
- Evaluate the effectiveness of air curtains
- Evaluate the effectiveness of traveling screens at Unit 3 vs fixed screens at Units 1 and 2
- Initiate preliminary design to move the traveling screens to the front of the forebays on Units 1 and 2, if the above proves successful
- Study and test the operation of a fish hatchery to mitigate fish losses
- Continue support for research and development of the horizontal traveling screen and fish basket (National Marine Fisheries Service)
- Conduct a population dynamics study of striped bass and white perch to determine the ecological significance of impingement mortality at Indian Point
- Continue the feasibility study and preliminary design of a common intake structure for all three units at Indian Point.

Consolidated Edison is actively pursuing all of these recommendations of the Fish Advisory Board (Section 13). Company engineers are designing a common intake structure for all three units which will have maximum intake velocities of 0.3 ft./sec. with flow reduction during the winter and 0.5 ft./sec. during the remainder of the year (Figure 3). This structure will provide low intake velocity, self-cleaning capabilities for the traveling screens, and the elimination of sanctuary areas near the intakes. Hydraulic model studies of the common intake structure (screened lagoon) were completed in compliance with requirements of the New York State Department of Environmental Conservation.

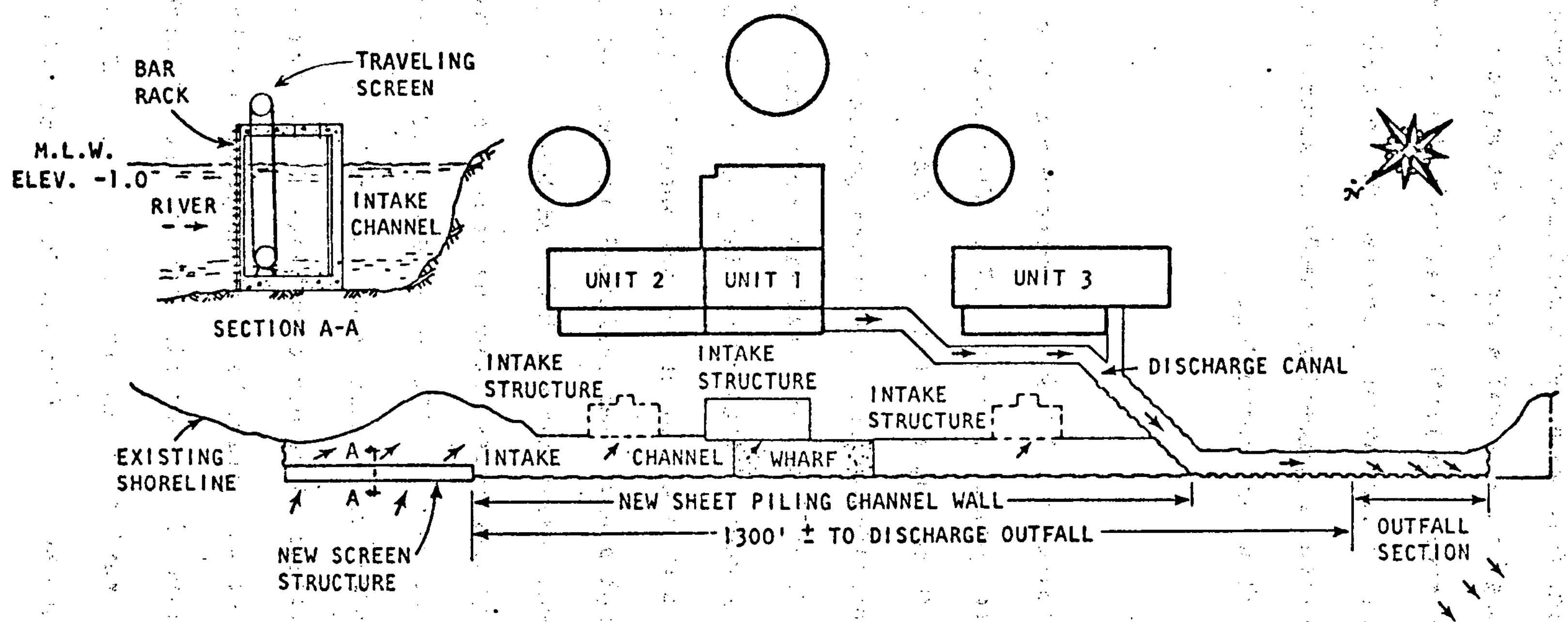

Figure 3. Proposed common intake structure for Indian Point.

The Board has also considered horizontal traveling screens and fish guidance systems. It found that in order to maintain an adequate bypass flow and to handle the large numbers and sizes of fish approaching the screens through the pumps there was little likelihood that such a system would reduce fish losses at Indian Point. The search for large capacity pumps to handle fish and other engineering methods to separate the handling of fish and bypass water flows is continuing.

FISH COLLECTIONS

Although Indian Point Unit 1 has been operational since 1962, records of fish impingement are incomplete until 1970. Fish collections were performed irregularly before 1970, making it difficult to determine total numbers collected per month or year. Consolidated Edison's investigation of fish impingement at Indian Point since April 1970 has included fish collections and manipulating intake velocities and screen arrangements. Sampling has been conducted at selected time intervals when the plant was not operating (April-December 1970). Since January 1971 samples have been collected and recorded daily. The fixed screens were cleaned once daily between 0800 and 1200. The traveling screens were cleaned once every four hours beginning at midnight. Fish collected from the traveling screens at 0800 and 1200 were identified, weighed and measured (total length). A subjective evaluation of the condition of each specimen was also recorded. Fish collected at other washings of the traveling screens were recorded as total number per intake bay. White perch was the dominant species in the collection but striped bass, tomcod, herrings and bay anchovy occurred in abundance for extended periods during the study. The available data have been treated to yield average number of fish per day by month (Table 1). The largest collections have occurred during the winter months (November through March).

Table 1. Average daily impingement at Indian Point Unit 1.

Data from Consolidated Edison.

	Year							
					1971		1972	
Month	1965	1966	1967	1970	Full Flow	60% Flow	Full Flow	60% Flow
January			7200[1]	20000[2]		453		679
February			4300	6000[2]		4853		1237
March	1100		4400	8000[2]		333		871
April	1500	500		1102	497		225	
May		700			181		30	
June	500	600		52	141		87	
July	3100	1600			51		22	
August	6300	1000		797	814		534	
September	1400	900		149	1217		1142	
October	1000	1300		343		117	797	
November	700	1400		1584		930		210
December		4600		1898		1127		106

[1] Fine mesh fixed screen tested in BAy 11.

[2] Included dead fish netted in front of fixed screens. During this period screens were fouled, improperly cleaned, and holes under screens were repaired.

From April 1970 to August 1971, a total of 38 species were collected at the Indian Point intakes. This total included 21 estuarine, 13 freshwater, and four coastal marine species. The abundance and diversity of species varied seasonally (Table 2). Species diversity was greatest during the fall, 1970, and the lowest in January and early February, 1971. The diversity of species collected on the screens corresponds to a similar seasonal diversity in the river. Raytheon (1971) collected 48 species in the vicinity of Indian Point, but 13 of these were rare in occurrence. Species diversity was lowest in winter, increased with water temperature, and declined again in late fall. The most abundant species in the river were the bay anchovy, white perch, tomcod, striped bass, alewife, hogchoker, and blueback herring. These are also the species which were collected in greatest abundance on the intake screens.

A relatively small number of species constitute the bulk of the fish collected at the Indian Point intake screens (Table 3). White perch, striped bass, tomcod, herrings (Alosa spp.), and bay anchovy have occurred in abundance for extended periods of time. From December 1970 to March 1972, these species were 97.1 percent of the total catch: white perch, 70.7 percent; tomcod, 8.3 percent; striped bass, 3.1 percent; herrings, 12.8 percent; bay anchovy, 2.2 percent; all other species, 2.9 percent. Definite seasonal variations have occurred in the species collected on the screens (Figures 4-7). White perch were more than 90 percent of the catch during April 1970 and December 1970 to March 1971. Striped bass were a small percentage of the catch throughout the year. Tomcod were numerous during June, August, and October. The herrings were abundant during the fall. The herring samples, in which species were accurately identified, were dominated by blueback herring. Very few American shad were collected. The bay anchovy was most abundant in the summer and fall.

Table 2. A list of fishes collected from the traveling screens at Indian Point Unit 1 and their seasonal occurrence. April 1970 to August 1970. Data from Consolidated Edison.

Species	Spring Apr-Jun	Summer Jul-Sep	Fall Oct-Dec	Winter Jan-Mar
White perch (*Morone americana*)	A	C-A	A	A
Spottail shiner (*Notropis hudsonius*)	A	-	C	C
Tomcod (*Microgadus tomcod*)	C-A	A	C-A	C
Catfish (*Ictalurus nebulosus*) (*I. catus*)	C	C	C	C
Striped Bass (*Morone saxatilis*)	C-A	C-A	C	C-A
Rainbow smelt (*Osmerus mordax*)	C-A	C	C	C
Sunfish (*Lepomis gibbosus*) (*L. macrochirus*)	C	C	C	C
Killifish (*Fundulus heteroclitus*) (*F. diaphanus*)	C	-	C	C
Stickleback (*Gasterosteidae*) (possibly 2 species)	U	-	U	U
American eel (*Anguilla rostrata*)	C	C	C	C
Golden shiner (*Notemigonus crysoleucas*)	C	-	U	U
Goldfish (*Carassius auratus*)	C	-	-	U
Herrings (*Alosa aestivalis*) (*A. pseudoharengus*) (*A. sapidissima*)	C	C-A	A	U
Yellow perch (*Perca flavescens*)	U	-	U	U
Johnny darter (*Etheostoma nigrum*)	U	-	U	U
Atlantic sturgeon (*Acipenser oxyrhynchus*)	U	-	U	U
Hogchoker (*Trinectes maculatus*)	C-A	C	C	U

(A=Abundant, making up at least 10% of catch; C=Common, of regular occurrence but not making up 10% of catch; U=Uncommon, of irregular occurrence; R=Rare, no more than a few specimens).

Table 2. Cont'd.

Species	Spring Apr-Jun	Summer Jul-Sep	Fall Oct-Dec	Winter Jan-Mar
Bay anchovy (*Anchoa mitchelli*)	-	C	C	-
Bluefish (*Pomatomus saltatrix*)	-	R	-	-
Weakfish (*Cynoscion regalis*)	-	R	-	-
Northern pipefish (*Syngnathus fuscus*)	-	-	C	-
Lookdown (*Selene vomer*)	-	-	R	-
Atlantic menhaden (*Brevoortia tyrannus*)	-	-	C	-
Carp (*Cyprinus carpio*)	-	-	R	-
Silverside (*Menidia sp.*)	-	-	U	-
Searobin (*Trigilidae*)	-	-	R	-
Hake (Gadidae)	-	-	R	-
Winter flounder (*Pseudopleuronectes americanus*)	-	-	R	-
Crappie (*Pomoxis sp.*)	-	-	R	-
Emerald shiner (*Notropis atherinoides*)	-	-	-	R
Largemouth bass (*Micropterus salmoides*)	-	-	-	R
Crevalle jack (*Caranx hippos*)	-	R	-	-

Table 3

SPECIES COMPOSITION OF FISH COLLECTED AT INDIAN POINT UNIT 1 TRAVELING SCREENS APRIL 1970 TO DECEMBER 1972. Data from Consolidated Edison.

Sampling Interval	Total no. of species	Total no. of fish	Total no. identified	White Perch	Striped Bass	Tomcod	Herrings[1]	Bay Anchovy	Rainbow Smelt	Spottail Shiner	Other
				Percent composition of total number identified							
4/4 - 4/16/70	16	6382	4962	76.2	2.8	1.3	0.04		3.3	11.5	4.86
4/20 - 4/26/70	15	10862	3346	90.4	2.1	0.7	0.2		4.5	0.5	1.6
5/19 - 5/21/70	6	23	23	30.4					26.1		43.1
6/9 - 6/15/70	6	261	216	19.9	12.5	63.9			0.9		3.3
8/7 - 8/17/70	12	8768	7742	1.2	3.2	72.0	1.0	20.1	1.1		1.4
10/6 - 10/21/70	18	2383	1898	16.3	2.5	11.9	34.8	23.0	2.4	3.1	6.0
10/22 - 11/5/70	20	46	5112	28.1	4.4	2.8	39.8	7.2	1.9	0.08	15.72
11/6 - 11/10/70	21	11085	6639	33.7	2.5	0.6	55.0	2.4	3.1	0.08	3.16
12/7 - 12/13/70	19	8736	7848	92.7	2.0	0.01	1.8	0.1	0.5	0.7	2.28
12/14 - 12/20/70	20	16136	15905	95.9	1.5	0.4	0.6	0.1	0.3	0.3	0.9
12/21 - 12/24/70	19	7462	7403	92.8	1.9	1.1	1.1	0.1	1.0	0.2	1.8
1971											
1/7 - 1/13/71	10	2205	2205	94.5	3.3	0.4	0.1		1.1	0.3	0.3
1/14 - 1/20/71	4	1461	1431	90.8	8.3	0.5			0.3		.0
1/21 - 1/27/71	6	2955	2950	97.3	2.3	0.07	0.2				0.13
1/28 - 2/7/71	7	1403	1403	93.0	6.3	0.3			0.07	0.1	0.32

Table 3 Cont'd.

Sampling Interval	Total no. of species	Total no. of fish	Total no. identified	Percent composition of total number identified: White Perch	Striped Bass	Tomcod	Herrings	Bay Anchovy	Rainbow Smelt	Spottail Shiner	Other
2/8 - 2/14/71	6	15915	8750	97.1	2.7	0.06			0.1	0.1	0.03
2/15 - 2/21/71	9	44490	24508	95.9	4.0	0.008	0.004		0.03	0.008	0.05
2/22 - 2/28/71	10	20506	13760	94.4	5.3	0.02	0.007		0.09	0.06	0.12
3/1 - 3/7/71	16	7339	5166	91.2	7.7	0.1	0.02		0.08	0.2	0.7
3/8 - 3/14/71	13	1639	1018	75.8	15.0	0.3				0.7	8.2
3/15 - 3/21/71	14	674	400	70.0	14.0	0.5	0.3			3.5	11.7
3/22 - 3/31/71	15	660	293	59.7	9.9	1.7			1.0	5.1	22.6
Total 4/4/70 - 3/31/71		176491	123800 #	99545	4438	6409	3463	2561	979	838	5567
			%	80.4	3.6	5.2	2.8	2.1	0.8	0.7	4.5

Table 3 Cont'd.

Sampling Interval	Total no. of species	Total no. of fish	Total no. identified	Percent composition of total number identified: White Perch	Striped Bass	Tomcod	Herring	Bay Anchovy	Rainbow Smelt	Hogchoker	Other
4/1 - 4/7/71	14	853	589	90.7	3.7	0.5			0.3		4.8
4/8 - 4/14/71	12	213	166	75.3	3.0				3.6		18.1
4/15 - 4/21/71	11	513	260	91.5	2.3	0.4			0.4		5.4
4/22 - 4/30/71	16	4717	4052	96.5	0.2	0.05			1.3	0.07	1.9
5/1 - 5/7/71	12	2945	2305	97.7	0.3		0.04		0.9	0.08	0.1
5/8 - 5/14/71	13	745	363	78.2		0.3	1.1		2.7	3.6	14.1
5/15 - 5/21/71	9	650	390	68.9	0.3		5.6		5.1	9.5	10.6
5/22 - 5/29/71	14	681	342	53.4		0.3	4.1		10.2	17.0	15.0
6/1 - 6/7/71	6	54	25	52.0		16.0	4.0		8.0	16.0	4.0
6/8 - 6/14/71	19	1673	1372	70.2	3.0	16.7	1.3	0.3	1.4	4.8	2.3
6/15 - 6/21/71	16	1080	742	77.9	8.3	4.1	2.8	0.5	0.6	3.0	2.8
6/22 - 6/30/71	18	487	321	28.0	18.0	23.7	1.8	7.0	2.2	9.0	10.3
7/1 - 7/7/71	13	256	82	15.8	18.3	30.4	4.8	9.7	4.8	8.5	7.7
7/8 - 7/14/71	13	354	249	32.5	10.8	36.9	4.0	4.8	4.0	4.4	2.6
7/15 - 7/21/71	8	697	338	28.7	0.3	36.9	17.1	15.1	0.8		1.1
7/22 - 7/31/71	4	383	135	19.2		41.4	22.2	17.0			
8/1 - 8/7/71	12	1607	1583	12.0	0.06	75.7	3.1	7.9	0.4	0.4	0.44

Table 3 Cont'd.

Sampling Interval	Total No. of species	Total no. of fish	Total no. identified		White Perch	Striped Bass	Tomcod	Herring	Bay Anchovy	Rainbow Smelt	Hogchoker	Other
					Percent composition of total number identified							
8/8 - 8/14/71	10	2140	1637		19.9	1.2	60.0	7.0	10.9	0.7	0.06	0.2
8/15 - 8/21/71	11	3281	2522		21.8	0.6	62.0	4.7	9.3	0.7	0.5	0.4
8/22 - 8/31/71	17	12605	11133		63.2	1.0	26.1	4.6	3.6	0.7	0.4	0.4
Total 4/1/71 - 8/31/71		35934	28606	#	17763	405	7305	989	1067	319	318	440
				%	62.1	1.4	25.5	3.5	3.7	1.1	1.1	1.5

Table 3 Cont'd.

Sampling Interval	Total no. of species	Total no. of fish	Total no. identified	White Perch	Striped Bass	Tomcod	Herring	Bay Anchovy	Rainbow Smelt	Hogchoker	Other
				Percent composition of total number identified							
9/1 - 9/30/71	19	18244		29.7	0.9	23.9	32.9	10.6	0.6	0.2	1.3
10/1 - 10/26/71	22	16176		33.7	1.6	4.4	57.3	0.5	0.3	0.1	2.2
11/1 - 11/30/71	21	37174		70.1	4.4	0.0	23.4	0.0	0.1	0.0	2.0
12/1 - 12/31/71	17	21870		92.7	2.2	2.4	2.9	0.0	0.1	0.0	1.9
1/1/72 - 1/31/72	13	14685		89.0	2.2	6.0	0.2	0.0	0.0	0.0	2.5
2/1 - 2/15/72	10	7721		75.8	1.1	20.8	0.1	0.0	0.0	0.0	2.2
Total											
9/1/71 - 2/15/72		115322 #		75088	2955	7783	24718	2003	201	51	2523
		%		65.1	2.6	6.7	21.4	1.7	0.2	0.0	2.2
6/23 - 6/29/72	14	369		61.0	0.0	28.7	2.9	0.0	0.0	0.0	7.4
6/30 - 7/5/72	13	71		60.6	2.8	11.3	8.5	0.0	0.0	0.0	16.8
7/6 - 7/12/72	11	58		60.3	1.7	12.1	3.5	0.0	0.0	0.0	22.4
7/13 - 7/19/71	12	189		87.8	2.1	0.0	1.1	0.0	0.0	0.0	9.0
7/20 - 7/26/72	16	230	231	26.1	7.0	50.4	0.9	0.0	0.4	0.4	14.8
7/27 - 8/2/72	15	291		20.3	18.9	43.0	2.1	6.2	2.1	0.0	7.4
8/3 - 8/9/72	21	5756		5.3	3.0	37.0	4.9	44.5	3.9	0.0	1.4
8/10 - 8/16/72	18	5065	5066	10.4	2.2	32.1	5.9	47.5	1.9	0.0	0.0
8/17 - 8/23/72	17	2176		13.1	3.2	31.2	6.6	42.7	0.9	0.0	2.3
8/24 - 8/30/72	18	2619	2620	14.4	2.4	44.1	4.0	33.3	0.5	0.2	1.1

Table 3 Cont'd.

Sampling Interval	Total no. of species	Total no. of fish	Total no. identified	Percent composition of total number identified							
				White Perch	Striped Bass	Tomcod	Herring	Bay Anchovy	Rainbow Smelt	Hogchoker	Other
8/31 - 9/6/72	17	10957		3.2	1.0	72.1	2.6	19.1	0.6	0.2	1.2
9/7 - 9/13/72	14	12590		3.2	0.8	79.3	1.2	12.5	0.2	0.1	2.7
9/14 - 9/20/72	15	3065		10.0	2.5	67.1	1.0	18.6	0.1	0.1	0.6
9/21 - 9/27/72	16	5637		12.8	1.2	73.5	0.7	10.5	0.0	0.1	1.2
9/28 - 10/4/72	20	5586		13.3	1.3	61.4	1.8	18.1	0.1	0.0	4.0
10/5 - 10/11/72	15	6122		30.1	1.9	53.0	2.7	9.3	0.1	0.1	2.8
10/12 - 10/18/72	22	4775		66.4	2.5	10.1	8.7	4.0	0.3	0.2	7.8
10/19 - 10/25/72	18	6020		77.3	1.4	4.3	12.5	0.9	0.3	0.3	3.0
10/26 - 11/1/72	18	2865		84.6	1.1	4.3	6.8	0.5	0.2	0.1	2.4
11/2 - 11/8/72	10	240		82.5	3.8	7.1	3.8	0.8	0.4	0.8	0.8
11/9 - 11/15/71	18	1937		88.5	3.1	1.8	2.3	0.6	0.4	0.1	3.2
11/16 - 11/22/72	14	2211		90.9	1.2	0.3	3.3	0.1	0.1	0.1	4.0
11/23 - 11/29/72	10	1592		92.3	2.3	0.9	1.2	0.1	0.2	0.0	3.0
11/30 - 12/6/72	12	943		87.4	4.1	4.1	1.0	0.6	0.4	0.0	2.4
12/7 - 12/13/72	14	800		87.9	2.5	4.5	0.4	1.1	1.0	0.0	2.6
12/14 - 12/20/72	14	884		86.8	2.9	1.1	0.5	1.0	0.3	0.0	7.4
12/21 - 12/27/72	12	599		81.1	1.2	2.3	0.3	0.0	2.2	0.0	12.9
12/28 - 1/3/73	10	217		55.8	6.5	16.1	0.5	0.0	0.0	0.0	21.1
Total 6/23/72 - 1/3/73		83787 #		24999	1517	37788	3167	13493	527	94	2202
		%		29.8	1.8	45.1	3.8	16.1	0.6	0.1	2.6

[1]Herring includes shad, alewife and blueback

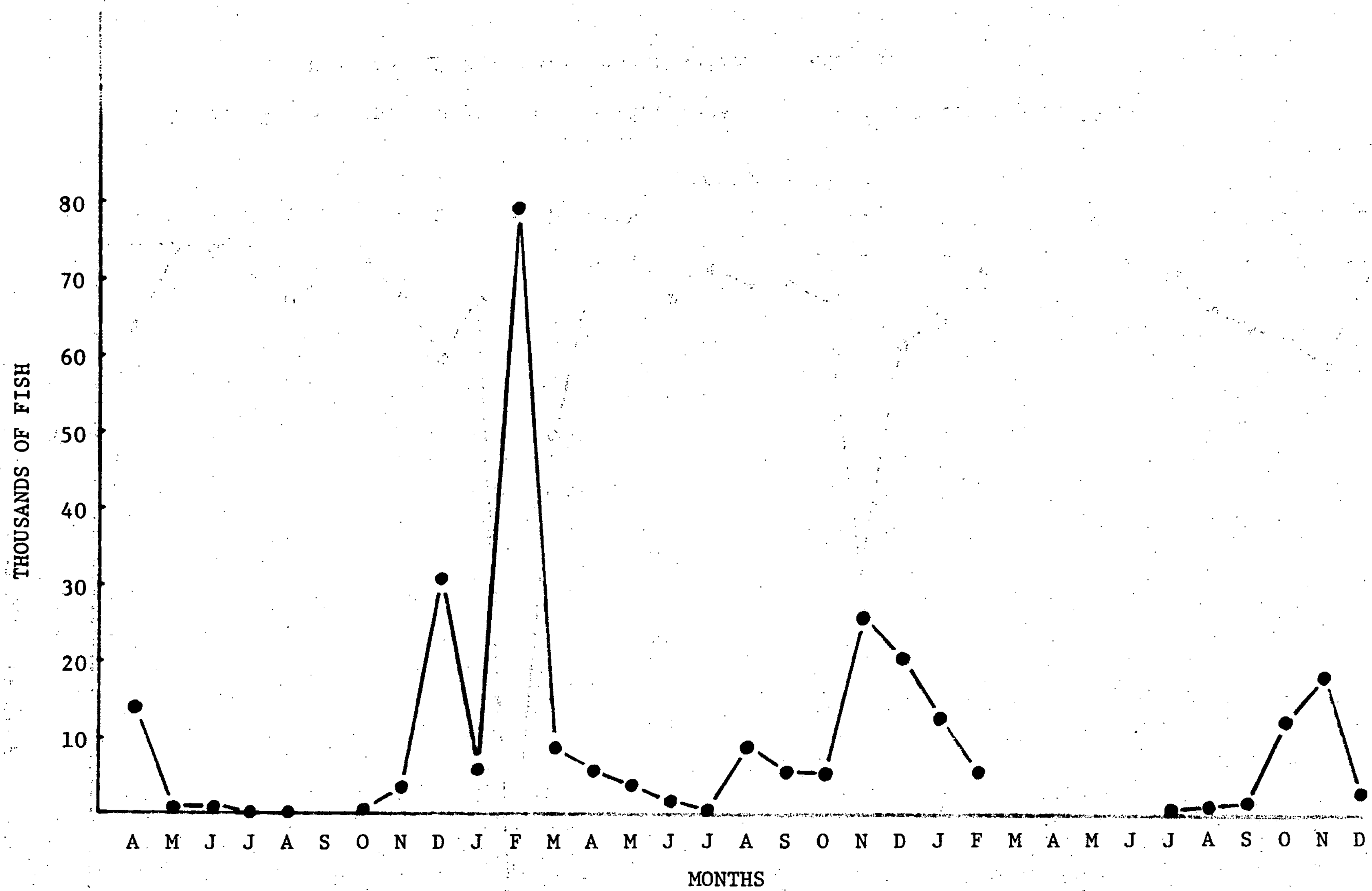

Figure 4. Seasonal abundance of white perch at Unit 1 intakes, April 1970-December 1972. Data from Consolidated Edison.

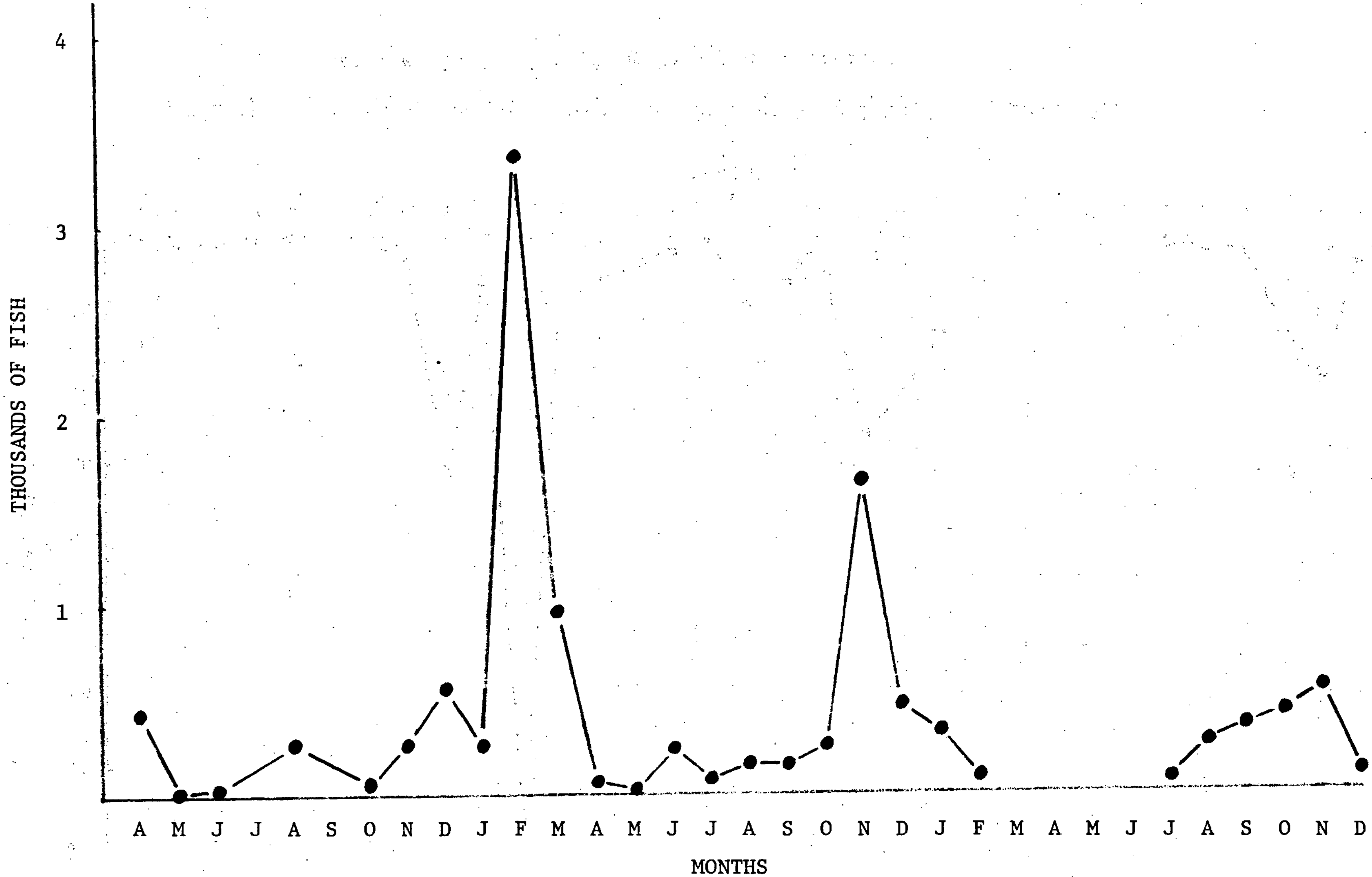

Figure 5. Seasonal abundance of striped bass at Unit 1 intakes, April 1970-December 1972. Data from Consolidated Edison.

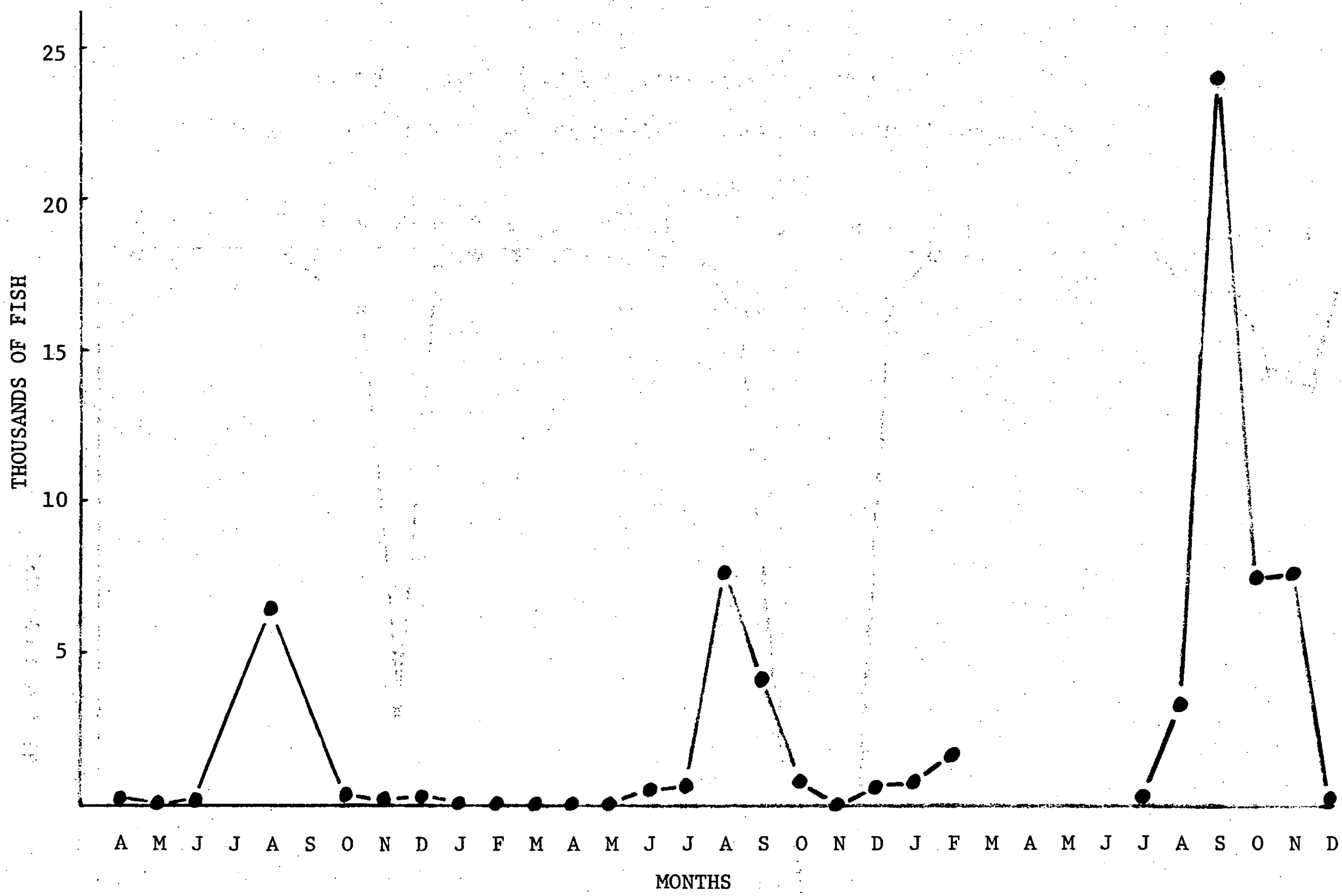

Figure 6. Seasonal abundance of tomcod at Unit 1 intakes, April 1970-December 1972. Data from Consolidated Edison.

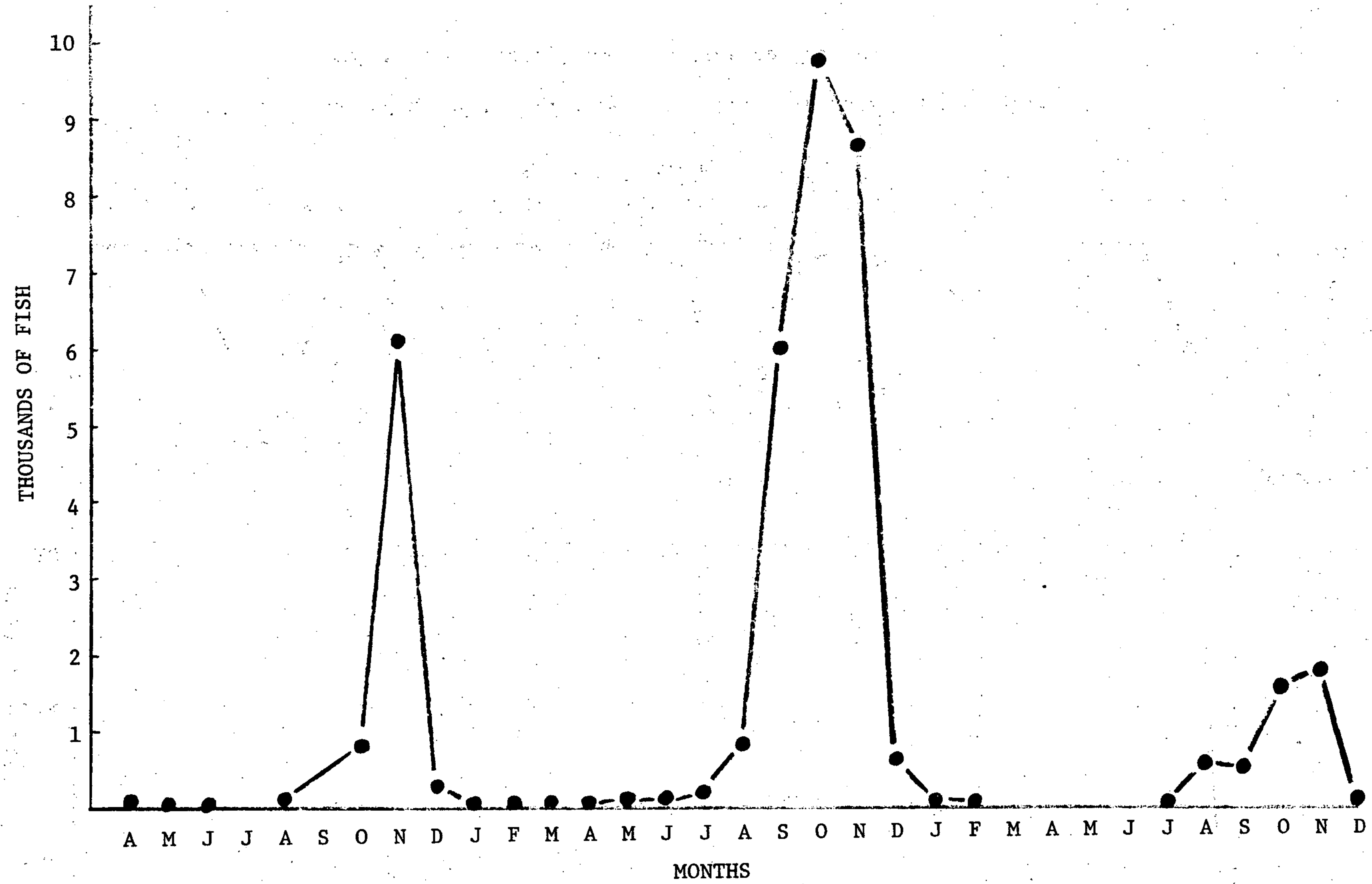

Figure 7. Seasonal abundance of herrings at Unit 1 intakes, April 1970–December 1972. Data from Consolidated Edison.

The fish collected on the intake screens at Indian Point are small in size throughout the year. Although a range of sizes are present, the average lengths and weights of species are small (Table 4). The large winter collections are principally white perch, between two and three inches in length. White perch of this size would be predominately young-of-the year fish, age 0+ (AEC, 1972).

Table 4. Average lengths and weights of fish collected at Unit 1 from April 1970 through February 15, 1972.

Species	Average length (mm)	Average weight (grams)
White perch	67.5	3.7
Striped bass	83.5	6.2
Tomcod	91.3	7.1
Bay anchovy	61.6	1.8
Spottail Shiner	74.0	3.8
Rainbow smelt	88.5	4.8

From the data collected at the Unit 1 intakes during 1971-72 it is possible to estimate annual fish collections at Unit 1 with current intake design and operational procedures (Alevras, 1973). There are enough complete sampling days during this time period to calculate average number of fish collected per day by month (Table 4). The monthly totals are summed to provide the annual collection, based on the assumption that the plant operates all days in the year. This figure is increased by a factor of 25% for collecting error to yield the projected number of fish collected annually at Unit 1 intakes. The final estimate for Unit 1 can be used to predict impingement at Units 2 and 3 assuming that impingement is directly related to flow rate and follows a similar pattern of abundance.

Given the estimate of annual impingement, the species composition and average weights can be used to project the annual impingement of species in absolute numbers and pounds (Table 5). Although the numbers of fishes collected on the intake screens seem large, the actual poundage is small.

The estimates of fish impingement are based on the assumption that the plants operate at full load all days in a year. This situation will probably never occur and, therefore, the assumption has the effect of over-estimating the total annual collection. The assumption was necessary because it is impossible to predict the time and duration of outages in any given year. As an example of the difference between the estimated collections and the actual, a comparison can be made between the estimated annual total based on 1970-72 data and the actual number collected in 1972. Table 5 shows that the estimated total exceeds the actual by 68.5%. The difference between the estimated total collection and the actual will vary from year to year depending on the time and duration of outages. In most years the actual collections are expected to be substantially less than the estimated total.

Table 5. Projected number of fish collected per month at Indian Point Unit 1 and the actual total collected during 1972. The projected number is based on average daily fish collections at Unit 1 during 1970-72. Data from Consolidated Edison.

Month	Average Number of Fish/Day	Projected Total/ Month	Pounds	Actual Collections for 1972	Actual Weights for 1972
Jan.	756 R	23,436	292.8	19,689	128.9
Feb.	3,843 R	107,604	1,345.4	35,865	346.3
Mar.	473 R	14,663	183.2	27,015	281.7
Apr.	497 F	14,910	186.3	6,747	69.3
May	181 F	5,611	70.1	933	8.0
June	141 F	4,230	52.7	1,990	46.1
July	51 F	1,581	19.6	694	64.5
Aug.	814 F	25,234	315.3	16,559	366.2
Sep.	1,217 F	36,510	456.3	33,249	565.4
Oct.	117 R	3,627	45.3	23,716	320.5
Nov.	930 R	27,900	348.6	6,306	61.0
Dec.	1,064 R	32,984	412.2	3,299	61.2
Total		298,290		176,062	
Adjusted Total		372,863*		220,077*	

(R = reduced flow; F = full flow)

*Total adjusted upward by 25% for undersampling.

Table 6. Projected number and weight of fish species collected annually at Indian Point Unit 1. Data from Consolidated Edison.

Species	Percent Composition	Projected Annual No.	Mean Weight (oz.)	Projected Annual Wt. (lbs.)
White perch	70.7	263,614	.13	2142
Striped bass	3.1	11,559	.22	159
Tomcod	8.3	30,948	.25	484
Herrings	12.8	47,726	.20	597
Bay anchovy	2.2	8,203	.06	31
Other	2.9	10,813	1.0	676
Total	100.0	372,863		4,089

Fixed Screens

Fixed screens were installed in all Unit 1 bays by December 1967 and essentially eliminated the impingement of large fish. Tests of the fixed screens indicated that they were a very effective barrier to fish entering the forebays (Table 7).

Table 7. Summarized results of the effectiveness of fine-meshed fixed screens at Indian Point intakes (January to March 1967). Adapted from Consolidated Edison (1970).

	Screened	Unscreened	
	Bay 11	Bay 12	Bays 13 and 14
Number of collections	59	61	59
Total fish collected	7016	30,180	48,811
Average fish per collection	119	495	827
Percent of total collected	8	35	57

Tests at the Unit 1 intakes during April 1970 indicated that the fixed screens influence the average length and weight of the fish collected (Table 8). When the fixed screens were not used, fish larger than those normally collected entered the bays, became trapped, and were subsequently impinged on the traveling screens. It is likely that the large fish would have escaped if

Table 8. Summary of species composition and average length and weight for the dominant species in the catch during tests of fixed screens, 21-23 April 1970. Data from Consolidated Edison.

Species	Bay 11 (unscreened) % of Total	Bay 11 (unscreened) Ave. Length mm	Bay 11 (unscreened) Ave. Wt. gm	Bay 12 (screened) % of Total	Bay 12 (screened) Ave. Length mm	Bay 12 (screened) Ave. Wt. gm	Bay 13 (screened) % of Total	Bay 13 (screened) Ave. Length mm	Bay 13 (screened) Ave. Wt. gm	Bay 14 (unscreened) % of Total	Bay 14 (unscreened) Ave. Length mm	Bay 14 (unscreened) Ave. Wt. gm
White perch	52.5	98.3	18.9	30.0	79.0	5.7	80.0	91.3	15.1	69.3	93.3	15.2
Smelt	15.8	109.9	8.9	70.0	90.3	5.6	----	----	----	19.3	122.6	10.9
Striped bass	15.1	94.1	8.8	----	----	----	20.0	100.7	86.0	5.7	92.0	7.2
Total fish		6843			224			165			2248	

fixed screens had been used at all bays. In general, the fixed screens reduce the number of large fish collected, especially during the summer months (Table 1). There is some indication that fixed screens also reduce the number of small fish impinged during the winter if the screens are properly maintained (Con Edison, 1970).

Tests of the effectiveness of secondary fixed screens were conducted from 22 October to 16 November 1971. Secondary fixed screens were installed approximately four feet behind the original fixed screens at Unit 1 to prevent live fish from entering the forebays during the daily cleaning of the outer screens. Results of the tests indicated that the secondary screens did not reduce fish mortality. When the secondary screens were used the debris and fish were merely transferred from the outer screens to the secondary screens requiring an additional screen washing with no appreciable improvement in fish protection.

Flow Reduction

The effectiveness of reduced circulator flow as a fish protective measure has been investigated at Indian Point. Initial experiments by Consolidated Edison during 1965 indicated a substantial increase in the number of small fish collected on the traveling screens when the intake velocity exceeded 1 ft./sec. (Figure 8). Bechtel Associates (1970) concluded after a review of fish protective systems that flow reduction through intake screens, by throttling or pump control, was the simplest method of reducing fish impingement. The Indian Point Fish Advisory Board after examining the results of temperature swim speed studies (King, 1970; Tatham, 1970) has also recommended velocity reduction as a method of reducing impingement mortality.

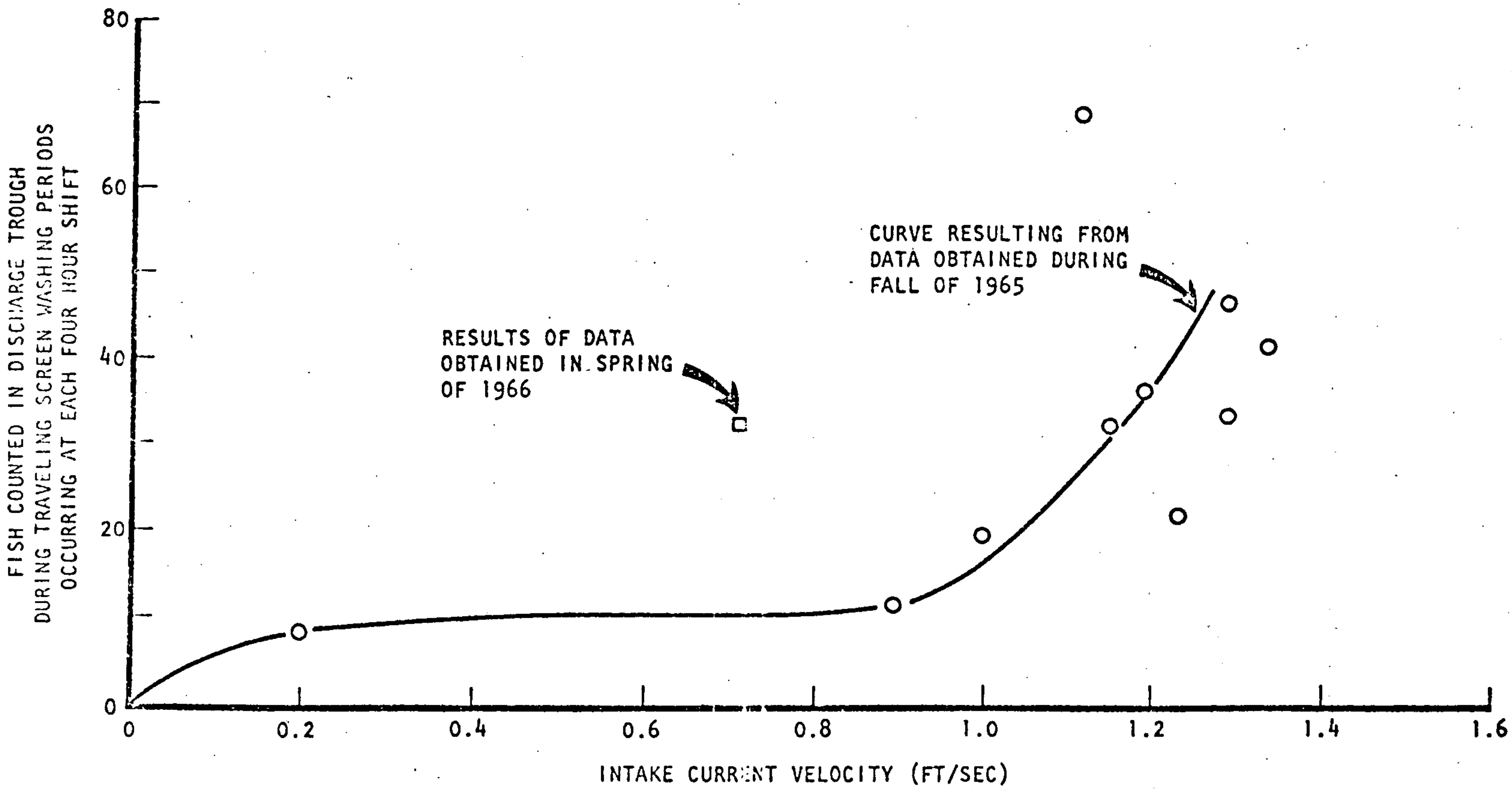

Figure 8. The relationship between intake velocity and fish impingement at Indian Point Unit 1 (Atomic Energy Commission, 1972).

Additional studies of the effectiveness of flow manipulation and fixed screens in reducing impingement mortality were conducted during 1970-1971. The circulator pumps were operated at full and 60% flow with selected bays screened and unscreened. Flow measurements at Unit 1 (approximately 2 to 4 ft. in front of the fixed screens) indicated maximum velocities of 0.7 ft./sec. at full flow and 0.3 ft./sec. at reduced flow. The results of these studies demonstrated that substantially fewer fish were collected at reduced flow than at full flow (Tables 9-11). Additionally, there was an indication that more and larger fish were collected from the unscreened bays at the greater intake velocity (Tables 7 and 8).

Based on the results of experiments with flow reduction and swimming speeds, the fact that the greatest impingement occurs in winter, and the recommendations of the Fish Advisory Board a decision was made to operate Indian Point 1 at reduced flow during the winter and modify the design of Units 2 and 3 to permit intake velocities of 0.5 ft./sec. during winter. Consolidated Edison now plans to operate the Indian Point plant at reduced flow from October through March of each year. This procedure will substantially reduce impingement mortalities during the winter when they are more pronounced while maintaining discharge temperatures within State thermal criteria and without significantly increasing entrainment losses.

Table 9. Number of fish collected from each intake bay at Indian Point Unit 1. April 21 to 26, 1970. Data from Consolidated Edison.

FULL FLOW

Date	Bay 11 unscreened	Bay 12 screened	Bay 13 screened	Bay 14 unscreened
4/21/70	2964	82	60	1169
4/22/70	2268	91	62	590
4/23/70	1611	51	43	489
Total	6843	224	165	2248

REDUCED FLOW (60%)

Date	Bay 11 unscreened	Bay 12 screened	Bay 13 screened	Bay 14 unscreened
4/24/70	98	8	17	31
4/25/70	30	9	4	19
4/26/70	28	3	4	9
Total	156	20	25	59

Table 10. Number of fish collected at full and 60% at Indian Point Unit 1 during 1970.* Data from Consolidated Edison.

Date	BAY 11	BAY 12	BAY 13	BAY 14
	Reduced flow		Full flow	
4/8	14	33	328	187
4/9	8	21	218	238
4/10	13	27	550	284
Subtotal	35	81	1096	709
Total per pump	116		1805	
	Full flow		Reduced flow	
4/11	398	238	78	43
4/12	231	313	63	33
4/13	143	114	20	22
Subtotal	772	665	161	98
Total per pump	1437		259	
	Full flow		Reduced flow	
12/14	626	663	45	15
12/15	1040	1289	160	77
12/16	1299	1515	29	9
12/17	828	824	35	8
12/18	1125	1391	182	86
Subtotal	4918	5682	451	195
Total per pump	10600		646	
	Reduced flow		Full flow	
12/19	622	500	658	1115
12/20	412	628	725	200
12/21	147	408	1604	1213
12/22	260	830	782	322
Subtotal	1441	2366	3769	2850
Total per pump	3807		6619	

*There are two circulator pumps controlling two bays each at Unit 1.

Table 11. Average daily collection of fish at Indian Point Unit 1, December 1970 - March 1972. Data from Consolidated Edison.

Month	Number of Sample Days at Full Flow	Mean Number of Fish/Day at Full Flow	Number of Sample Days at Reduced Flow	Mean Number of Fish/Day at Reduced Flow
January	-	-	22	756
February	-	-	23	3843
March	-	-	57	473
April	10	497	20	66
May	20	181	8	174
June	23	141	-	-
July	15	51	-	-
August	7	814	1	255
September	20	1217	4	108
October	10	2190	12	117
November	19	3958	8	930
December	6	2480	27	1064
Total	130		182	

Air Curtains

The effectiveness of air curtains in front of the intakes has been tested by Consolidated Edison and Quirk, Lawler & Matusky, Engineers. Initial tests in front of the open intake bays without fixed screens were not effective in reducing impingement. However, recent tests of the air curtain in front of the fixed screens indicate that it may reduce fish collections at the intakes (Table 12). The results indicated that Bay 12 collected only 5.7 percent of the total catch when the air curtain was operative compared to 34 percent when the air curtain was not operating.

Table 12. Total number of fish, average number per day and percent of total collected from the four intake bays at Indian Point Unit 1 for three intervals. Data from Consolidated Edison.

Time Interval	Bay 11	Bay 12	Bay 13	Bay 14	Total
2/2 - 5/72					
Total number	2,044	1,908	1,013	1,385	6,350
Average per day	511	477	253	346	1,588
Percent of total	32.2	30.0	15.9	21.8	
2/17 - 29/72*					
Total number	3,779	1,440**	8,403	11,679	25,301
Average per day	378	144	840	1,170	2,530
Percent of total	14.9	5.7	33.2	46.2	
3/6 - 15/72					
Total number	2,005	2,736	2,147	532	7,420
Average per day	201	274	215	53	742
Percent of total	27.1	36.9	29.0	7.1	

*excluding 2/21, 22, 23/72

** air curtain operating - Bay 12

This represents a significant reduction in the number of fish collected at Bay 12 when compared with its past record. From October 1970 through November 1971, there are 162 days of data with complete fish counts. During this period, Bay 12 collected 27.6 percent of the total catch at Unit 1. From 11 February to 25 May 1971, Bay 12 collected 29.9 percent of the total catch. For the time intervals immediately before and after the air curtain test, Bay 12 collected 30 percent and 36.9 percent of the total fish. Based on the data, it can be assumed that Bay 12 will collect approximately 30 percent of the total catch at Unit 1 under normal operating conditions. During the air curtain test, Bay 12 collected only 5.7 percent of the total catch - an 81 percent reduction from the expected number for this bay. This limited data is inadequate to disprove the hypothesis that the air curtain reduces the total number collected and does not change the distribution of collections among the four screens.

During the test period, the surface water at the intakes and daily screen cleaning process were observed. When the air curtain was operative, the water surface at Bay 12 was very turbulent where the air broke the surface, keeping the screens clean, thereby reducing the velocities through the screens and the frequency at which the screens must be raised for cleaning. Fixed screen 12 (with air curtain) was very clean when compared to the other screens. It appears that the air curtain may reduce impingement by physically forcing fish and debris away from the screens. The fixed screens remain relatively clean, thereby reducing the "jet" flows normally associated with fouled screens.

Tests with the air curtain have been expanded and are continuing. The air curtain was extended across all four bays of Unit 1 and has been in operation since 1 December 1972. Consolidated Edison is presently awaiting analysis of air bubbler tests conducted during 1972 and early 1973. Air curtains have been installed at all bays at Unit 2 and are being designed for Unit 3. The New York State Department of Environmental Conservation requires that the intakes at Indian Point Units 1 and 2 be operated with the air curtains when ambient river temperature is below 40°F (letter of 31 May 1972).

Swim Speed Experiments

In addition to fish impingement and protection studies at Indian Point, Consolidated Edison has supported biological research in other areas. The reduction in impingement rates with reduced flow at the intakes has led to the hypothesis that fish swimming speed is directly related to their inability to avoid the intake screens. Since the largest collections occur during the winter and are dominated by small fish, there appears to be a correlation between swimming speed, size, and ambient temperature. These hypotheses have been investigated by Ichthyological Associates and reported by King (1970, a, b, c) and Tatham (1970).

Tatham (1970) used a modified MacLeod test chamber to determine the maximum swimming speed (S/max) of white perch, striped bass, and other estuarine fishes. Both white perch and striped bass demonstrated a significant increase in S/max with increases in length (Table 13). Various acclimation temperatures above 75°F were used in the experiments, and there was no increase in S/max with increased temperatures. The swimming speeds of selected species were extensively reviewed (i.e., Blaxter and Dickson, 1959; Boyar, 1961; Brawn, 1960; Brett, 1965; Dahlberg et al., 1968; Hocutt, 1970; Houde, 1969; King, 1969; Kotkas, 1970; MacLeod, 1967; and Rosenthal, 1968).

King (1970) utilized the Beamish respirometer to determine the maximum sustained swimming speeds of white perch. The environmental parameters of current velocity, temperature, light intensity, dissolved oxygen, and salinity were measured or held constant during the experiments. All white perch (size range 84-178 mm) tested could swim in excess of 1.0 ft./sec. for 30 min.; but at 1.6 ft./sec., more than 50 percent of those tested for 30 min. were overcome by the current. Additional experiments were performed to determine the critical swimming speed and median endurance times of white perch at various temperatures. The overall trend was a decrease in critical swimming speed with decreasing temperatures and length (Table 14 and Figure 9).

Condition of Impinged Fish

In an attempt to learn more about the cause of death of the fish collected at the intake, during the spring of 1970 samples of fish were sent to biologists and pathologists for examination. The four examinations performed were in agreement that there was no indication of a specific cause of death. Mucus clogging of the gills was listed as a cause of death in one case, but the cause of this condition could not be established. Necropsy techniques for fish are limited and it is, therefore, difficult to establish the cause of death with any degree of certainty (Consolidated Edison, 1970).

Currently (1972) selected tissues (gill, kidney) from representative Hudson River fish (white perch, Atlantic tomcod) are being examined histologically. The study includes a sampling of impinged and "normal" Hudson River fish tissue for abnormalities and frequency of occurrence. This approach is being used to determine if a condition

Table 13. Maximum swimming speed (S/max) of some estuarine fishes. Adapted from Tatham (1970).

Species	Mean fork length (mm)	S/max (ft/sec)
Rough silverside	91	0.7
Tidewater silverside	62	1.7
Bluefish	53	0.7
Striped bass	42	0.6 - 1.3
White perch	56	0.3 - 1.5
Bay anchovy	62	0.5

Table 14. The critical swimming speed* of white perch at various acclimation temperatures and fork lengths. Adapted from King (1970).

Number of Specimens	Mean fork length(mm)	Temperature (°F)	Critical swimming speed (ft/sec)
10	82.6	41	0.85
10	83.4	45	0.97
8	89.3	54	1.25
10	125.0	54 - 57	1.40
20	146.6	55-61	1.60

*Critical swimming speed = speed at which a fish can swim for 30 minutes.

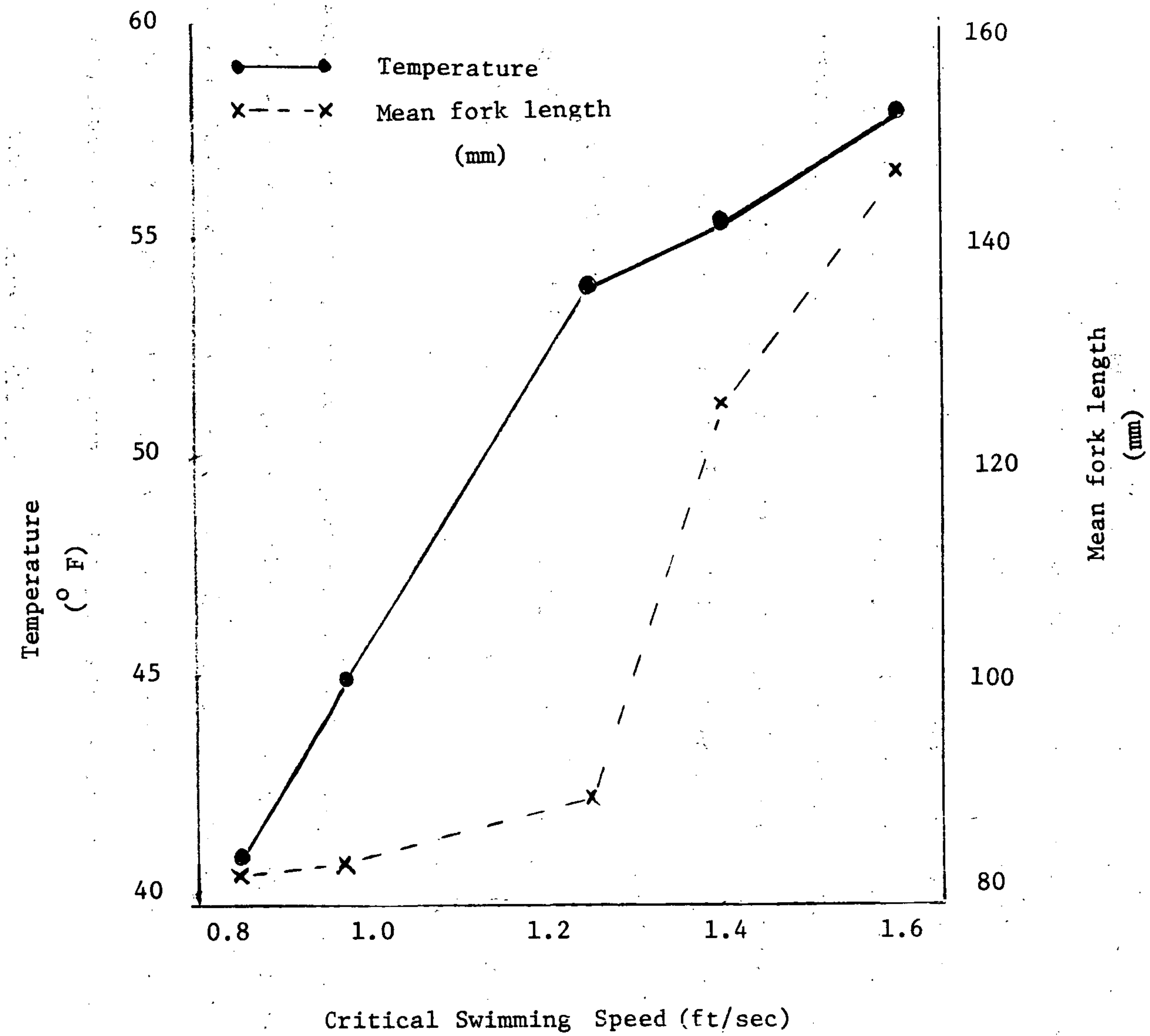

Figure 9. The critical swimming speed(speed at which a fish can swim for 30 minutes) of white perch at various acclimation temperatures and fork lengths. Adapted from King (1970).

factor difference is apparent between impinged and river fish. Initial results show that gill pathology was evidenced in a significant number of impinged fish, approximately 50%, as compared to approximately 10% in "normal" river specimens (Texas Instruments, unpublished data). To date, the data suggests that the impinged fish have a poor condition factor when compared to fish taken from the river. Furthermore, the most probable cause of fish death is suffocation, but the cause of suffocation is especially difficult to determine since a number of environmental factors can create this stress response.

In general, white perch constitute the bulk of the large collections contributing more than 90 percent of the total catch during the winter. Recent observations indicate that adult white perch taken from the screens have a higher incidence of external parasites, Lironeca ovalis, than adults collected from trawls the river stations (Texas Instruments unpublished data):

		River Stations	
	Intake Screens	Indian Point	Ossining
Sample size	533	327	573
Percent infestation	5.8	0.3	0.5

A recent comparison of netted and impinged adult white perch and striped bass at Indian Point Unit 1 has demonstrated that the impinged fish weigh less per unit length than the netted fish (Figures 10 and 11) (Texas Instruments, unpublished data). The differences in weight per unit length are significant at the 99 percent confidence level for both species. This indicates

	Adjusted weights of fish	
	River (g)	Screens (g)
White perch	38.5	29.8
Striped bass	42.2	30.7

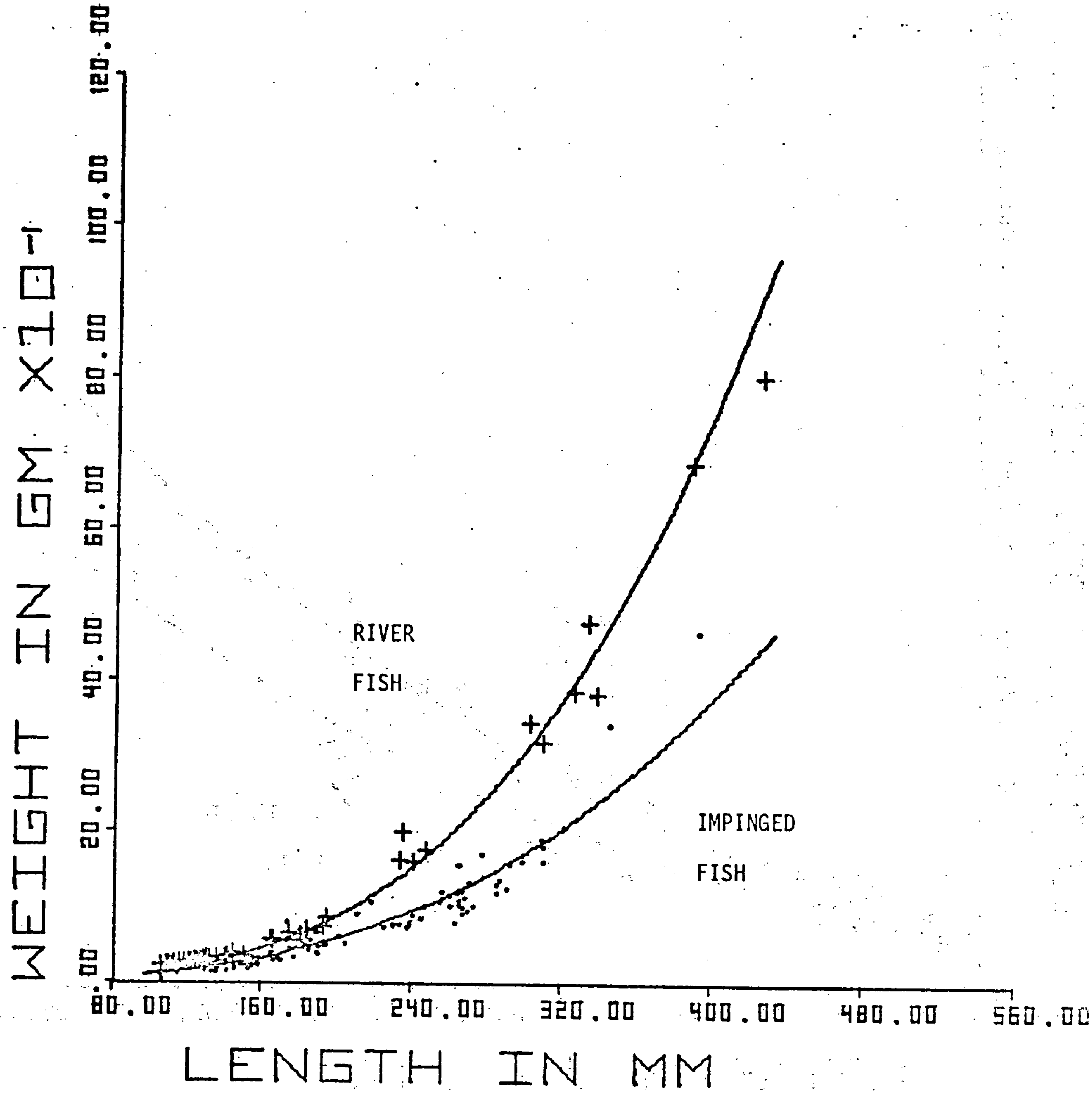

Figure 10. Length to weight relationship for white perch captured by conventional techniques in the Indian Point region of the Hudson River and impinged at the intake screens of Consolidated Edison's nuclear power plant at Indian Point for October 1972. Data from Texas Instruments.

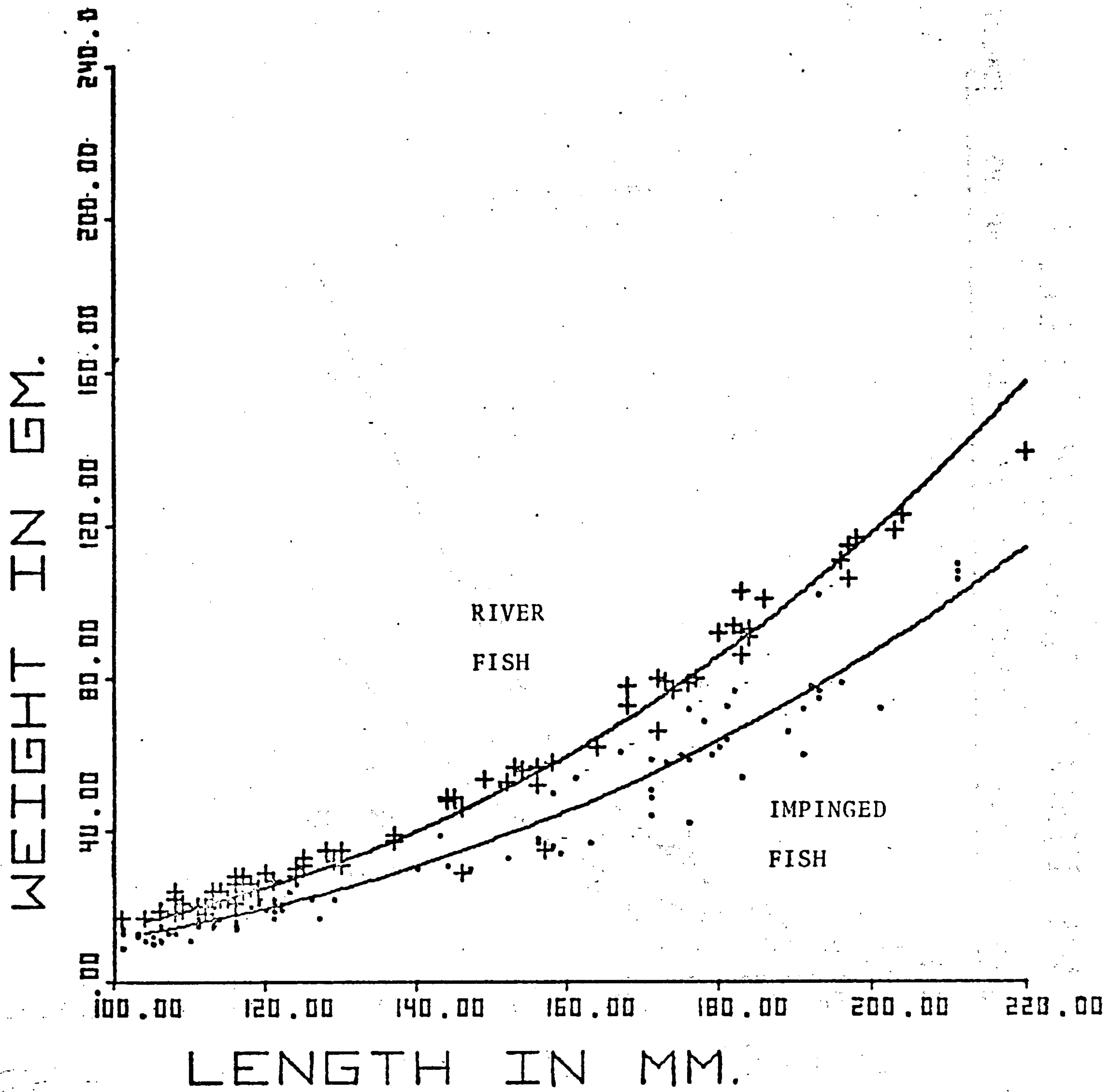

Figure 11. Length to weight relationship for striped bass captured by conventional techniques in the Indian Point region of the Hudson River and impinged at the intake screens of Consolidated Edison's nuclear power plant at Indian Point for October 1972. Data from Texas Instruments.

that the fish collected on the intake screens have a relatively poor condition factor when compared with those in the river. It suggests that the Indian Point plant is behaving like a natural predator, selectively harvesting the weak, injured, or diseased individuals of the fish populations. The removal of these individuals from the populations may reduce competitive pressures on the more fit representatives enhancing their survival and reproductive potential and affecting population stabilization at more resistant levels. This type of predation would likely result in normal compensatory mechanisms in the populations and perhaps be of limited ecological significance.

Hudson River Fisheries Data

A comparison of historical data (Greeley, 1937; Commerical Fishery Statistics) and recent fish collections (Raytheon, 1971; Lauer, 1971) indicates that there has been relatively little if any change in the relative abundance of species in the Hudson estuary. With the exception of American shad, the species which are collected regularly on the screens and were common to abundant in 1937 still maintain their dominance.

Commercial fishery statistics for the Hudson River are available from 1913 to 1969 (Table 15, Bureau of Commercial Fisheries) but must be interpreted with reservations. The accuracy of such historical data is difficult to determine. Successive observations are not independent of one another; the efficiency of fishing gear has probably doubled over the period of record without any concomitant change in effort statistics; catches of the various species are not recorded by gear type; and changes in environmental conditions, such as water quality, are hopelessly confounded with the possible effects of the fishery. Despite these limitations, some useful insights can be gained from the commercial fishery statistics.

Table 15. HUDSON RIVER FISHERY FOR ANADRAMOUS, CATADROMOUS AND BRACKISH WATER SPECIES, 1913 - 1969 (Bureau of Commercial Fisheries)

POUNDS

Year	Shad	Striped Bass	White Perch	Tomcod	Herring	Total*
1913	87,115	990	10,295	2,050	92,175	215,787
1917	38,304	1,683	28,698	4,170	49,935	146,798
1918	220,602	9,449	22,179	7,526	88,224	552,047
1922	128,324	5,436	36,541	1,637	73,431	289,480
1925	110,359	4,341	26,834	2,807	92,188	254,520
1929	157,895	378	13,793	970	146,835	324,806
1930	165,004	1,345	16,016	905	138,504	328,457
1931	342,611	5,330	14,436	420	185,707	583,747
1932	397,754	4,508	16,325		91,432	573,646
1933	347,656	13,616	19,235	830	174,969	574,552
1934	314,200	10,905	31,225	2,580	196,848	572,373
1935	453,300	18,667	60,552	1,610	274,405	837,395
1936	834,400	20,120	46,856	1,087	208,282	1,141,692
1937	976,000	28,854	26,538	3,214	227,865	1,312,226
1938	972,500	24,579	35,421	4,710	244,521	1,396,039
1939	1,516,400	29,937	24,479	2,255	198,806	1,814,072
1940	1,297,700	34,634	39,856	1,802	173,453	1,574,341
1941	1,341,000	21,336	46,426	1,362	222,975	1,658,534
1943	1,640,000	30,889	30,155	100	169,056	1,899,061
1944	1,651,200	60,918	13,848	901	157,644	1,922,342
1945	2,091,300	79,350	17,166	35	123,619	2,332,880
1946	1,446,900	50,622	8,458	108	131,302	1,707,785
1947	957,400	48,453	2,249	250	106,189	1,149,343
1948	1,121,600	38,830	21,028	155	90,468	1,312,512
1952	487,600	29,501	2,901	85	88,501	617,923
1953	465,000	19,352	9,320		70,753	576,754
1955	503,696	73,400	9,206	3,861	12,400	615,375
1956	579,734	92,824	3,446		67,904	756,659
1957	468,205	84,500	6,000	300	56,100	624,605
1958	433,463	77,100	12,500	400	66,100	606,263
1959	492,468	133,100	8,400	1,200	45,600	694,168
1960	273,936	132,900	4,350	1,700	38,200	458,486
1961	236,445	70,700	6,300	800	33,800	366,345
1962	218,149	48,100	4,100	1,100	38,200	318,649
1963	132,564	46,700	5,800	1,300	32,300	228,964
1964	78,200	29,500	5,700	2,500	37,000	159,700
1965	237,521	36,700	3,600			
1966	166,332	44,342	1,600			
1967	176,358	54,642	1,490			
1968	254,372	60,800	1,700			
1969	243,104	77,155	2,600			

* Includes additional species not presented in this table.

American shad and striped bass are the most important commercial species, and shad have historically constituted the bulk of the commercial catch. Eel, sturgeon, white perch, tomcod, smelt, and herrings are also taken in the fishery. Since 1945, the peak year for the harvest of American shad, the commercial catch has declined in rough parallel to the effort statistics (McFadden, 1971). Commercial fishing declined from a peak in 1945 of 95 regular and 350 casual fishermen to 6 regular and 127 casual fishermen in 1964. The historical decline in the commercial fishery is explained mainly by a marked decline in the shad population due to overfishing, damming of spawning streams and pollution, with a consequent decline in fishing effort. Economics has also played a part in the decline of the fishery.

The annual commercial harvest of striped bass in the Hudson River has fluctuated by a factor of six since 1935. Assuming that all data points are equally reliable, no consistent relationship exists between fishing effort and the catch of striped bass. It appears that this species has not experienced total mortality severe enough to reduce the population below its optimum level of productivity, and the historical data provide no indication of what this level may be.

The harvest of white perch, mainly caught incidental to fishing for other species, has declined in parallel with the effort statistics. The data indicate that increases in effort have been accompanied by increases in yield up to the maximum or record, some 60,000 pounds. If this catch was drawn from 50 sq. mi. (32,000 acres) of river, it represents a yield of less than 2 lb./acre. On the basis of documented determinations of fish yields from natural waters, it would be conservative to estimate that the Hudson River could sustain an annual yield of ten times this level for the same area (McFadden, 1971). The historical data provide no indication of the maximum sustained yield which could be expected from the population.

An average annual total of 847,731 pounds of fish have been removed from the Hudson River by the New York commercial fishery during the period of record (1913-1964). This harvest represents not only fish produced in the Hudson estuary but also anadromous species produced in other coastal areas and harvested in the Hudson during migration. The commercial statistics suggest that the striped bass and white perch harvests are still below maximum sustained yield due to low fishing intensity while the productivity of the shad population has declined dramatically due to excess exploitation and environmental changes (McFadden, 1971).

It is possible that the additional mortality created by the operation of the Indian Point Unit 1 since 1962 could influence the catch of sport and commercial species during the last few years. The commercial fishery statistics since 1962 indicate that this has not occurred (Table 15). The commercial harvest of shad and striped bass has increased since a low in 1964, while the fishing effort remained relatively constant. The commercial harvest of white perch has declined throughout the decade, but there has been a corresponding decrease in the number of licenses purchased for gear which collects this species. During the late 1960's, the sport fishery in the Hudson River was also reported to be very good.

Tomcod, herrings, and bay anchovy constitute a small part of the catch at the Indian Point intakes. The commercial harvest of tomcod has increased steadily since 1945 despite the decline in fishing effort, while the harvest of herrings has declined steadily with decreasing effort. There are no commercial statistics for the harvest of bay anchovy. The results of field sampling, 1969-1970, indicated that the most abundant species in the Indian Point area were bay anchovy, white perch, tomcod, striped bass, alewife, hogchoker, and blueback herring in numerically declining order (Raytheon, 1971).

Based on the continued abundance of these species in the area, it is unlikely that the operation of the Indian Point plant caused incremental additions to mortality rates to reduce these populations below their optimum levels of productivity.

Theoretical Effects of Additional Mortality

The effects of impingement mortality on the fish populations of the Hudson River are still being investigated, and it is unlikely that the removal of individuals will significantly reduce the abundance of fishes until it exceeds the compensatory reserve of the species. Compensatory reserve allows populations to mitigate additional mortality by an increase in survival, growth rate, or reproductive rate among survivors. Jensen (1971 a) found that mortality due to fishing was compensated by a higher age-specific fecundity in exploited brook trout populations. In comparing exploited and unexploited populations, he concluded that reproduction always balanced mortality. Conversely, Jensen (1971 b) using a theoretical math model demonstrated that a 5 percent increase in mortality of the 0+ age group decreased the yield of the trout fishery. An additional mortality of 50 percent of the 0+ age group resulted in the extinction of the population, even though the effect did not become apparent for several years. The mathematical model employed in deriving the results did not consider compensatory survival in the 1+ and older age groups or possible migrations in estuarine ecosystems. The potential for compensatory reserve and migration should be considered before extrapolating the results of this model to Hudson River populations. Any reduction in numbers sufficient to cause the extinction of a fish population would be detected by the current ecological monitoring program at Indian Point before irreversible adverse impact occurred.

A mathematical model more applicable to Hudson River fish populations has been developed by Quirk, Lawler & Matusky, Engineers for striped bass (Lawler, 1972). This is a transport model which relates river hydrodynamics to the life cycle of striped bass in the Hudson River. The model includes biological compensation as a population parameter. Major parameters of the model are life cycle parameters, transport parameters, and plant and impact parameters. The reduction of the striped bass population by operation of Indian Point Units 1 and 2 was evaluated for conditions described as "current best estimate of impact" and "apparent maximum impact". The results of entrainment and impingement mortality on the population are given in Table 16. These results show clearly that operation of Units 1 and 2 should not be expected to cause a substantial or irreversible adverse impact on the river's striped bass population, particularly during the first 10 years of operation.

Other Studies

In addition to the field studies of fish impingement and protection at Indian Point, Consolidated Edison employed Bechtel Associates (1970) to conduct a survey of fish screening systems. The most fruitful sources of information were the major utilities, and State and Federal agencies on the west coast, where concern for the salmon fisheries has resulted in the development of considerable fish screening expertise. The fish protective measures investigated in the survey included screening mechanisms, fish bypass systems, and plant operational procedures. The study concluded that there appear to be three potential remedial actions applicable to Indian Point Unit 1:

Table 16. Effect of two unit plant operation on Hudson River striped bass population (from Lawler, 1972).

Age Group	Percentage Reduction after Years of Operation		
	1 Year	5 Years	10 Years
	Run #1 - Current Best Estimates of Impact*		
1 Year Olds	2.5	3	3.5
Years 1 to 13	2	3	3.5
	Run #2 - Apparent Maximum Impact*		
1 Year olds	4	5	6
Years 1 to 13	3	5	6

* The primary parameters controlling these estimates are the distribution of early stages in the Hudson River near Indian Point, the ability of at least some of these stages to avoid the intake, and the degree of cropping which takes place during plant passage. These have been designated "f" factors. Selection of values is discussed in detail in Chapter III.

- Reduction of the intake flows
- Increase in the screening area and approach channel cross section to reduce the approach velocity
- Installation of a fish pump system in the screen well to return fish to open water promptly

The effectiveness of fish pumps and flow reduction has been demonstrated at the west coast plants and Indian Point, respectively.

In addition to the experiments which have been conducted at Indian Point, current research on fish protection at intakes is reviewed by Consolidated Edison as it becomes available. A number of fish protection measures have been investigated by others and may be considered for adoption at Indian Point if applicable. Bates and Van Der Walker (1969) experimented with water and air jets as a means of deflecting fish from intakes. Most fish avoided the water jet, but 5 to 10 percent swam through the barrier. Water jets showed promise, but the system required extensive maintenance due to clogging by debris and rust. Air curtains yielded their best results during the day and were limited, if not totally ineffective, at night. A mechanical fish collector has been installed at the Contra Costa steam plant (Pacific Gas and Electric Company, California), and young striped bass are pumped from in front of the traveling screens to safety with a survival of 98 percent (Kerr, 1953). A combination of louvers and bypass system has proven useful in diverting shad, salmonids, striped bass, and catfish from water intakes (Bates and Logan, 1960; Ruggles and Ryan, 1964; U.S. Department of Interior, 1957; U.S. Bureau of Commercial Fisheries, 1961). Louvers have the disadvantages of high head loss and difficulties in removing debris. Although still in the experimental stage, horizontal traveling screens with bypass have shown promise in safely diverting salmonids from intakes (U.S. Fish and Wildlife Service, 1970; Bates, 1970). Consolidated Edison is actively sponsoring additional research on this method. It has been demonstrated that salmonids are repelled from the source by small explosions (Burner and Moore, 1962). Forced air "explosions" such as are used in seismic exploration result in very low fish mortalities and may be useful in fish deflection. The application of specific fish protection devices depends upon variables, i.e., species present, tidal oscillations, plant water requirements, etc. Consequently, the methods of fish protection which have proven successful elsewhere are not necessarily applicable to Indian Point.

Consultants

The magnitude of fish impingement has been a concern to Consolidated Edison, State and Federal agencies, sport enthusiasts, and conservationists, and Consolidated Edison is continuing its search for an intake system that will further reduce the impingement. The pertinent question is whether or not impingement mortality will significantly affect the natural abundance of fishes. At the request of Consolidated Edison, this question has been considered in detail by Dr. G. J. Lauer (New York University), Dr. J. T. McFadden (University of Michigan), and Dr. E. C. Raney (Ichthyological Associates). Based on the extensive biological data which have been collected on the Hudson River (Greeley, 1937; New York State Conservation Department, 1943; Perlmutter, 1967, 1968; Carlson and McCann, 1969, Lauer, 1971, Raytheon Company, 1971), it was concluded that the numbers and species of fishes that would be impinged by continued operation of the plant would not have a significant or irreversible adverse impact on the fisheries of the Hudson River (Lauer, et al., 1972). Even substantially larger numbers of fish could be impinged without significant or irreversible adverse environmental impact.

This conclusion was supported by the fact that the white perch comprise more than 70 percent of all the fish collected on the screens. The removal of individuals from the population will not reduce the sustainable population size or yield to the fishermen until it exceeds the compensatory reserve of the species. Compensatory reserve allows increased survival rates among survivors if an increase in mortality has appreciably reduced the density of the population. This phenomenon is the result of decreased competition for food, shelter, and living space. White perch also mature at an early age, have a high fecindity, slow growth and short life span, and are consequently able to withstand high mortality without affecting the sustained populations. Approximately 3 percent of the fish collected on the screens are very small (3 in.) striped bass. This incremental increase due to plant operations in the level of mortality is not expected to cause a significant or an irreversible adverse impact on the striped bass population while the current ecological studies are in progress (Section 13). The white perch and striped bass collected on the screens are immature individuals which have not entered the reproductive stage of their life cycles. Removal of these fish does not directly reduce the reproductive potential of the populations. Current studies on the population dynamics of white perch and striped bass at Indian Point have been designed to detect problems in time to implement the necessary changes to avoid any irreversible adverse impact.

Based on the results of extensive literature review and intensive field and experimental studies, Dr. E. C. Raney (1972) has concluded that operation of the Indian Point plant during the next 8 years will cause no irreparable or irreversible damage to the striped bass populations of the Hudson River, adjacent limited coastal areas of Long Island and northern New Jersey, or the major Atlantic coastal populations. Moreover, the results of meristic and tagging studies indicate that the Hudson River striped bass are a distinct race with a restricted and limited contribution to the Atlantic Coast fishery. The major contribution to the Atlantic Coast fishery comes from production in the Chesapeake and Delaware bays.

Dr. J. T. McFadden (1972) has testified that striped bass populations typically fluctuate in abundance by a factor of four and possess substantial compensatory reserve. This compensatory reserve enables striped bass populations such as that of the Hudson River to mitigate, through increases in natural survival rates, losses imposed by the activities of man. A large number of scientific studies have demonstrated that annual removals of 25-30% are commonly sustained by fish stocks. Consistent with this general observation of exploited fish stocks, New York striped bass have persisted or even increased in numbers during periods of increasing exploitation by man. It is concluded that any postulated reduction in Hudson River striped bass due to the operation of Indian Point would be mitigated by a significant compensatory response. Should the compensatory response be too weak to replenish losses, the fish population would begin a gradual decline. This decline would be reflected in population parameters which are currently being monitored before irreversible damage to the population occurred. Several scientific studies clearly demonstrate that changes indicative of population damage can be detected by the methods employed in the Indian Point ecological study (Section 13). Should serious ecological damage occur from the operation of Indian Point Units 1 and 2, it would be clearly demonstrated when the ecological study is completed and Unit 3 is scheduled to begin operation in the second part of 1974. On the basis of any reasonably postulated loss rate due to operation of Units 1 and 2 commencing in spring 1973, the fish stocks of the Hudson River would not be subjected to irreversible damage by 1981, the date when alternatives to once-through cooling for all units would be operational if construction were commenced in 1977 following completion of the ecological studies.

In the interim Texas Instruments Incorporated is currently under contract to Consolidated Edison to continue fish impingement studies at Indian Point. These studies have been designed to systematically evaluate the effectiveness of reduced intake velocities, air curtains, fish pumps, and traveling screens versus fixed screens in reducing mortality at the intakes. Sonar counting and integration techniques will be employed to correlate fish population densities in the river with fish impinged on the screens. The results of these studies will be incorporated into the population dynamics studies (Section 13) to determine the significance of impingement mortalities upon white perch and striped bass populations.

DISCUSSION

Impingement is one of many mortality factors affecting fish populations in the lower Hudson. Fish populations are controlled by two general classes of factors: extrinsic factors, such as predators or other species which compete for food, space or other environmental requisites; intrinsic factors, such as population density, which result in intraspecific competition for environmental requisites. Each fish species has a reproductive potential determined by its physiology and life history, and environmental factors reduce the actual replacement rate to something below this potential (Tanner, 1966). An increase in mortality due to some extrinsic agent, such as a fishery, natural predator, or the operation of a power plant, will be at least partially mitigated by an increase in reproductive rate, increase in growth rate, or an increase in survival at some responsive life history stage. Each fish population has the capacity, within limits, to compensate for additional mortality. A population may maintain its equilibrium through a combination of low mortality rate and low reproductive rate, through a combination of high mortality rate and high reproductive rate, or through other means. It is also possible to balance a high mortality rate with recruitment from adjacent populations in the Hudson estuary. Any of these situations could reflect an ecologically healthy population, and in the latter cases a sizeable component of the total mortality could be man-induced. Studies of striped bass populations have indicated that there is a compensatory response to changes in density (McFadden, 1972). Over a certain range of population density as the numbers of spawners are reduced, the size of the year class of progeny they produce will remain the same or even increase. Through this mechanism fish stocks have persisted or even expanded during periods of increasing exploitations by man.

The Hudson estuary in the vicinity of Indian Point does not represent a closed ecosystem. Consequently, the abundance of fishes in the area is also dependent upon the migration of individuals into and out of the estuary. Any available habitat temporarily vacated by man-induced mortality at Indian Point can be rapidly filled by migrant individuals from adjacent areas. The recruitment of individuals from contiguous habitats of greater density is one way in which population numbers can increase until they reach the carrying capacity of the ecosystem. In closed ecosystems, i.e., bacterial cultures, crater lakes, and islands, populations can be reduced until local extinctions occur, if additional mortality cannot be compensated by recruitment or reproduction. Large reductions in the abundance of white perch, striped bass, tomcod, herrings, and bay anchovy due to impingement mortality are unlikely, for these species are widespread in distribution, prolific, and highly mobile. Impingement mortality could adversely affect locally a species endemic to the Indian Point area if the mortality rates exceeded the compensatory reserve of the species. However, endemic species are not present or collected on the screens at Indian Point.

A population may be considered ecologically harmed when it is subject to a mortality rate so great that the maximum possible increase in reproductive rate does not compensate adequately to maintain the population. The population would then decline in abundance until it reaches a new stable level or begin to fluctuate violently. If the incremental mortality rate imposed on the population cannot be compensated by modifying the source of mortality, or by natural compensation and stocking, the population could dwindle to extinction in a closed system. The commercial fishery statistics suggest that the annual harvest of white perch and striped bass may be lower than their maximum sustained yield. The shad population declined from its former levels of abundance and productivity due to over-exploitation and environmental changes. It is assumed that the shad population lacks the resistance to environmental change which may be attributed to the white perch and striped bass. From this it may be inferred that the white perch and striped bass populations have absorbed additional mortality without suffering irreversible damage. However, the limits to which these species can absorb additional mortality are not yet known.

In addition to its intrinsic ecological properties, each fish population is subjected to important influences from sympatric species. Fisheries research has indicated that interactions between closely related species generally yield two types of results: elimination of one or more species, and segregation of species into different habitats or feeding niches (Nilsson, 1963). Segregation has been further divided into selective segregation and interactive segregation. Selective segregation is a definite difference in habitat and/or food selection due to ecological isolation, and interactive segregation is defined as interactions between species which compel them to magnify any differences in habitat or food selection (Nilsson, 1965). The white perch, Morone americana, and striped bass, Morone saxatilis, occupy the same habitat and demonstrate similar food selection during their early life histories in the Hudson estuary (Texas Instruments, unpublished data). It is possible that young white perch and striped bass compete for the same food supply. If this is the case, the impingement mortality of white perch at Indian Point might benefit the more valuable striped bass population to the detriment of a species of less commercial or recreational value. The extent of interaction between these species is presently unknown, but ecological studies now in progress should adequately define this relationship (Section 13).

Although the numbers of fishes collected on the intake screens seem large, the actual poundage is small. The species collected on the screens are predominantly young-of-the-year which have not entered the reproductive stage of their life histories. Consequently, the removal of these fishes reduces the reproductive potential of the populations of the Hudson estuary only to the extent that the number of fish produced in the Hudson reaching maturity is decreased. The commercial fishery has demonstrated that a substantial exploitation of fish expressed either in numbers or pounds can be sustained by a fish population without adversely affecting the fishery as a whole. Cases of fish populations sustaining annual removals of 25-30% of the stock or more have been documented. Indeed, the white perch population of the Hudson River has sustained annual removals of 60,000 pounds with evidently no adverse effects.

It is possible to compare the number of young-of-the-year white perch collected on the intake screens at Unit 1 with the potential number of young-of-the-year removed by the commercial fishery. The comparison can be made by estimating the number of young-of-the-year which would have been produced by an annual commercial harvest of adult white perch. The formula for this estimate is

$$N = \frac{C}{W} (R) \quad (F) \quad (S)$$

where:

N = young-of-the-year

C = commercial catch in pounds

W = average weights of adults in pounds

R = percent females in the catch

F = fecundity

S = survival to 1 year

Assuming a commercial catch of 3,000 lb, fecundity of 30,000 or 100,000 eggs per female and survival of 0.01 or 0.001 to age 1+

$$N = \frac{3000}{0.3} (0.5) \times \begin{matrix}(30,000)\\(100,000)\end{matrix} \times \begin{matrix}(0.01)\\(0.001)\end{matrix}$$

the potential number of young-of-the-year ranges from 150,000 to 5,000,000. If we increase the commercial catch to 60,000 lb/yr, the potential loss of young-of-the-year during the following year is 3 to 100 million. Yet the white perch population in the Hudson estuary has been able to sustain levels of more than 3,000 lb/yr mortality for about 40 years with apparently no irreparable or irreversible damage. The annual number of young-of-the-year collected on the intake screens at Unit 1 is estimated to be 184,530 (0.7 x 263,614, see Table 6). Consequently, it is unlikely that mortality from the low commercial harvest (2,000 lb/yr) and impingement of white perch will cause an adverse or permanent impact on the population while environmental studies are in progress at Indian Point.

The number and weight of fish collected at Unit 1 under current operating conditions (Table 6) can be used to predict the anticipated annual impingement at Units 2 and 3. Assuming the impingement is directly related to flow rate, this is accomplished by multiplying the projected annual impingement at Unit 1 by a factor of 3. Thus the projected annual impingement for Indian Point becomes:

	Number	Weight
Unit 1	372,863	4,089
Unit 2	1,118,584	12,263
Unit 3	1,118,584	12,263
Total	2,610,041	28,615

This estimate assumes that all three units will operate every day of the year which is not the case. The estimate will be reduced by the annual refueling outage of each unit, and impingement may be further reduced by the operation of air curtains in front of all intake bays.

Ecologically, the biomass of fish removed from the immediate area of the plant through impingement is much more relevant than impact based on removal of individual fish (McFadden, 1972). Estuaries are very productive areas, and sustained fishery production of 50 pounds per acre in the Gulf of Mexico and 155 pounds per acre in the Chesapeake Bay and its estuarine tributaries have been reported. These fish production figures are much greater than the annual averages of 1.5 lbs/acre/yr for all world marine fishing; 27 lbs/acre/yr for the North Sea fishery; and 1 to 7 lbs/acre/yr for the Great Lakes. If the extreme assumption is made that all fish impinged at Indian Point come from the 4 square miles of river in the immediate area, an annual removal of 11.2 lbs/acre for all species combined can be calculated for operation of all three units at Indian Point. When compared to the minimum estimates of fish biomass in estuaries mentioned previously, these postulated removals are insignificant. When it is further considered that the removals almost certainly come from an area larger than the 4 square miles, and hence the poundage removal per acre of estuary is even less than the figures given, the significance of mortality by impingement is reduced still further.

Since the largest numbers of fish are collected during the winter months, Consolidated Edison now plans to operate the Indian Point Plant at reduced (60 percent) intake flows from October through March of each year. Tests have indicated that flow reduction can reduce the average daily collections as much as 76 percent at Unit 1. Flow reduction will reduce the total annual mortality of fish at the intakes until a common intake structure can be fully evaluated. Based on the results of flow reduction tests, swim speed tests, and the advice of the Fish Advisory Board, this operational procedure should continue to reduce fish impingement at Indian Point to a level substantially below that previously experienced. If the present "best available projection" of fish impingement is reasonably accurate, the numbers of fish impinged with all units will be no greater than the magnitude of the problem which existed at Unit 1 alone before 1970. This incremental increase in mortality would not be expected to cause irreparable or irreversible damage by 1981.

CONCLUSIONS

The fish populations of the Hudson River have been subjected to additional mortality as a result of impingement on the intake screens at Indian Point Unit 1. There are definite seasonal variations in the numbers and species of fish collected on the screens. The largest impingements occur during the winter months and are dominated (90 percent) by white perch, two to four inches in length. Tomcod, striped bass, herrings, and bay anchovy constitute about 26 percent of the annual catch. The species which are most abundant in the river are the ones collected with greatest frequency on the screens. Although the effect of additional mortality on the fish populations is not yet known, it is unlikely that plant operation has significantly reduced the abundance of fishes in the estuary.

Based on the projection on page 65 of fish impingement the normal operation of all three units will remove less than 2,610,000 fish or 28,615 pounds of fish from the Hudson River in the vicinity of Indian Point. When compared with the minimum estimates of fish biomass in estuaries these postulated removals are insignificant. This loss of biomass would be mitigated by a significant compensatory response in the fish populations. Should the compensatory response be too weak to replenish losses, the fish populations would begin a gradual decline. This decline would be reflected in population parameters which are currently being monitored before irreversible damage to the population occurred. Should serious ecological damage occur from the operation of Indian Point Units 1 and 2, it would be clearly demonstrated when the current ecological study is completed and Unit 3 is scheduled to begin operation in the second part of 1974. On the basis of any reasonably postulated loss rate due to operation of Units 1 and 2 commencing in spring 1973, the fish stocks of the Hudson River would not be subjected to irreversible damage by 1981, the date when alternatives to once-through coding for all units would be operational if construction were commenced in 1977 following completion of the ecological studies.

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THE BIOLOGICAL EFFECTS OF THERMAL DISCHARGES AT INDIAN POINT

Consolidated Edison Company of New York, Incorporated

New York

15 January 1973

ABSTRACT

A brief review of the literature suggests that the warm water discharge at Indian Point (Units 1, 2 and 3) will probably not initiate identifiable changes in the estuarine communities, migration patterns or spawning habits, but may cause shifts in species abundance in the area of the thermal plume. The temperatures of water discharged by the plant will not exceed 90^{o} at the surface; 66% of surface width and 50% of the cross section will be less than a 4^{o}F rise in accordance with the thermal criteria of New York State. Previous studies indicate that damage to estuarine biota increases sharply at summer temperatures above 90^{o}F but appears minimal below 90^{o}F. The present state of understanding of community interactions is inadequate for accurate predictions of the indirect and long term effects of the Indian Point thermal discharge on the local Hudson River ecosystem. Biological studies have been initiated to describe and monitor the complex community interactions and define the thermal receiving capacity of the aquatic system at Indian Point.

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INTRODUCTION

The objective of this appendix is to discuss the impact of thermal discharges by the Consolidated Edison Indian Point nuclear power plants on the Hudson River ecosystem. The effects of elevated temperatures on organisms of each trophic level (decomposers, producers and consumers) are considered by review of information from previous thermal studies at Indian Point and other pertinent literature (comprehensive reviews, symposia and bibliographies).

An evaluation of the biological effects of the thermal discharge at Indian Point requires information on the area influenced by the elevated temperatures. Models exist which predict the thermal distribution and hydrological factors which affect plume configuration and extent. Under conditions of maximum severity, the thermal plume of $4^{\circ}F$ or more above ambient Hudson River temperatures will cover approximately 600 surface acres, while about 1600 surface acres will be bounded by the 2° F isotherm (See section 9.3). The area of the plume (within $2^{\circ}F$ isotherm) represents 2.2% of the surface area of the Hudson River estuary between Troy and the Battery (approximately 153 river miles).

Literature on the subject of "thermal effects" is increasing at a geometric rate and comprehensive studies on the ecological effects are being conducted at many major electric power plants. The results are far from complete, but suggest that previous predictions of species replacement were correct and that environmental changes were proportional to the amount of heat discharged into the aquatic system.

The accuracy of predictions regarding the effects of large thermal discharges increase with understanding of the community interactions and the importance of individual species in the ecosystem. The present knowledge of community structure at each plant site is inadequate for reliable predictions. Interpretations from the findings at one site do not necessarily apply to each individual situation. Estimates of the total effect of a discharge on a given aquatic ecosystem range from absolutely no effects to complete devastation dependent on the source and reliability of the estimate. The extent of damage to the aquatic ecosystem can be monitored by trained biologists as a plant operates to provide ecological information with increasing accuracy on the long term changes and in time to permit the modification of the cooling system before irreversible damage or significant adverse effects have been imposed.

Con Edison is presently monitoring the biological effects of a warm water discharge on the Hudson River biological community at Indian Point. Predictions from the study will include the effects of elevated temperatures on the Hudson River biota.

PREVIOUS STUDIES AT INDIAN POINT

INTRODUCTION

Previous studies at Indian Point have resulted in primary base line information describing the Hudson River biological communities and their interactions. The difficulty in reaching conclusions about thermally caused changes in the local ecosystem was compounded by the wide diversity of organisms superimposed on seasonal and yearly fluctuations in species abundance, the variation in the thermal discharge and the relatively small extent of the previous warm water plume. Population studies presently are in progress (Texas Instruments Incorporated) and will continue as all three units become operational. This research is being performed to define the extent of biological change, if any, directly related to the influence of the combined warm water discharges.

DECOMPOSERS

Studies (Lauer and Howells, 1971) have indicated that the temperature tolerance of resident bacteria will not be exceeded by the increase of 15° F, which is the expected temperature rise of water in the discharge canal at Indian Point. At summer ambient temperatures of 74-76° F, total bacterical counts remained constant after exposure to an increase of 20° F for 45 min. but were decreased by a rise of 30° F for 15 min. The latter condition is not expected at Indian Point. Coliform counts were unaffected by increases of 30° F for 45 min. From winter ambient temperatures of 32° F at exposures of 40-80° F, bacterial counts showed a slight trend of decreasing numbers with increased exposure, while coliform counts decreased at a rate of about 10 colonies for each additional $10^{o}F$ rise in temperature. Although elevated summer thermal exposures (as cited above) reduce population density of decomposers, this effect is not expected to occur at the Indian Point maximum summer discharge temperature of $88-89^{o}F$ (see Section 9). Lauer (1972b) states that the thermal discharge will have negligivle impact on river populations of bacteria.

PRODUCERS

Small unicellular floating plants are responsible for most of the conversion from solar to stored chemical energy in the aquatic ecosystem at Indian Point, although detritus from producers upriver may be the major energy source for the estuarine community. Phytoplankters are the basic food source of many zooplankters, which themselves are food for larger organisms. Seasonal shifts in species composition, diversity and abundance occur normally and have been related to temperature, light intensity, salinity and available nutrient supply.

Diatoms are the dominant planktonic plants in the Indian Point area. The most abundant genera were Asterionella (in June), Nitzschia (in March), Coscinodiscus and Cyclotella (in late summer) Melosira (during most of the year), Chaetoceros, Skelotonema and Tabellaria. Green and bluegreen algae, which increase in abundance in October and November, include Actinastrum, Pediastrum, Scenedesmus, Ulothrix, Anabaena, Microcystis and Oscillatori. Phytoplankters increase in abundance in spring and reach a maximum in late spring or early summer(Lauer and Howells, 1971). Generally, there were no significant differences in abundance or species composition in samples taken from the east and west channel. Phytoplankton populations at Indian Point were similar to those of other river stations (Lauer and Howells, 1971).

Beaause phytoplankton is dependent upon currents for movements, and can not actively avoid discharge areas it could be susceptible to fluctuations in water temperature. Laboratory studies on phytoplankton (Lauer and Howells, 1971) indicated that when ambient water temperatures are 39.2° F, increases of 28° F for 60 min. or 35-42° F for 30 min. have no effects that can be detected visually. Additional laboratory studies (Lauer and Howells, 1971) were conducted on the effect of increased temperature on the rate of photosynthesis. In the spring (ambient 34-45° F), water temperature increases of 28-35° F for 5-25 min. resulted in increased photosynthesis; increases of 40° F for 40 min. reduced photosynthesis. During summer, when ambient water temperatures are higher (79°F), a water temperature increase of 25° F resulted in decreased photosynthesis. No significant changes in abundance or composition of phytoplankton populations within the Husdon River will occur as a result of planned operations of Units 1 and 2 (Lauer, 1972 b).

Although some rooted aquatic plants exist in the Hudson River near Indian Point (Table 1), they are limited to very shallow waters by the high turbidity. They are probably of little significance as photosynthetic producers (when compared with phytoplankton), but may contribute to the aquatic ecosystem by: providing shelter for small fishes or other epiphytic and benthic organisms; preventing erosion of sediments; forming organic detritus which can be utilized as a food source by some smaller organisms; and by binding chemical effluents from the discharge. Few studies have been conducted on the diversity, distribution and abundance of higher aquatic plant communities along the shores at Indian Point.

Table 1. Aquatic vascular plants which have been identified in collections from the Hudson River near Indian Point.

Chara sp.	_Potomogeton crispus_
Eleocharis sp.	_Potomogeton pectinatus_
Elodea sp.	_Potomogeton perfoliatus_
Myriophyllum sp.	_Potomogeton_ sp.
Najas flexilis	_Spartina_ sp.
Nitella sp.	_Trapa natans_
Pontederia cordata	_Vallisneria americana_

(From U.S. Atomic Energy Commission, 1972)

CONSUMERS

The zooplankton community consists of small floating organisms which may be in the water column permanently or temporarily (such as the larval stages of many benthic species). The zooplankton graze on phytoplankton and bacterial organisms, and in turn, are an important food source for many larval and adult fishes. Great seasonal shifts in species composition and abundance occur and are related to natural fluctuations in the aquatic environment. Many of the microcrustacea and other forms of plankters are mobile and can control their movements through the estuary, to some degree, by vertical movements any by riding tides, density currents, etc.

Seasonally, the Indian Point area supports a rich and diverse zooplankton community. Collections by New York University in January indicated that the plankton community was much reduced over winter (Lauer and Howells, 1971). The dominant organisms during early spring were rotifers. Their abundance is thought to be a benefit to subsequent zooplankton populations as a food and nutrient source. Copepod nauplii were dominant in late spring. Cladocera were most abundant during June, although they were never numerous. The freshwater associated species of copepods, Ectinosoma carticoine and Canuella sp. appeared in spring while most copepod adults reached maximum abundance in July through October. Eurytemora hirundoides, Microauthridion littorale and Cyclops biscuspidatus were most common forms. A more marine form, Acartia tonsa, appeared in fall. Another peak in abundance of copepod nauplii occurred in September through October. By December all forms of zooplankton were sparse.

Raytheon (1971) showed that many species of macroinvertebrate zooplankters were also common during summer. Free swimming juveniles of Neomysis americana were one of the most abundant bottom water species during June, July and August. Distribution information suggests that juveniles were not as sensitive to low salinities as were adults. The amphipods, Gammarus and Monoculoides were abundant near the bottom, while Leptocheirus occurred in large numbers at shallow stations in April and May.

Field and laboratory investigations by New York University indicated that temperatures in the Indian Point discharge plume, which conform to the New York State standards of maximum upper temperature, will not be lethal to species of the micro and macroinvertebrate zooplankton that have been studied, at the exposure times studied (Lauer, 1972a). Laboratory experiments of the upper temperature tolerance of the copepod Halicyclops sp. show that the species completely survived 60 minute exposure to a rise of 28° F from spring ambient temperatures of 48° F. A thermal increase of 42° F reduced survivors to 30% after a 2.5 minute exposure. From summer river temperatures of 77° F a rise of 15° F reduced survival to 76-86% of the initial test population. The cladoceran, Daphnia pulex, experienced no mortalities when exposed to 17° F increase in summer temperatures of 68-79° F for 30 minutes, but none survived a rise of 26° F for a one minute exposure. It should be emphasized that no mortality of Halicyclops sp. or Daphnia pulex should occur at the maximum "expected" Indian Point thermal plume temperature, 87° F. Unidentified ostracods collected at Indian Point intake at ambient temperatures of 75° F survived a 29° F temperature rise for 30 minutes. They exhibited only 20-54% survival at an increase of 32° F for 30 minutes. Gammarus survived a rise of 43° F from an ambient of 45^{o} F but survived only an 18^{o} F increase at summer ambient temperatures of 78^{o} F (exposed time of 30 minutes). Neither ostracods nor Gammarus mortality is expected at maximum plume temperatures. Lauer (1972b) stated that the planned operation of Units 1 and 2 will cause no significant effect on zooplankton abundance in the Hudson River (particularly Gammarus and Neomysis). A field study of the discharge canal with Unit 1 operating demonstrated temperature differences between canal water and ambient Hudson River water range from 5^{o} F in July to 18^{o} F in December, 1969. Monthly collections of zooplankton indicated that the elevated temperatures had no discernable effect on the microinvertebrate populations (Raytheon, 1971).

There were pronounced seasonal fluctuations in abundance of the planktonic stages of various fish species. Most species were numerous primarily during spring at mid-channel stations in the western half of the river. Atlantic tomcod, Microgadus tomcod, larvae were most abundant during early spring in the higher salinity waters south of Indian Point (Raytheon, 1971). Striped bass, Morone saxatilis, spawned upriver of the study area and eggs were first collected in early May at mid-depths or near bottom. Larvae in bottom samples reached peak abundance at all river stations during late June and early July in the vicinity of Indian Point. The greatest concentrations of planktonic striped bass at Indian Point occurs at channel stations with greater abundance occurring first upstream; numbers of specimens collected declined sharply in July. Laboratory temperature tolerance studies show that striped bass eggs and larvae will be able to tolerate temperatures found in the discharge plume (Lauer, 1972b). Larvae of the white perch, Morone americana, were more numerous near the bottom in deep channel stations north of Indian Point. They were most abundant during

May and June. By July, planktonic stages were much reduced in the water column (Raytheon, 1971). Larval stages of alewife, Alosa pseudoharengus, and blueback herring, Alosa aestivalis, were most abundant in surface collections at stations adjacent to and north of Indian Point. Larvae appeared in the Indain Point area in early May. Distribution of the early stages of bay anchovy, Anchoa mitchilli, suggested that most spawning occurs south of Stony Point. Larvae reached peak abundance in July at stations south of the primary study area. Planktonic stages of other less numerous species were most common in June and July (Raytheon, 1971).

Benthic organisms are primarly sedentary in habits and live in or on the bottom. Most are detritus feeders, while some are primary or secondary consumers. Due to the immobility of most benthic organisms, temperatures above the survival limits of the species could possibly result in the elimination of that species from the area of thermal influence should the plume encroach upon that specific depth. This condition is unlikely over most of the plume but may occur around the area of the immediate discharge. At Indian Point, the benthic community is relatively low in diversity and uniform in distribution (Raytheon, 1971). The polychaete worm Spio setosa, and the isopod, Cyathura polita, were the most common macroinvertebrates living in the silty clay bottom sediments of the Indian Point area. S. setosa increased in numbers during summer. The amphipod, Gammarus fasciatus, was an abundant member of the benthic community. It could not be collected representatively by bottom grabs but was collected in trawls and seines. The barnacle, Balanus, and mussel, Congeria, were the dominant organisms found in areas of shell bottom

Epifauna refers to animals which tend to become attached to solid surfaces exposed to the water. Common epifaunal animals in the Indian Point area include barnacles (Balanus), mussels (Congeria) and amphipods (Corphium). Large sets of Balanus occurred in June, but by October were much reduced and had ceased setting. Corphium, which was abundant in July, ceased setting by October while Congeria, also abundant in July, continued to increase in numbers through October. Balanus settlement at the effluent station of the Indian Point plant was lower than would be expected from normal salinity related distribution patterns (Raytheon, 1971). However, this study should be considered inconclusive as it represents limited data.

Many studies have been conducted on the fish populations of the Indian Point area; most have considered the distribution, seasonal changes of abundance, migration patterns, spawning grounds and spawning times of fish which inhabit the area during various seasons of the year. This baseline information is imperative for more comprehensive investigations of population sizes, mortality rates, community structure and the effects of the power plant on specific fish populations and communities. Very little information exists on the effects of the warm water discharge on the distribution and health of local fish.

Each summer (June-August) from 1965 to 1969, fish were collected by beach seining from 12 shore stations along both sides of the Hudson River. This study indicated no significant difference between the samples of east side and west side populations (Lauer and Howells, 1971). A total of 38 species of fish were caught and identified (Table 2). Of these species, only 11 were caught

Table 2. All fish species caught during a five-year study of shore stations along the Hudson River (Lauer and Howells, 1971).

*Alosa aestivalis (Glut or Summer Herring)
*Alosa pseudoharengus (Alewife)
*Alosa sapidissima (American Shad)
Anchoa mitchilli (Anchovy)
Anguilla rostrata (American Eel)
Apeltes quadricus (Fourspine Stickleback)
*Carassius auratus (Goldfish)
Catostomus commersoni (White Sucker)
Cyprinus carpio (European Carp)
Caranx hippos (Crevalle Jack)
Esox niger (Chain Pickerel)
Esox vermiculatus (Grass Pickerel)
*Etheostoma nigrum (Johnny Darter)
*Fundulus diaphanus (Freshwater Killifish)
*Fundulus heteroclitus (Saltwater or Banded Killifish)
Ictalurus melas (Black Bullhead)
Lepomis auritus (Redbelly Sunfish)
*Lepomis gibbosus (Pumpkinseed Sunfish)
Lepomis macrochirus (Bluefill Sunfish)
Menidia beryllina (Tidewater Silverside)
Menidia menidia (Northern Silverside)
Microgadus tomcod (tomcod)
Micropterus dolomieui (Smallmouth Bass)
Micropterus salmoides (Largemouth Bass)
Mugil curema (White Mullet)
Notropus atherinoides (Emerald Shiner)
*Notropus hudsonius (Spottail Shiner)
*Notemigonus crysoleucas (Golden Shiner)
Osmerus mordax (Rainbow Smelt)
Perca flavescens (Yellow Perch)
Pomatomus saltatrix (Bluefish)
Pomoxis nigromaculatus (Black Crappie)
*Morone americana (White Perch)
Morone saxatilis (Striped Bass)
Semotilus corporalis (Fallfish)
Strongylura marina (Atlantic Neddlefish)
Syngnathus fuscus (Northern Pipefish)
Trinectes maculatus (Hogchoker)

* Major species caught from 1965-1969

frequently enough and in large enough numbers to be considered major recurring species. It was quite apparent that species abundance and distribution varied greatly from station to station, as well as from year to year at the same station. The fluctuations were probably natural, and reflect normal environmental changes and short-term population changes. Annual variations in fish populations were not significant.

During the summer of 1969, New York University sampled at two sites (brackish and freshwater) to determine 24-hour fluctuations in fish populations. Twelve fish species were collected at both stations; nine species were found only at Esopus (freshwater), and eight species were found only at Buchanan (brackish) (Table 3). Species abundance displayed wide variations during a 24-hour period. The brackish water site at Buchanan was found to possess a more transient fish population than the freshwater station. Only 25% of the species captured at Buchanan could be considered seasonal residents of the area.

At Indian Point, fish samples were taken at east-shore and west-shore sites (Table 4). At the east-shore site, four species (spottail shiner, striped bass, silverside and white perch) represented 75% of the total annual catch. The spottail shiner population at the east-shore site (Verplanck) is dominated by mature fish in the spring. In July and August there is an influx of young-of-the-year shiners into the area. Young striped bass, 0+ age group, are also abundant in shore seines during July and August at Indian Point.

Surface and bottom trawls conducted monthly by Raytheon (1971) between 1969 and 1970 in the Indian Point vicinity resulted in the collection of 48

Table 3. The occurence of fish* species taken from the Hudson River by seine in 1969. (Modified from Lauer and Howells, 1971).

	Buchanan (mile 52)				Esopus (mile 86)			
	June	July	Aug.	Oct.	June	July	Aug.	Oct.
Summer herring	8	846	1218	532	-	1190	518	658
Alewife	46	4572	166	152	3	-	31	28
Pumpkinseed sunfish	-	8	-	-	44	140	180	326
Emerald shiner	-	-	2	-	-	-	12	-
Freshwater killifish	10	-	-	-	163	34	472	66
Golden shiner	2	4	-	-	38	226	14	62
Goldfish	8	-	-	-	-	1147	775	306
Johnny darter	20	4	30	36	16	167	808	138
Spottail shiner	570	195	378	978	310	1789	782	454
Striped bass	66	4	2044	1202	-	-	28	2
White perch	264	1998	706	568	238	128	42	76
Largemouth bass	-	-	-	4	1	-	2	20
Redbelly sunfish	-	-	-	-	8	-	-	130
American eel	-	-	-	-	13	-	-	36
Yellow perch	-	-	-	-	-	-	6	4
Fourspine stickleback	-	-	-	-	5	8	63	144
European carp	-	-	-	-	-	8	2	2
Fallfish	-	-	-	-	-	-	-	36
Bluegill sunfish	-	-	-	-	-	25	-	-
Black bullhead	-	-	-	-	--	10	2	-
Black crappie	-	-	-	-	-	-	2	8
Anchovy	-	-	34	76	-	-	-	-
Bluefish	-	10	-	-	-	-	-	-
Banded killifish	4	-	-	-	-	-	-	-
American shad	-	-	204	18	-	-	-	-
Rainbow smelt	-	-	2	-	-	-	-	-
Northern silverside	8	-	500	2236	-	-	-	-
Tomcod	-	2	8	-	-	-	-	-
Northern pipefish	-	-	-	10	-	-	-	-
TOTAL CATCH PER 10,000 sq. ft.	1006	7634	5292	5812	839	4872	3739	2496
TOTAL NUMBER OF SPECIES	11	10	12	11	11	12	17	18

*Number of fish calculated per 10,000 sq.ft. of shore area seined, for each 24-hour sampling date and each station.

Table 4. Relative abundance of fish species (per 100,000 sq. ft. seined) at Indian Point West shore (mile 43, Tompkins' Cove) and East shore (mile 42, Verplanck). (Modified from Lauer, 1971).

	April - Dec. 1968		March - Oct. 1969	
	West shore	East shore	West shore	East shore
Banded killifish	1224	44	240	15
Spottail shiner	368	464	120	260
Blueback herring	360	98	650	66
Johnny darter	302	30	200	47
Alewife	184	271	400	98
Fourspine stickleback	136		90	
Pumpkinseed sunfish	90		40	12
Mummichog	68	10	190	
White perch	26	725	90	120
Striped bass	22	84	150	250
American eel	20	10	3	15
Silversides	12	6	340	160
Golden shiner	12		10	6
Yellow perch	8		6	
Brown bullheak	8	3		
Bluegill sunfish	6		3	
Crevalle jack	6		6	3
American shad	2	40		3
Rainbow smelt	2			3
Chain pickerel	2			
Emerald shiner		10		
Pipe fish		6		
Blue fish		3		
Goldfish			8	
Redbreast sunfish			3	
White sucker			3	
Pin fish			3	
Total Species	20	15	20	14

species of fish. The most abundant fishes were bay anchovy, Atlantic tomcod, hogchoker, white perch, alewife, blueback herring and striped bass. A difference was noticed in species numbers and abundance between 1969 and 1970 in relation to plant operation. Young-of-the-year alewife and blueback herring were more abundant in the plant vicinity than other areas during the fall of 1969 when the plant was operating than in 1970. There were large concentrations of white perch throughout the year in the Indian Point area. Numerous fish species migrated past the plant, especially in late winter and spring for spawning. American shad, striped bass, rainbow smelt, blueback herring, alewife, and Atlantic sturgeon spawn above the plant site; Atlantic tomcod and bay anchovy spawn primarily below the plant; the American eel migrates to the ocean to spawn (Raytheon, 1971).

Analysis of community overlap information (Raytheon, 1971) indicated that depth was a dominant factor in the distribution of nonpelagic fish species. A deep water community exists in the Indian Point vicinity and a shoal water community exists in Haverstraw Bay and, probably, Peekskill Bay. Atlantic tomcod and hogchoker were characteristic species of deep water, while white perch and striped bass preferred shoal water (except during winter months). Community overlap among surface trawl collections suggested a quite uniform community of pelagic species (primarily bay anchovy, alewife, blueback herring) throughout the study area regardless of bottom depth.

Adult American shad were sonic tagged and tracked during their upstream spawning migration to determine their migratory behavior in the vicinity of Indian Point (Raytheon, 1971). The study indicated that shad spend time in

Haverstraw Bay before going upstream to spawn and that they utilized the river channel in the vicintiy of Indian Point during upstream and downstream migrations. Shad that were sonic tagged initially wandered about, presumably until they became oriented. Some fish wandered aimlessly for only a few minutes while others first traveled downstream. A total of 11 shad were tagged and tracked. Seven of these fish went south from the study area, were lost or died. Five shad were tracked past the Indian Point generating station. No conclusions should be drawn from this study.

Thermal choice experiments were designed by Raytheon (1971) to determine the effects of heated and unheated effluent water on the behavior of selected organisms. Although the plant was in operation and heated effluent was available only one day during the tests, the results suggest one fish species which may avoid areas of elevated temperatures and one species which may be attracted to the discharge area. Atlantic tomcod was the most active species and a substantial number of them chose the slightly cooler river water. A general increase in activity was noted for white perch and banded killifish as seasonal temperatures increased. The increased movement and preference of effluent water by banded killifish on May 20 is significant since Unit 1 was on-line, although no direct relationship should be concluded from a single days observation (Raytheon, 1971). Relatively little movement of this species occurred prior to this date.

OTHER PERTINENT STUDIES

INTRODUCTION

The literature on the effects of temperature on aquatic life is extensive. Although biological habitats and communities which are affected by thermal discharges are very diverse and each is unique in the interaction of its environmental components, **many** generalizations can be made from studies that have been completed. Bibliographies include Raney and Menzel, 1969; Kennedy and Mihursky, 1967; Coutant, 1970; also many comprehensive reviews and symposia are available: MacKenthun, 1967; Parker and Krenkel, 1969; de Sylva, 1969. The most recent and complete review of information pertinent to the Indian Point area is the U. S. Atomic Energy Commission (1972) Final Environmental Statement for the Indian Point No. 2 Nuclear Generating Plant. It would be redundant to attempt a massive review of information that is readily available in many forms. General findings from several reviews will be summarized here, with some detail on species and conditions which occur at Indian Point.

1. Although any change in the environment will enable some species to be more successful than they were before the change, other species will be less successful and probably decrease in numbers, the thermal discharge at Indian Point from Units 1 and 2 is expected to have no significant effect on the local biological communities or the entire Hudson River ecosystem (Lauer, 1972b; McFadden, and Raney, 1972).

2. There exists a temperature beyond which each organism cannot survive in an area. Important maximum temperature limits include those which are lethal, cause stress, or inhibit and reduce growth, activity and reproduction.

Critical temperatures are species specific and vary to some degree with the thermal acclimation of the organism. The maximum discharge temperatures at Indian Point will be below the upper lethal temperatures of most local organisms.

3. Temperature appears to be one of the most important factors regulating the geographic range of most aquatic organisms by controlling metabolic rates, and it directs the distribution of motile organisms within a habitat of variable temperatures.

DECOMPOSERS

The aquatic microbiological communities are considered to be extensive in the estuarine environment. Population size appears limited primarily by nutrient supply, and therefore, is approximately proportional to the amount of organic material present in the system (Resi, 1967). Decomposer communities exhibit rapid population replacement rates and dramatic seasonal succession of species. Elevation of stream temperatures has been found to favor warm tolerant species (Resi, 1967).

Protozoans will be mentioned in this section, although individual members may be classed as decomposers, consumers and even producers, in some cases. Cairns (1969) reported that there was a marked reduction in the number of species in a community of freshwater protozoans after severe acute thermal shocks (some to 122^{o}F), but communities recovered rapidly after elevated temperatures were terminated. No evidence from nine year studies suggested that protozoan communities had been affected by thermal increases from warm water discharges in the Savannah and Potomac Rivers.

PRODUCERS

A large part of the photosynthetic producers in an aquatic system are the unicellular floating plants. These derive nutrients from the water and energy from the sun to produce carbohydrates. The depth to which these plants are efficient in their energy conversions greatly depends on the depth of light penetration through the water column. The high turbidity in the Hudson River limits photosynthetic activity to the upper waters.

Studies of the effects of increased water temperature on phytoplankton are basically of two types: descriptive and laboratory. Some descriptive studies have attempted to monitor changes in the abundance, density and diversity of phytoplankton communities in the area of warm water discharge. Other descriptive studies have attempted to present measurements of the physio-chemical environment in which a species is normally found. Laboratory studies have attempted to evaluate the effects of warm water on growth, respiration and photosynthetic rate of various species in culture. Lethal limits for some phytoplankters have also been defined.

A laboratory study which indicates this shift from diatoms to blue green algae was described by Cairns (1956). A mixed population of algae was subjected to increasing temperatures. At 68°F, diatoms dominated cultures and a large number of species were represented. Above 86°F, a few individual diatoms were present, but green algae predominated. From 95 to 104°F blue green algae were dominant. The latter group of organisms are often considered aesthetically and ecologically detrimental to an aquatic environment. Consolidated Edison's facilities at Indian Point will remain under the state of New York's thermal discharge requirements and will not contribute to the thermal selectivity of the blue green algae in the Hudson River.

Fogg and Reimer (1962), who presented measurements of the habitats in which selected species of diatoms were found, noted that temperature ranges were broad for the species considered (Table 5). The authors noted further that few stenothermal species (able to withstand only slight fluctuations in temperature) have been reported and that the great bulk of diatom species are eurythermal (able to withstand wide variations in temperature).

The productivity of natural populations of phytoplankton of the York River was affected by increases in water temperature. Productivity was evaluated using C^{14} uptake as a measure of the rate of photosynthesis (Warinner and Brehmer, 1966). During the winter, when ambient river temperatures are naturally low, increases in water temperature (up to 25°F) enhanced primary production. At ambient temperatures above 58°F, increasing the temperature more than 10°F significantly depressed primary production. Results indicate that the greater the temperature rise, the greater the depression of production. During summer (ambient river temp. 68-81°F) an increase of 6°F was sufficient to depress production. In general the range of tolerance to temperature narrows as ambient river temperatures increase, and only a small temperature rise results in great reduction in production at ambient river temperatures over 77°F. These results are in conflict with those of Lauer (1972b), who showed no decrease in productivity of phytoplankton at Indian Point at predicted plume temperatures.

Table 5. Diatoms and associated thermal ranges based on sampling and on compilation of data reported in the literature (adapted from Fogg and Reimer, 1962)

	RANGE OF OCCURRENCE °F	
	Sampling	Literature
Melosira varians [1]	54 to 104	32 - 104
Navicula confervacea [2]	63 to 82 - 95	59 - 104
Cymbella tumida [2]	54 to 86 - 95	59 - 95
Nitzschia amphibia [3]	54 to 86 - 95	36 - 104

1. occurs at Indian Point
2. genus occurs at Indian Point (species at IP not identified)
3. other species in this genus occur at Indian Point.

Rates of photosynthesis were also used to evaluate the effects of increased temperatures on phytoplankton of the Patuxent River Estuary (Morgan and Stross, 1969). The results indicated that an increase in temperature of about 14°F stimulated photosynthesis when ambient water was 61°F or cooler. A 14°F increase inhibited photosynthesis when natural water temperatures were 68°F or warmer.

Studies conducted on the effects of elevated water temperature on aquatic vascular plants indicate that some species are apparently very tolerant of warm water, whereas others are adversely affected by increased temperatures. Trembley (1960) conducted a detailed survey of rooted aquatic vegetation on both sides of the Delaware River above and below the Martins Creek Steam Electric Station. Results indicated little difference in the growth of rooted aquatics between upstream and downstream points. In 1958 and 1959 surveys, Elodea and Potomogeton spp. specimens were growing directly in the path of warm water.

Anderson (1969) reported the disappearance of a Ruppia maritima population near the effluent of an electrical generating station on the Patuxent River, Maryland. Another rooted aquatic, Potomogeton perfoliatus, which grows with R. maritima was more tolerant of elevated temperatures (to 95°F), and replaced Ruppia in areas where it had declined. Further studies were conducted by Anderson (1969) on respiration rates of P. perfoliatus in heated and unheated water. It was concluded, that this plant is capable of physiological adjustment to higher water temperature as the leaf matures because only older leaves tend to respire less at the elevated temperatures.

CONSUMERS

The invertebrate plankton community represents a trophic level intermediate between the producer organisms and many higher forms of estuarine life. Their position is essential to growth and development of planktonic stages of many fish. Despite their ecological importance, little is known of the response of plankton populations to various environmental conditions such as temperature. Several studies have indicated that plankters are highly resiliant to changes in their environment.

Information on the lethal limits of planktonic copepods from other localities may suggest upper limits of more common Indian Point species. Acartia tonsa of the Chesapeake Bay area, also found at Indian Point during periods of high salinity, can withstand 86°F for 24 hours if acclimated to 77°F (Heinle, 1969). Eurytemora affinis, the same genus as several dominant copepod plankters at Indian Point, suffered complete mortality in 24 hours at 86°F. This is not meant to infer that those species found at Indian Point will respond in a similar manner. In order to determine this additional investigations are necessary. The upper thermal tolerance limits of the above two copepods were near the normal temperatures of their habitat during summer. Heinle (1969) also demonstrated that acclimation temperatures had little effect on the upper thermal tolerance limits.

Development and survival of individual plankters is affected by fluctuations in water temperatures during the daily cycle of ambient and elevated temperatures, therefore water temperatures can indirectly affect plankton population sizes. Mortality was much greater in the planktonic larvae of crabs, exposed to fluctuating temperatures between 59 and 68°F than it was at exposures to water of a constant 68°F (Costlow and Bookout, 1969).

It has not been demonstrated that the seasonal distribution or production of zooplankton is reduced by thermal discharges. Although prolonged exposure to temperatures of 86°F or above would probably eliminate two important copepods species in the Patuxent River (Heinle, 1969), results of a three summer study of plankton population in the area of the Patuxent River power plant indicated no detectable reduction in production or standing crop of the copepod, Acartia tonsa, (Mihursky, 1969). Populations of larger organisms (the ctenophore, Mnemiopsis leidyi) appeared reduced in the area of thermal discharge, possibly due to entrainment rather than elevated temperatures (Mihursky, 1969).

Information from several studies indicates that the abundance and diversity of benthic organisms in temperate river systems was greatly reduced at water temperatures above 86°F to 90°F. At Indian Point the area of decreased diversity will be confined to the discharge canal and the immediate vicinity of the discharge ports. The affect that this altered portion of the river will have on the entire estuary is insignificant. Temperatures which cause death or sublethal effects vary considerably with the invertebrate species. The effect of temperature as the primary limiting factor was demonstrated by Coutant (1962) who observed an increase in number and diversity of benthic organisms as sampling progressed from point of thermal discharge to ambient river temperatures. A community of marine benthos was stressed during summer by combined effects of naturally high ambient water temperatures in the York River and a thermal discharge (Warinner and Brehmer, 1966). The authors found the effect of the surface discharge, which had a Δ T of about 14°F and a maximum flow of 220,000 g.p.m. at peak loads, extended 300-400 meters. Many authors have found that the habitat and benthic community recover with distance from the warm water effluent. Recovery distance was dependent on the magnitude and extent of the thermal discharge.

Some temperature tolerance work has been conducted on invertebrate benthic organisms of the same genus or species as those common in the Indian Point area. A study of species from the Patuxent estuary has determined median tolerance levels after 24 hours for organisms acclimated to about 60°F; Neomysis americana (77°F), Crangon septernspinosa (81°F), Gammarus fasciatus (88°F) Monoculodes sp. (84°F) and Rithropanopeus harrisi (91°F) (Mihursky and Kennedy, 1967). The median tolerance level of the most temperature sensitive species, N. americana, could be increased to about 90°F by acclimation to 86°F. Although data are not conclusive, this species appears to avoid the outfall area of the Patuxent River power plant (Mihursky, 1969). Neomysid shrimp are seasonally important as a food species for several fish of the Indian Point area, although they move into the area only during periods of high salinity. Lauer (1972b) found that sizable mortalities of Neomysis may occur in the discharge canal when temperatures exceed 90°F, but additional flow from 3 Units will decrease exposure time and increase tolerance. Although the blue crab, Callinectes sapidus, appears to be relatively tolerant of high temperatures, about 40,000 were exposed to lethal temperatures at the Chalk Point power plant on the Patuxent River during their alongshore movements in the estuary (Mihursky, 1969). Discharge temperatures at Indian Point will never reach the 104°F known to be tolerated for short periods by blue crabs (Gallaway and Strawn, 1972).

Normal activities and breeding in most species may be inhibited at temperatures below those necessary to cause direct mortality (Parker and Krenkel, 1969). The ultimate effects of exceeding critical upper activity and breeding temperatures would be population decreases similar to those from direct lethal exposures. The American oyster, Ostrea virginica, ceases necessary ciliary action at temperatures above 90°F (Stewart, 1967). Prolonged exposure to elevated temperatures would be lethal, but oysters survive in waters which seasonally reach 93°F for short periods (Gunter, 1957). Oysters of the Hudson River, which seldom reach to Indian Point, would not encounter temperatures of above 90°F at any point in the discharge area.

Damage to benthic communities will increase as the temperatures of bottom waters approach and exceed 90°F (Mihursky, 1969). Many benthic species which are eliminated from local areas of high temperatures during summers, would probably reestablish with dispersal stages from the surrounding ecosystem during the following spring period. This seasonal shift in populations would simulate the natural seasonal changes in organisms with northern affinities at the southern extent of their geographic distributions.

Epifaunal communities are particularly suited to studies of the effects of warm water on aquatic life because these communities are sessile, not buried in the substrate and contain a large proportion of species normally found in the benthos. Cory and Nauman (1969) state that temperature is probably the most important environmental factor controlling the lives of the epifauna. Nauman and Cory (1969) described the epifaunal communities in the intake and effluent canal of a steam electric plant on the Patuxent River Estuary. The average surface water temperature in the effluent canal was 11°F above ambient and the biomass production of organisms (measured as dry weight) in the canal was nearly three times as great as production of the epifauna at the intake. In general, the species composition and seasonal patterns of attachment of organisms were similar in effluent and intake. Higher species diversities were recorded in the effluent canal, except during July and August. There was a decline or disappearance of Sagartia, Corophium and Gammarus in the effluent canal in July and August (average water temp: 91.4°F; maximum: 100.4°F). An earlier and larger set of Balanus occurred in the effluent canal. Lauer (1972b) found that Gammarus sustained no mortality in the Indian Point discharge canal at Δ T's up to 15°F over the summer ambient temperatures.

Many researchers have concluded that the direct effects of a local warm water discharge on adult fish will be small if temperatures are below lethal levels (Raney, 1971). The mobility of adult fish enables them to avoid areas of adversely high temperatures. The effects of elevated temperatures on eggs and larvae which pass through the area, and the sublethal effects of long term exposure on a given population are much less understood. Eggs and early larval stages are subjected to local conditions, which they are relatively unable to escape; and larval development requires a restricted range of temperatures. Concentration of fish in the discharge through thermal preference suggests additional problems due to exposure of fish to sudden temperature changes. Several researchers have related increased incidence of fish disease to elevated temperatures (de Sylva, 1969) while thermal stress is believed to be a prime factor in bacterial caused mortalities of white perch in the Chesapeake Bay area (Mihursky, McErlean and Kennedy, 1970). It is not known if these findings would be true for the Indian Point area.

Avoidance of potentially harmful temperatures by species found in the Indian Point area has been the subject of recent studies. Gift and Westman (1971) determined the avoidance temperatures of some of the estuarine fishes from the Great Bay area of New Jersey. They also investigated upper avoidance breakdown temperatures; these represent the temperatures which will cause the loss of locomotor control and the ability to escape from ultimately lethal conditions. It was concluded that summer estuarine water temperatures above 87°F were unacceptable to many species, and that temperatures above 94°F could be expected to result in the death of most important estuarine species, if avoidance behavior were not possible (Figure 1). It was also noted that the thermal tolerances of larger fish appeared lower than those of smaller fish. The maximum avoidance temperature of the white perch, an abundant Indian Point species, was 95°F, when fish were acclimated to summer temperatures (77°F) and 44°F when fish were acclimated to 34°F in studies conducted in Delaware (Meldrim and Gift, 1971). Striped bass appeared slightly less tolerant than white perch, but more tolerant than the stripers studied by

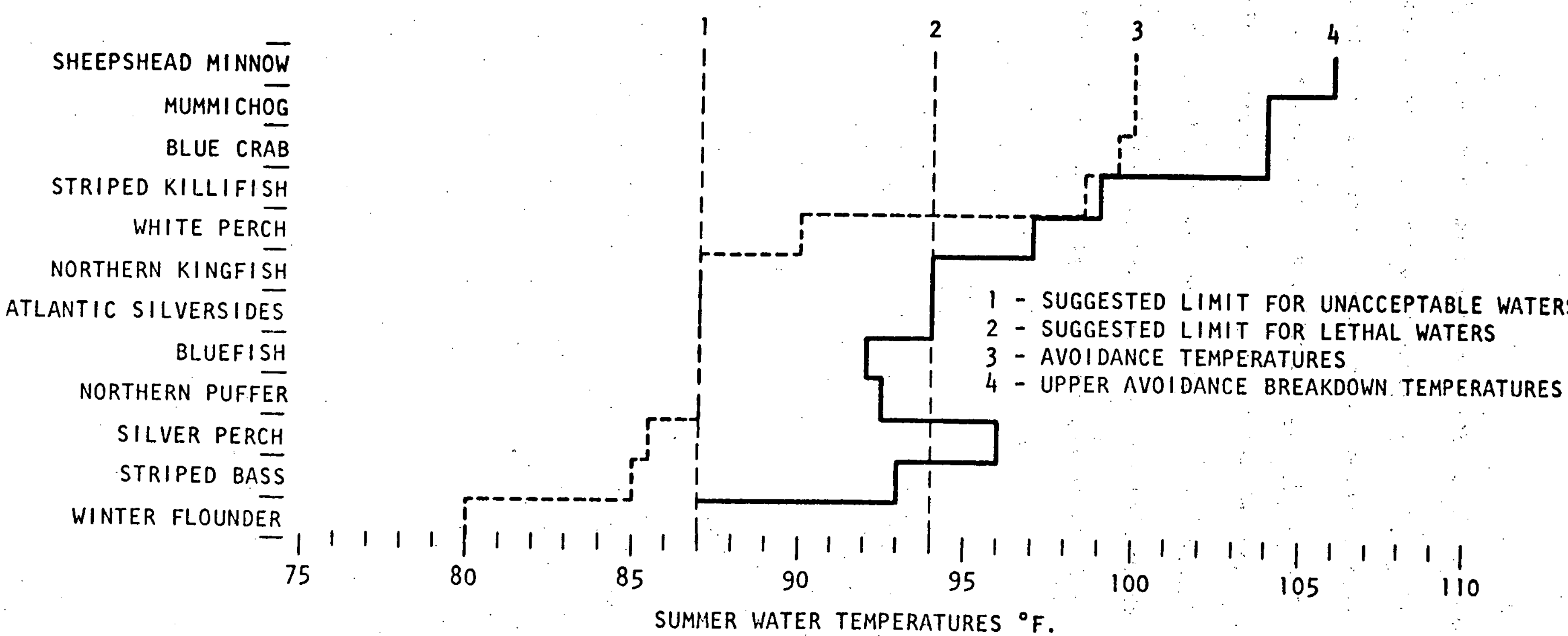

Figure 1. Water temperatures during summer which are avoided by and lethal (on short exposure) to estuarine species (modified from Gift and Westman, 1971).

Gift and Westman (1971). Striped bass from 81°F avoided 94°F and those from 41°F avoided 55°F. The relationships between avoidance temperatures, upper avoidance breakdown temperatures and upper thermal tolerance limits for the Atlantic silversides, Menidia menidia, are represented in Figure 2. Meldrim and Gift (1971) determined that the field temperature, salinity and length of the fish all affected the avoidance temperatures found in the laboratory. Although the thermal discharge will never exceed 90°F, many of the Hudson River species will avoid any temperatures which may be harmful.

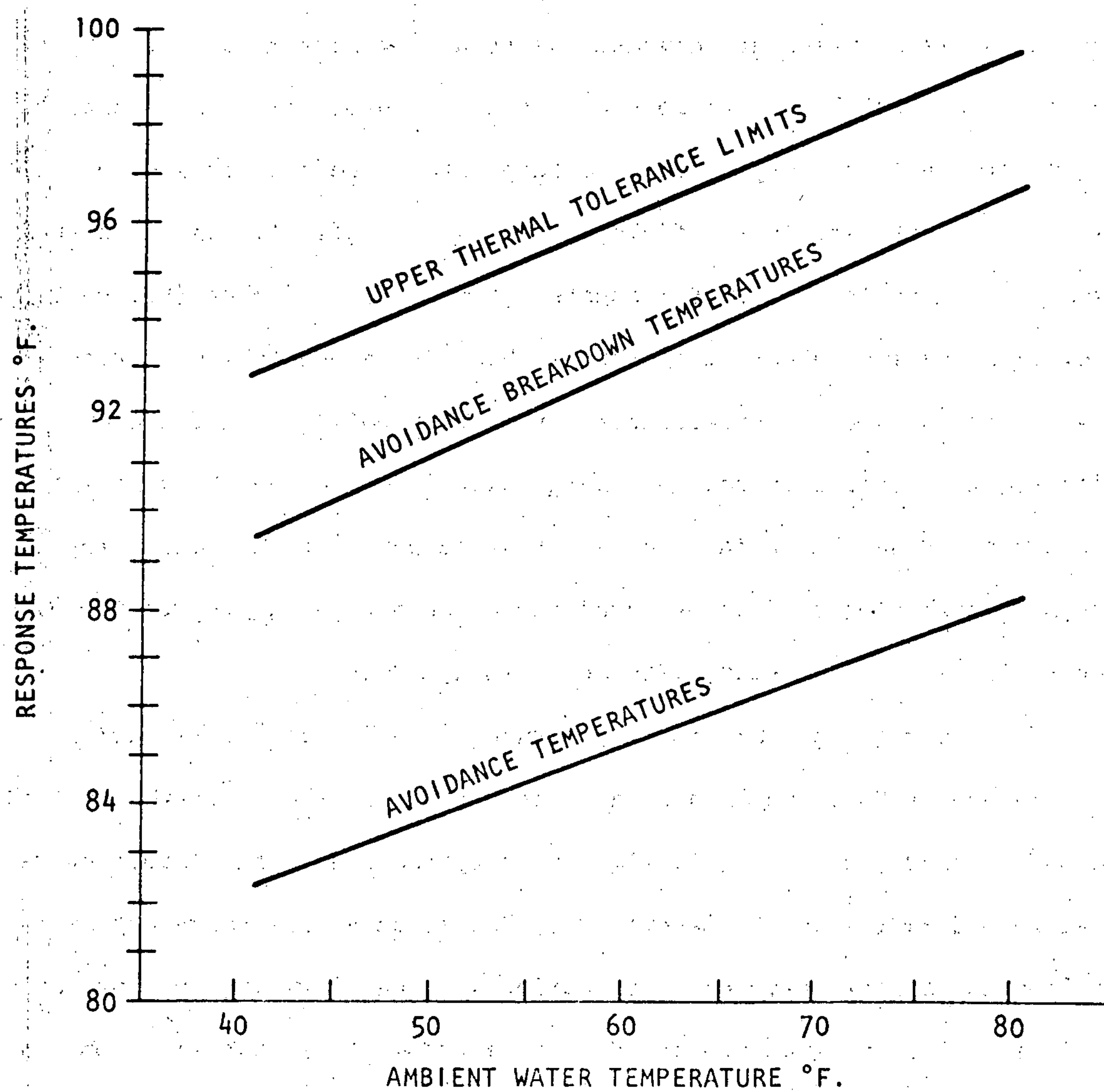

Figure 2. Three regression lines demonstrating the relationship between the ambient water temperatures and the thermal responses (upper) avoidance temperatures, upper avoidance breakdown temperatures, and upper thermal tolerance limits (LD_{50}) of Menidia menidia (Summer-Fall period) (from Gift and Westman, 1971).

Although areas of very high temperatures are avoided by fish, their long term distribution and movement patterns may be more affected by a species specific thermal preference. A close correlation is thought to exist between laboratory determined temperature preferences and thermal distribution of fish in the field, but only Neill (1971) has shown the exact relationship for several species of warm water fishes (Figure 3). Many fish species select temperatures which are above ambient during all seasons of the year. This indicates that fish would be influenced by some specific temperature in the thermal gradient produced by the warm water discharge. General findings suggest that temperate fish species leave areas of high elevated temperatures during summer and aggregate in heated waters in winter (Trembley, 1960 and Gammon, 1971).

White perch from ambient temperature of 75°F preferred a maximum temperature of 90°F, while during winter they selected 41°F from an ambient of 34°F (Meldrim and Gift, 1971). Salinity had a definite effect on temperature selections in the laboratory. Preferences for equivalent ambient acclimation temperatures differed during periods of rising (spring) and periods of falling (autumn) field temperatures. Less extensive temperature selection tests have been conducted on many of the species of the Delaware Bay area, but comparison of results is difficult because of variation in the seasons each species was tested.

Temperature selection in an environmental gradient is important in determining fish distribution, but little is known of the proportion of a population affected by given discharge area or the residency period of fish within the warm water. The consequences of extended warm water habitation, especially during periods of cold ambient water temperatures,

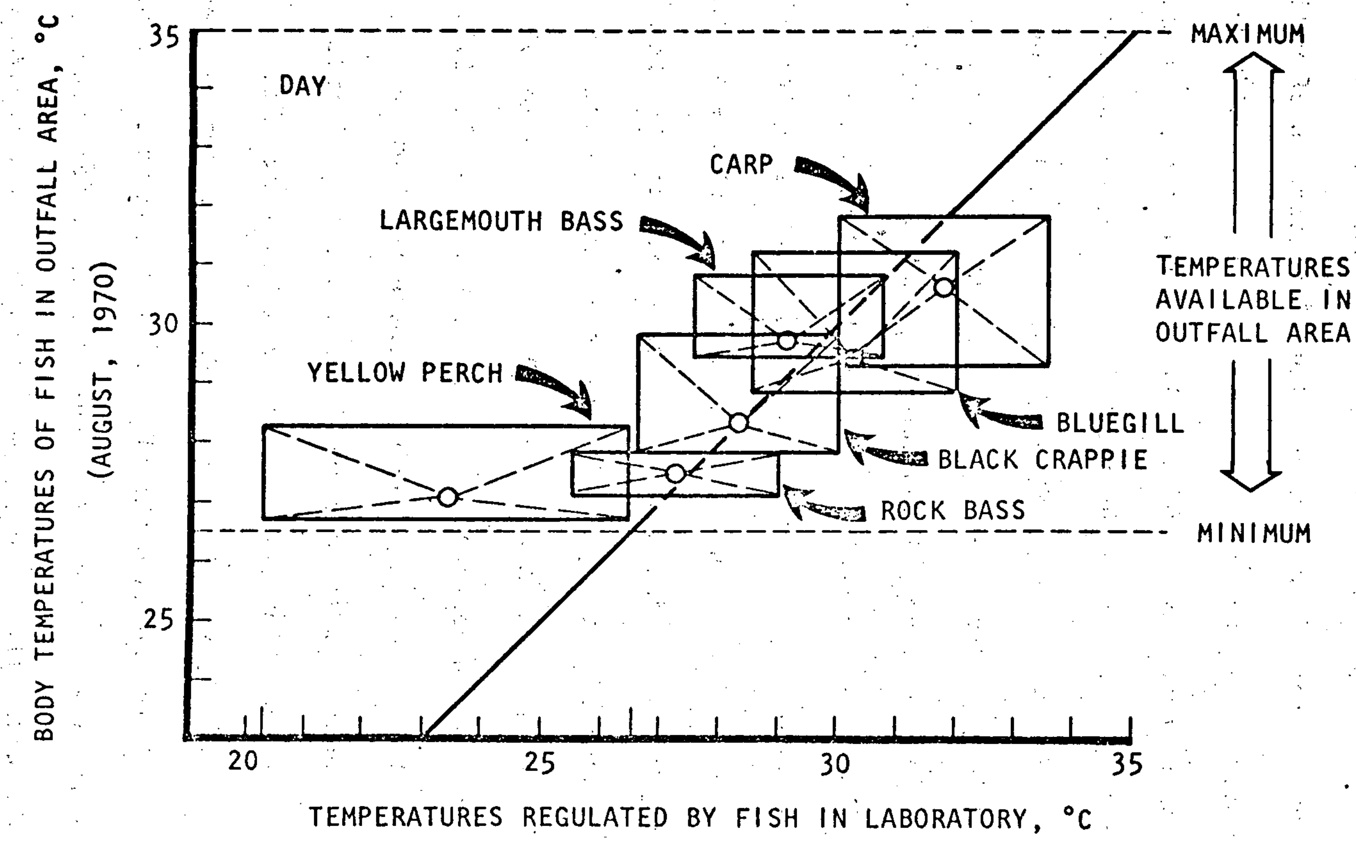

Figure 3. Body temperatures of six fishes in the outfall area during afternoon in August 1970 compared with diurnal temperatures they maintained by behavioral thermoregulation in the laboratory. A solid circle indicates the median body temperature and midpoint of the preferred range of temperature for each species. Rectangles indicate, vertically, interquartile ranges of body temperature and, horizontally, the preferred range of temperature. (The preferred range is limited by median upper and lower turn-around temperatures. from Neill, 1971).

may have detrimental sublethal effects on fish populations. Research is needed to determine if specific chill periods are necessary for sexual development in the Indian Point fish species. Normal maturation of yellow perch eggs requires a five month period of water temperatures of 43°F or below (Great Lakes Fishery Laboratory, 1970). The reproductive potential of largemouth bass appeared to have been adversely affected by overwintering in an area of elevated temperatures in a Missouri reservoir (Witt, Campbell and Whitley, 1970). Long term alterations in local species composition may take place by changes in the competitive advantage of thermal tolerant species. Cold water species on the southern limits of their distribution may be excluded from areas of elevated temperatures. Aggregation in warm water during winter could acclimate fish to unseasonable high water temperatures and may result in mortalities from a rapid decrease in temperatures, if the thermal discharge were discontinued. Young white bass acclimated to temperatures of from 41 to 59°F exhibited 50% mortality over a one week period when transferred to near ambient temperatures of about 32.9°F (Edsall, 1972, personal communication). White perch (144-750 mm) transferred from 44 to 34°F exhibited significantly depressed opercular rates and equilibrium loss, although two of the four fish tested regained equilibrium after 3 hours (Meldrim, Gift and Petrosky, 1971). Rapid decrease in temperatures is unlikely at Indian Point because the plume will be composed of discharges from 3 independent power plants. More research is needed on the possible indirect and sublethal deleterious effects of warm waters on temperate fish populations.

Adult fish near a thermal discharge may be exposed to sudden rises in temperature from changes in plume configuration due to shifts in wind or current directions or sudden decreases in temperature from winter discontinuation of warm water source. Nickum (1965) studied eight species of fresh water fish and concluded that rapid changes up to 20°F produce little effect unless the species lethal limit was exceeded. Increases of greater than 20°F resulted in frequent mortalities, sometimes delayed 24 hours or more after exposure. Tolerance to changes among species varied little, and fish size appeared unrelated to ability to survive sudden changes in temperature. Fish appeared more sensitive to rapid changes during spring and early summer. Young white perch and striped bass survived short period exposures to increases of 15°F above ambient, if less than 80°F, but exposure for longer than 15 minutes resulted in mortalities (Meldrim and Gift, 1971). Striped bass appeared more sensitive than perch because some stress was observed in all tests of 15°F elevations. During summer, the Δ T of the plume will not exceed 9-10°F which is below the exposures tolerated in the above experiments, therefore, the Indian Point discharge should not cause stress to most fish species. Sudden decreases in temperature in the discharge canal or river during winter would not be expected at Indian Point because it would be unusual for all three Units to go off line at the same time.

Possible effects of elevated temperatures on fish migration include the obstruction of the spawning route and physical injury to adults or young moving past the thermal discharge. Raney (1971) states that the ability of fish to avoid lethal temperatures and migrate around local areas of warm water reduces the possibility of fish kills to nil. Marcy, et al. (1972) showed that young American shad were capable of traversing the heated effluent of the Connecticut Yankee plant during their downstream migration. Fish were able to avoid areas of lethal temperature (86°F). Migrating adult salmon and trout avoid areas of thermal discharges in the

Columbia River (Coutant, 1969), while American shad (Moss, 1970) and many of the other fish species from the Indian Point area (Gift and Westman, 1971) avoid temperatures which are below their upper lethal limits. Although most thermal discharges at Indian Point during summer will be confined to local surface areas of below avoidance temperatures, the temperature and extent of the plume will determine the effects on the migration pattern of each fish species.

DISCUSSION

Many biologists who have studied warm water discharges, have concluded that the direct adverse effects of waste heat appear to be limited to the immediate area of the discharge and are usually confined to the season of maximum ambient temperatures (Trembly, 1961; Alabaster and Downing, 1966; Mihursky, 1969; Gammon, 1971; Raney, 1971; Cairns, 1972).

Studies to date at Indian Point suggest that operation of Units 1, 2 and 3 until 1981 will cause no irreversible damages to the Hudson River ecosystem. If current investigations and monitoring programs indicate significant change during this period, an alternative cooling system could be implemented. The Hudson River's striped bass population has a substantial compensatory reserve which would appreciably reduce losses in the population due to operation of Units 1 and 2 (McFadden, 1972). Raney (1972) predicted that there would be no irreparable damage to striped bass populations of the Hudson River or Long Island Sound and no effect on the major Atlantic Coast populations by operation of Units 1 and 2. No significant changes in abundance or composition of bacteria, phytoplankton or zooplankton will result from the planned operation of both Units (Lauer, 1972b). Thermal tolerance tests, also by Lauer, show that there should be no effect on the egg and larval stages of striped bass at temperatures encountered in the thermal plume.

Biological studies indicate that damage to temperate aquatic communities increases at temperatures above 90°F in summer and that many species can tolerate short rapid increases of 15°F above ambient, when the resulting temperature does not exceed 90°F. Physico-chemical evidence also suggests that physical changes in the structure of a water molecule at temperatures from 86 to 91°F may affect basic biological activities and that long exposure may ultimately be lethal to organisms not genetically adapted to living within that range (Drost-Hansen, 1969). The general relationship between temperature and estuarine fauna of the Chesapeake Bay area has been described in thermal-biotic predictive models (Mihursky, McErlean and Kennedy, 1970). Since many of the same species exist at Indian Point, the model may suggest relationships similar to those found in Hudson River fauna. The model predicts that about 90% of the resident organisms will be within their temperature range, at 85°F and below, while only 30% will be within their range at 90°F and above. The discharge at Indian Point will never exceed 90°F, and will seldom exceed 87°F. Therefore, most organisms should be well below critical temperatures even in the limited area of the plume directly about the submerged discharge ports.

The reliability of estimates of the total biological effects of the Indian Point thermal discharge on the aquatic community would be directly related to the quantity and quality of biological information on which the estimates are based. Conservative estimates are best when attempting to describe effects which may result in cumulative or irreversible changes to the ecosystem. Estimates of suggested general community thermal tolerance limits, herein, are based on information available to date and predictions made in relation to other similar studies.

The warm water is expected to be primarily a surface phenomenon which will have little or no effect on the phytoplankton populations at Indian Point (Lauer, 1972). Although diatoms were replaced by blue-green algae near the discharge of the Connecticut Yankee plant, the change does not seem to portend obnoxious conditions (Merriman, 1971). Plankton studies to date in the Chesapeake Bay (Cairns, 1969) and at Indian Point (Lauer and Howells, 1971; Lauer, 1972) have found no population changes related to thermal discharges, although the close relationship between abundance of specific phytoplankters and the physio-chemical components of the aquatic environment suggest that even small increases in water temperature may cause shifts in local phytoplankton populations similar in magnitude to naturally occuring fluctuations. Seasonal shifts may occur, but the consequences of these changes are assumed to be slight if replacement takes place by similar species with similar positions in the trophic structure. Lauer (1972b) states that no significant changes in abundance or species composition will be experienced by Hudson River phytoplankton populations due to operation of Units 1 and 2.

Similar thermally related changes also may occur in the bacterial, zooplankton, benthic and fish communities in a restricted area near the discharge at Indian Point. Sensitive members of the benthos which might undergo abnormal seasonal shifts in abundance or eventually be reduced include *Neomysis americana*, present at Indian Point only during periods of high salinity, and *Crangon septemspinosa*. *Gammarus fasciatus* is an important invertebrate food item for many estuarine fish species at Indian Point which may benefit from slightly elevated temperatures. Fish species which appear to avoid warm water or are easily stressed by elevated temperatures include the very abundant Atlantic tomcod and the more rare winter flounder and sturgeons, all of which are benthic species and would not be subjected to elevated temperatures at Indian Point. Several species are thermally more tolerant and may increase in abundance by having a competitive advantage over less tolerant species. The more tolerant fish include many of the local sunfishes, white catfish, brown bullheads, carp, goldfish, several of the forage species and possibly white perch and striped bass.

Of estuarine organisms, plankton appear to be the most vulnerable to thermal discharges. Local species replacement and seasonal shifts in abundance of phytoplankton and most zooplankton at Indian Point will probably cause little change in the functioning of the Hudson River ecosystem, but species changes in the ichthyoplankton may result in more noticeable community disruption. Indirect effects of exposure to elevated temperatures may result in increased or decreased survival of fish eggs and larvae. Spatial distribution and thermal tolerance of the eggs and early larval stages of striped bass indicate that during the most temperature sensitive stages of development (the early post-hatch yolk-sac larvae and gastrula stage) both occur in greatest abundance near the bottom (Lauer, 1972) far from exposure to plume temperatures. Older larvae migrate vertically in the water column diurnally and are only abundant at the surface during short periods of the night. These larval stages demonstrated a sixty-minute exposure maximum temperature tolerance of 88^{o}F (Lauer, 1972b) which is above the predicted surface plume temperatures even during the warmest summer periods. The peak abundance of eggs and larvae of other fish species (eel, silversides, smelt, anchovy, clupeids and white perch) collected at Indian Point occur during spring prior to maximum plume temperatures, with the exception of anchovy and silversides. The anchovy spawns south of Indian Point and should not be greatly effected by the thermal discharge.

Physical change in the current velocity or volume of flow of the Hudson River from seasonal runoff or tidal flows will affect the spatial distribution of the elevated temperatures. These, in turn, determine the extent of the aquatic community in contact with waters above ambient temperatures. Large runoff associated with increased rainfall during spring and fall should diminish the effects of elevated temperatures by dilution of the discharge and by transporting surface waters downstream more rapidly.

Under normal summer operating conditions, temperatures of cooling water in the discharge canal will seldom exceed 15° F above ambient river temperatures and will be reduced to about 9-10° F above ambient in the outfall area. The temperatures of cooling water will be reduced by forced mixing with waters of ambient temperatures very shortly after it is discharged through the submerged ports. This conclusion is supported by both QLM and Alden models. Maximum differential between temperatures of cooling waters and ambient river is 24° F. This would be possible only under certain conditions between October and April when Units 2 and/or 3 are at full capacity and cooling water intake is reduced to 60% of full flow. This temperature difference would occur only during winter conditions and would be reduced to 13-16° F immediately after mixing with the river resulting in a plume temperature of approximately 54.5° F during most of the winter.

The temperature of discharge water should be about 9-10° F above the ambient river temperature under normal summer operating conditions (3 units at full capacity and full flow at the surface). During the summer months of maximum ambient temperatures, the maximum temperature of the discharge should not exceed 89° F at the surface. This temperature will occur very rarely and is below the upper lethal limits of most species found at Indian Point for which data are available. The maximum differential between discharge and ambient temperatures in winter should result in a plume temperature no higher than 46° F over a small surface area. The effects of this elevated temperature on the local aquatic flora and fauna may be both positive and negative. Growth and activity may be stimulated among procedures, decomposer and consumers, while increased metabolic rates and disease may have adverse effects on some organisms. Studies in progress will determine the effects of the thermal discharge on the Hudson River aquatic communities (Section 13).

The discharge of waters less than 90°F by the Con Edison power plant may cause local shifts in the abundance of some of the aquatic organisms present at Indian Point, but it is not expected to cause major changes in resident species or to adversely affect the interrelationships between organisms in the functioning estuarine community. Replacement of existing species by other species cannot be considered objectionable if the general functional characteristics of the entire system are not seriously disturbed (Cairns, 1972). Discharges of waste heat, even below 90°F should not exceed the receiving capacity of the ecosystem into which they are released.

Mathematical models to predict the effect of Indian Point cooling water discharge (Units 1,2 and 3) on the thermal distribution in the Hudson River have indicated that the subsurface discharge would meet the NYSDEC thermal standards (Quirk, Lawler and Matusky, 1970). More recently, a hydraulic model has been developed by Alden Research Laboratories to determine the combined effects of Indian Point (Units 1, 2 and 3), Bowline (Units 1 and 2) and Lovett (Units 1 - 5) power plants on the Hudson River thermal distribution. Although preliminary results suggest that river water temperatures may be elevated in excess of the New York State thermal standards (Section 9.3), the model assumed conditions of maximum severity with river flow reduced to 4,000 cfs, low summer heat transfer coefficients and all three Units operating at full capacity. These severe river conditions would occur only 2% of the time (Quirk, Lawler and Matusky, 1970). Whether or not preliminary estimates of thermal conditions at full scale operation are verified, Con Edison will operate the Indian Point power plants to remain within the thermal limits established by New York State.

The combined thermal discharges from Indian Point Units 1 - 3 and other Hudson River power plants will not significantly increase the water temperatures of the river, but will extend the area exposed to elevated temperatures. Discharges from the operations of the Danskammer and Roseton plants located north of Newburgh will probably have little or no influence on the water temperatures or the estuarine communities in the Indian Point area. The rapid regeneration times of planktonic flora and fauna during most of the year indicates that any changes in the plankton populations which may have occurred near the northern power plants would have returned to normal river conditions before reaching the Indian Point area 22 miles downstream. The thermal discharges from all the proposed units of the Indian Point, Bowline and Lovett power plants may increase surface temperatures 2 - 4°F over large areas of the Hudson River between Indian and Croton Points under critical summer conditions (Quirk, Lawler and Matusky, 1971). The Hudson River ecosystem may be little stressed by the additional heat load, but the proportion of the aquatic community in contact with the elevated temperatures will increase. There is no evidence that any type of sub-lethal effect has or ever will occur at Indian Point.

Advantages of a large surface area of warm waters (about 1600 acres within the 2°F isotherm) may include increases in primary productivity of phytoplankton with benefits at other trophic levels resulting in a more productive estuarine system. Although critical life stages of many fish and benthic organisms are planktonic, they would be directly affected by elevated temperatures only in small local areas near the thermal discharges.

The area of water temperatures of 4°F above ambient (approximately 600 acres) will induce biological changes (beneficial or deleterious) on a scale large enough to be documented by monitoring the estuarine ecosystem for changes in the community structure (details of the monitoring study are presented in Section 13).

The risk of environmental damage increases in proportion to the size of the aquatic community in contact with elevated temperatures. Although slight species shifts at the phytoplankton level will probably result in equivalent species replacement with no effect to the planktonic stages of fish and benthic organisms, the remote possibility exists that thermal stress of a single species of phytoplankton may cause consequences at other trophic levels (zooplankton through fish larvae). The apparently slight risk must be considered in relation to the increasing demand to utilize the aquatic environment to its full thermal capacity without greatly stressing the normal functioning of the Hudson River communities. The combined thermal discharges of Indian Point, Lovett and Bowline power plants will result in elevated surface temperatures over a limited area of the total estuary. The effects will probably be local and temporary in terms of the biological communities of the Hudson River estuary.

Interrelated laboratory-field research is necessary to define ecological consequences of short and long term exposure to important species to elevated temperatures. Although long term changes in community structure maybe confused by the combined effects of multiple causitive factors and a great deal of natural variability, constant monitoring of populations will increase the reliability of ecological predictions. To date, studies indicate that the thermal discharge from Indian Point Units 1, 2 and 3 will have little direct effects on Hudson River communities. Biological programs have been initiated by Con Edison to describe and monitor the complex community interactions and define the receiving capacity of the aquatic system at Indian Point. Only through environmental planning and management can use of the aquatic environment be maximized with minimal damage to the biological community.

CONCLUSIONS

The Con Edison generating plant will continue to operate within the present New York State thermal standards. The temperature of water discharged into the Hudson River by Con Edison will never exceed 90°F with the exception of the small area surrounding the submerged ports. Previous studies indicate that damage to estuarine biota increases sharply at summer temperatures above 90°F but appears minimal below 90°F. The literature also suggests that most organisms of the Indian Point area can tolerate temperatures above those which will be discharged with all three units at full capacity. The thermal discharge at Indian Point may cause small scale and local changes in the estuarine community. Some organisms at all trophic levels may be stressed causing shifts in species abundance and, possibly, species replacement within the local areas of maximal temperature additions. The present state of understanding of community interactions is inadequate for accurate predictions of the effects of the Indian Point thermal discharge because little research has been conducted on the indirect and long term effects of elevated temperatures on the estuarine ecosystem. Although above ambient thermal exposure may stress some planktonic organisms in the Indian Point area, any adverse effects will probably be limited to the immediate area of the discharge during summer. The discharge will be avoided by several species of estuarine fishes.

Con Edison is currently monitoring the aquatic biota at Indian Point for important changes in community structure. Sublethal effects of long term exposure and indirect effects of the warm water discharge are being investigated (see Section 13). This information will contribute to development of more biologically sound thermal standards and plant operating procedures. Biological research is designed to determine the thermal receiving capacity of the estuarine environment with minimal damage to the biotic community and maximum sustained use of the resource.

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TELEPHONE: 617 829-4323

Mr. H. Bremer
Consolidated Edison Company
4 Irving Place
New York, New York 10003

November 2, 1972

RECEIVED
NOV 13 1972
H. C. BREMER

INDIAN POINT III EXTENDED MODEL
THREE UNIT TESTS

Dear Mr. Bremer:

Enclosed please find results from the recent tests using the Indian Point III extended model for three unit operation at Indian Point.

Prior to this series of tests, the upstream boundary of the model was extended about 2.7 miles to minimize the loss of heat during flood tide and, therefore, to better approximate a build-up to "steady-state" river temperatures. With the model extension, dispersion, rather than advection became the predominant mechanism of transporting heat across the upstream model boundary, and this upstream heat flux was thus markedly reduced. The river runoff simulated was 20,800 cfs which is estimated, by Quirk, Lawler and Matusky in their report "Influence of Hudson River Net Non-Tidal Flow on Temperature Distribution", to be the minimum flow available for dilution. At this river runoff salt carried by upstream moving seawater just reaches Indian Point. Freshwater flows larger or lower than this value provides more dilution of heat rejected into the river due to contribution of more river runoff or density-induced circulation, respectively. The heat transfer coefficient in the model was measured during each test. The average coefficient represents a prototype value of about 118 BTU/Day · F · Ft^2.

Since it is not possible to distort the behavior of a buoyant jet, tests were conducted in the 1 to 50 uniform scale model and the resulting data used to calibrate the distorted scale discharge structure in the river model. The tested Indian Point outfall structure consisted of 12 ports, 15 feet long by 4 feet high, with a centerline spacing of 21 feet. The centerline submergence of the ports was 12 feet. Two steady ebb flow currents, 0.4 and 0.8 fps, were used both in the 1/50 scale and distorted scale river model. The maximum surface temperature rise observed in the 1/50 model was between 9 and 11F above the intake temperature. Since steady currents were used, this maximum temperature rise does not reflect residual temperature build-up nor plant recirculation. The discharge structure in the distorted model was modified so that the near field temperature rise pattern matched that obtained in the uniform scale model tests. Similar calibration tests had been completed for the Lovett and Bowline discharge structures.

The prototype operating conditions, given to ARL for simulating each of the plants during model testing, are given in Table 1.

TABLE 1

PLANT OPERATING CONDITIONS

Plant	Units	Condenser Rise F	Condenser Flow Rate cfs
Indian Point	1-3	14.8	4550
Bowline	1-2	13.8	1710
Lovett	1-5	14.8	720

Two test series were conducted, one with all three plants operating and another with Lovett not operating. Table 2 correlates test numbers to plants operating in accordance with the conditions of Table 1.

TABLE 2

TEST NUMBER IDENTIFICATION

Test Number	Plants Operating
406 407 412	Indian Point, Bowline and Lovett
408 409	Indian Point and Bowline

Temperature rises above ambient for each hour in the 12.5 hour tide cycle are shown for the five tests in Figures 1 through 65. Generally, the data show that with the present discharge configuration the 4F isotherm extends across the river at some location at all times with Lovett operating and approximately 90 percent of the time without Lovett operating. The 4F isotherm occupies less than 50 percent of the cross-sectional area at all times in both cases.

To provide a simplified but quantitative comparison of these five tests, the average surface temperature, both temporal and spacial, was computed as a function of distance along the river centerline, and the results are shown in Figures 66 and 67. Figure 66 shows some differences in data for the three tests conducted with Lovett operating. These differences are basically due to changes in model test conditions such as control of atmospheric characteristics and plant condenser rise. Test 406 represents the best control of test conditions and should be considered most representative of prototype conditions with Lovett operating. Figure 67 shows that test data without Lovett operating agree well.

Figure 68 compares the average surface temperature rise of the tests with Lovett to the average of the tests without Lovett, and demonstrates in summary form the effect of operating Lovett. The temperature rise was increased by about 1/2 F when Lovett is operating, and most of the increase was downstream of Indian Point.

Tidal average temperature rise patterns are shown in Figures 69 and 70 with Lovett operating, Test 406, and without Lovett operating, Test 409, respectively. These data summarize the interaction of Indian Point and Lovett with respect to surface temperature patterns. Without Lovett operating, the widest section of the 4F isotherm associated with Indian Point operation is located at the Lovett cross section. Operation of Lovett extends the 4F isotherm across the entire river.

In order to provide a quantitative evaluation of temperature stratification in the river at the four instrumented cross-sections, the surface average temperature rise was divided by the cross section average temperature rise. This has been called the thermal stratification factor (TSF) and is shown in Table 3.

TABLE 3

THERMAL STRATIFICATION FACTOR

Test Number	Section *			
	A-A	B-B	C-C	D-D
406	1.67	1.41	1.76	1.44
409	1.65	1.46	1.77	1.43

*Refer to Figures 69 and 70 for location.

The TSF was a maximum at the Lovett cross section C-C and decreased as river mixing and heat transfer to the atmosphere decreased surface temperatures. Since a fully mixed river would have a TSF of 1.0, the table indicates that full mixing was not achieved and that thermal stratification existed. A more effective discharge structure, such as a deep-water multiport diffuser may produce reductions in both maximum and overall surface temperature rises by better mixing the plant effluent with river flow.

If there are any questions concerning these data, or if we may provide any further information, please let us know.

Very truly yours,

Lawrence C. Neale

Lawrence C. Neale

JBN/vmw
cc: Dr. H. Moy

Enclosures

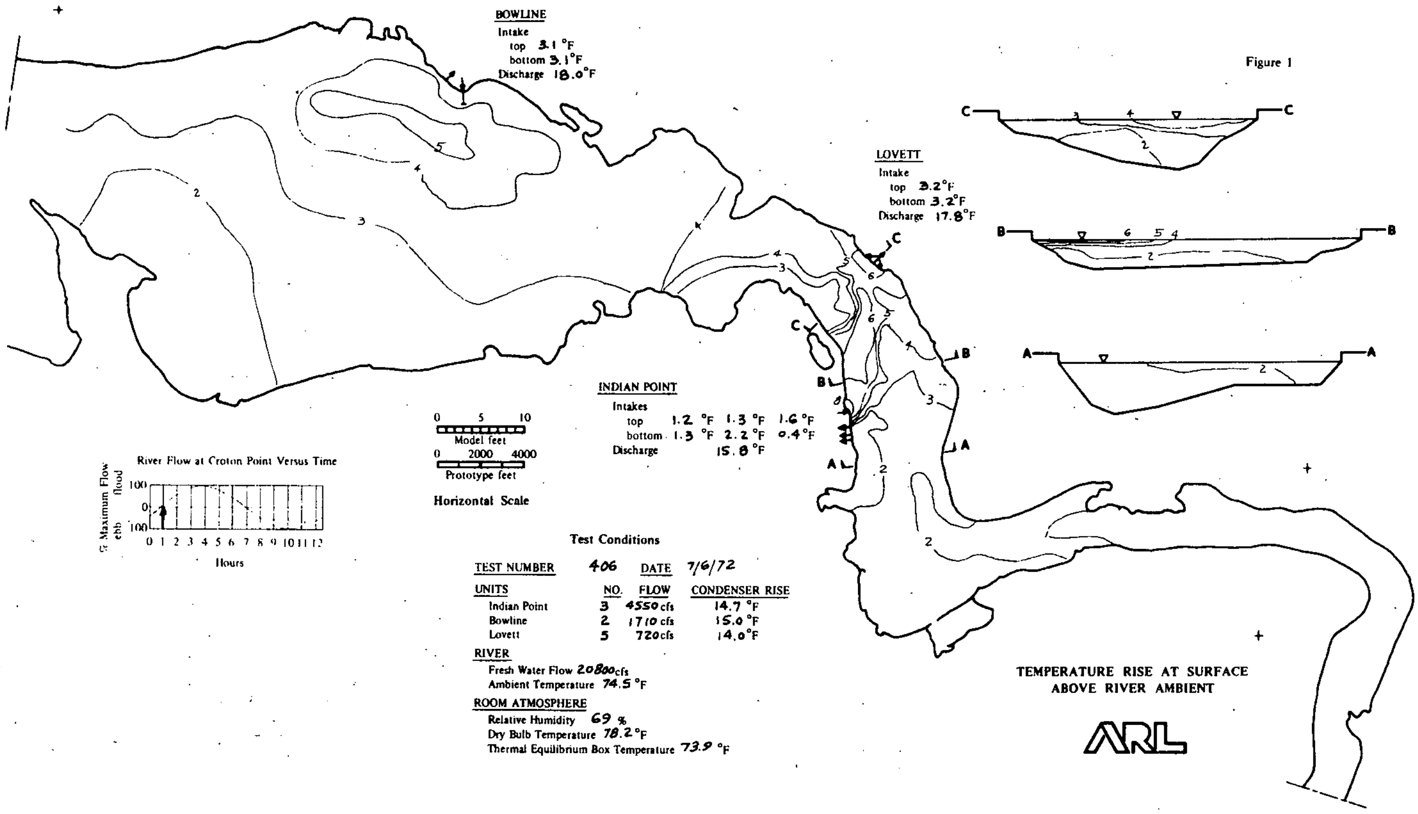


Figure 1

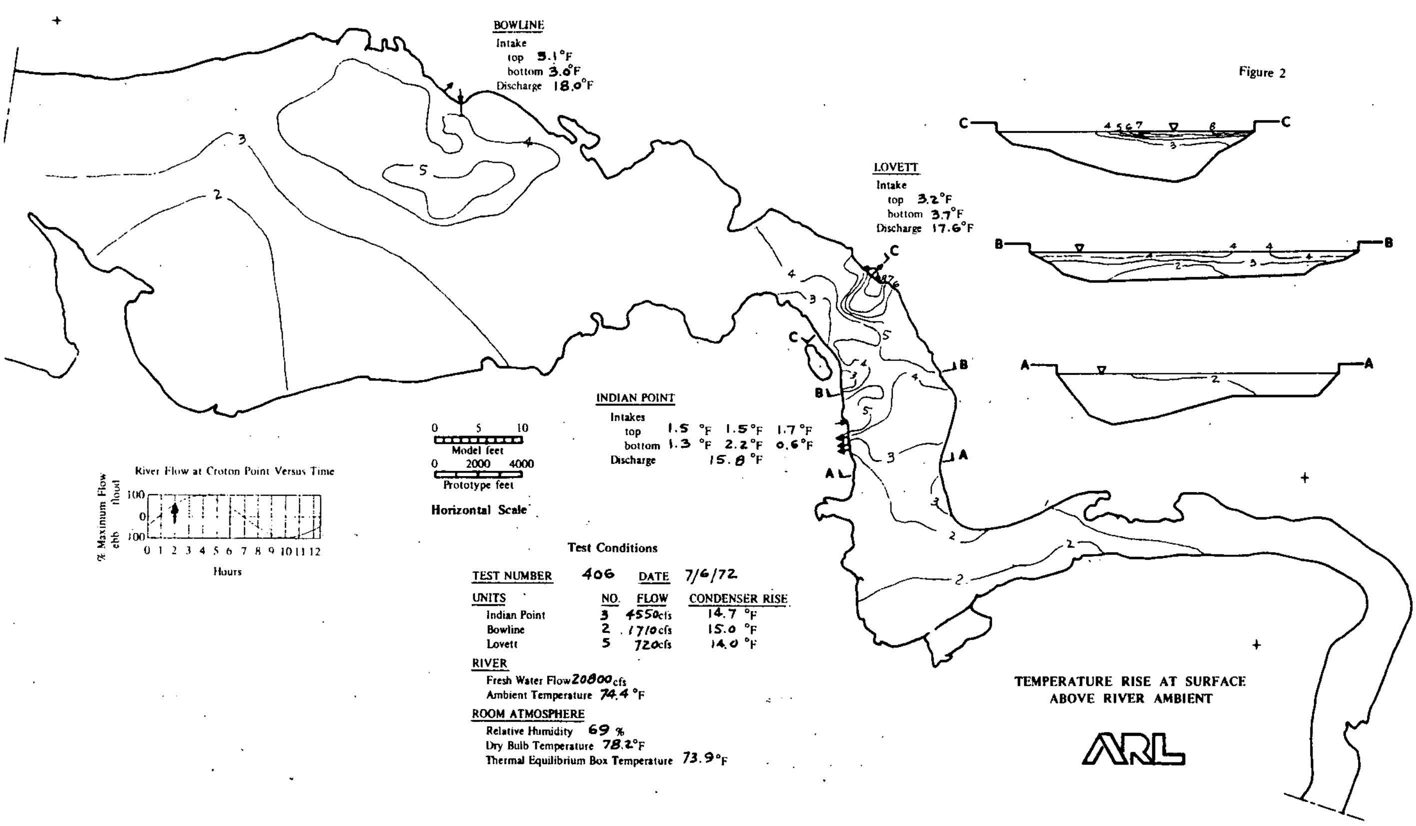


Figure 2

Figure 3

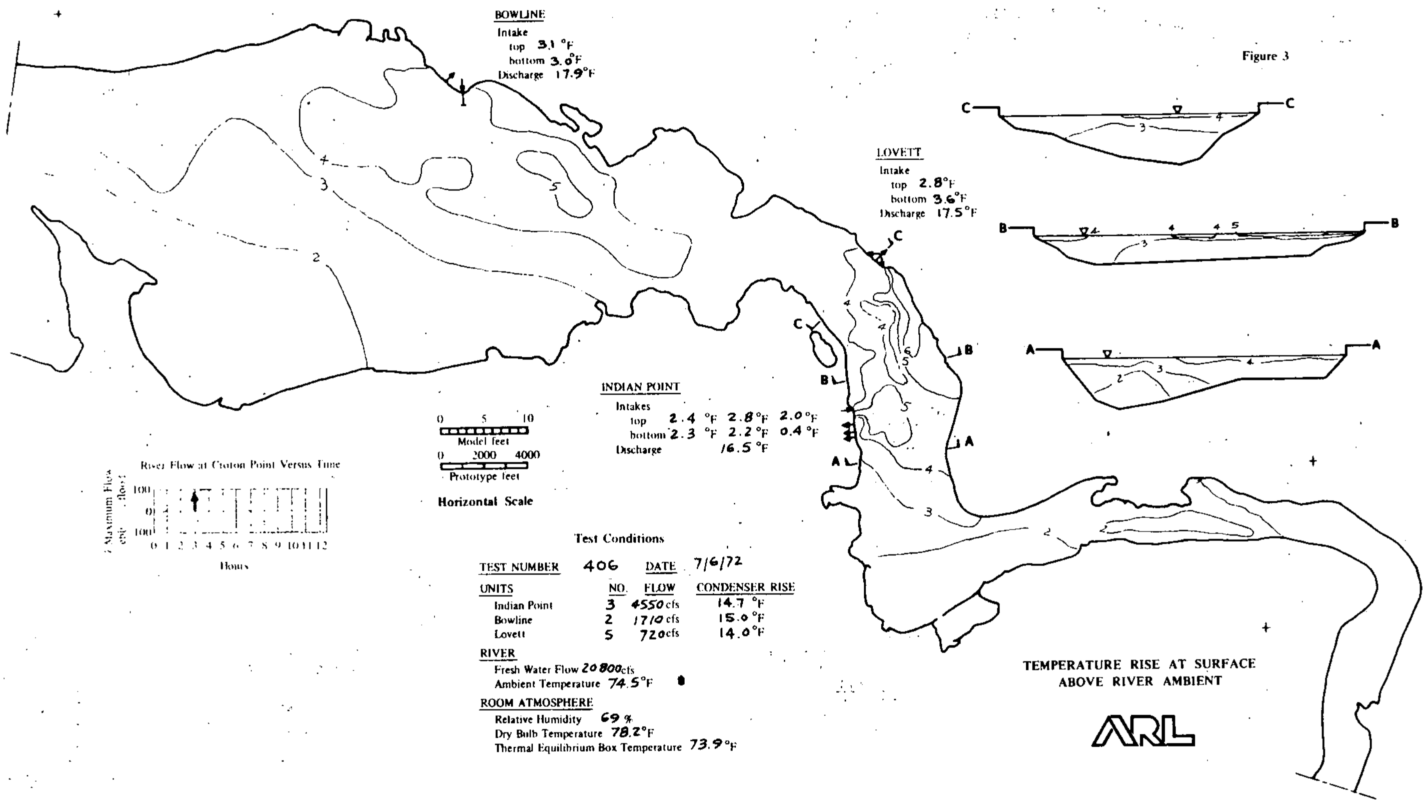


Figure 4

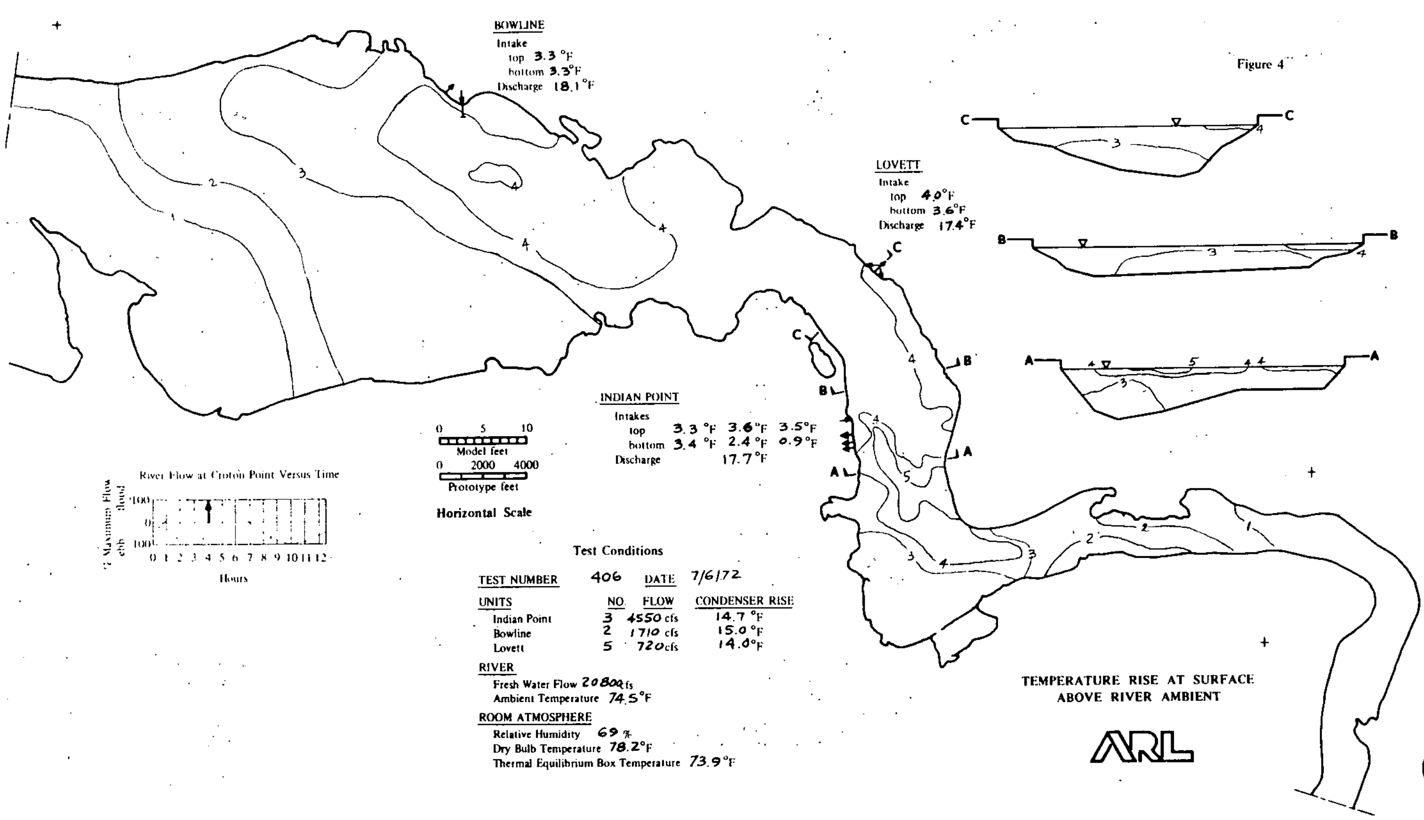


Figure 5

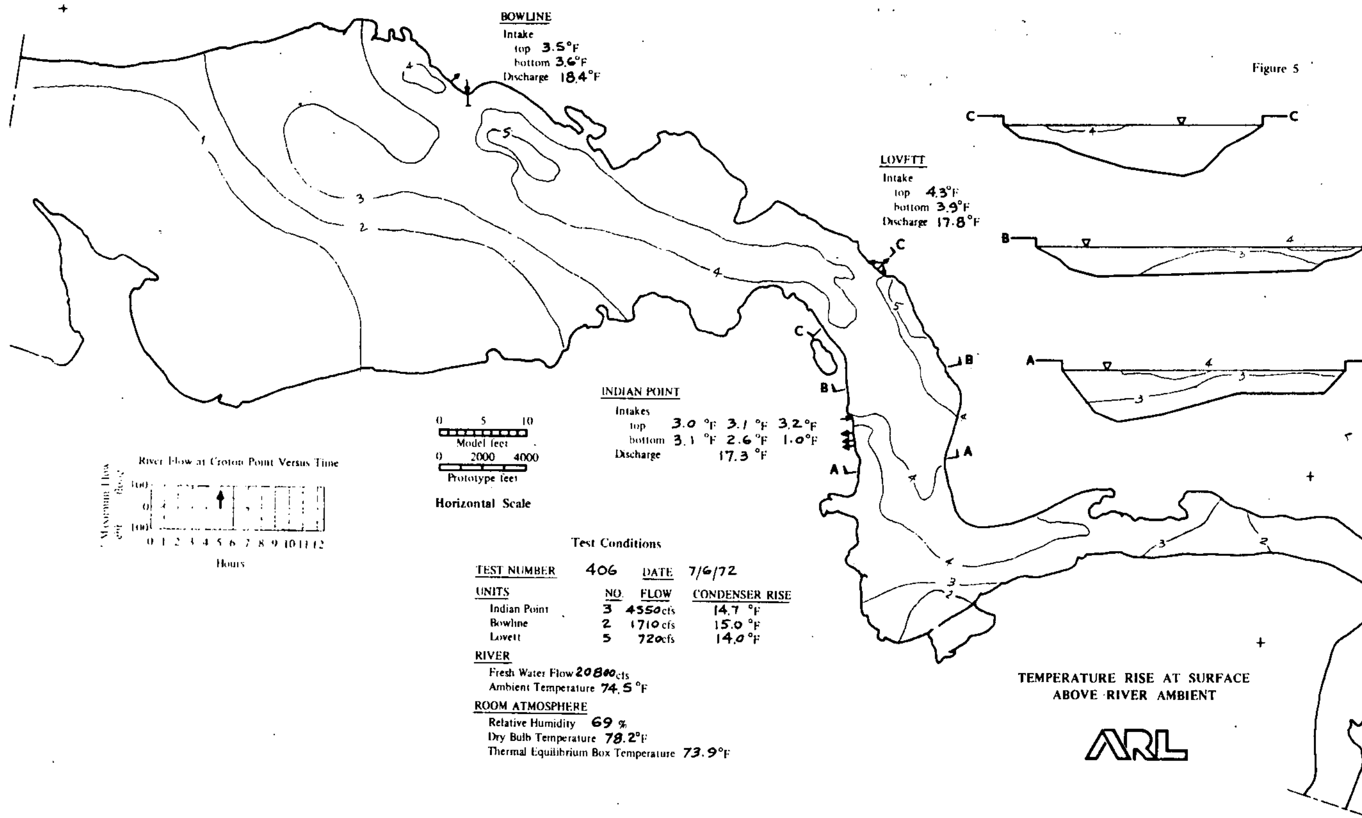
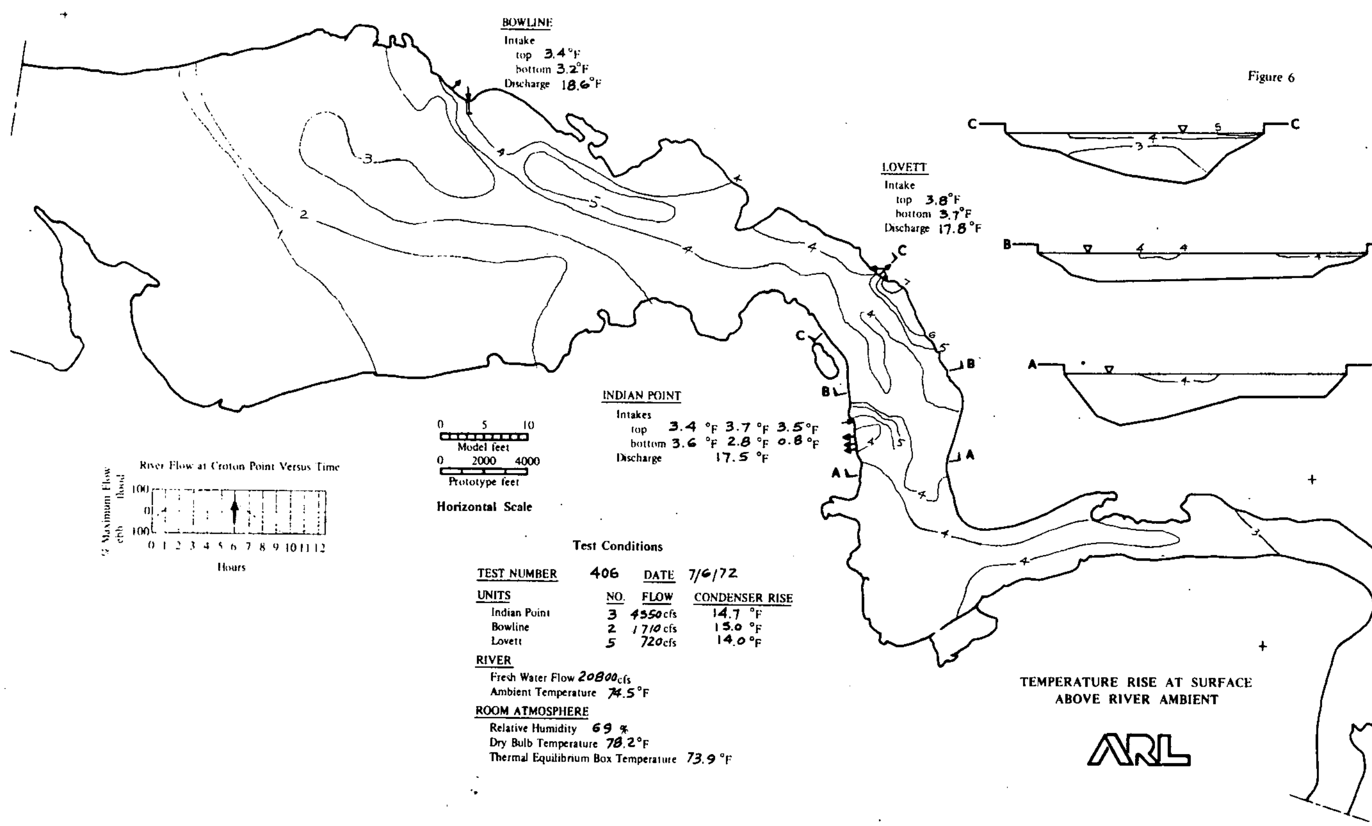
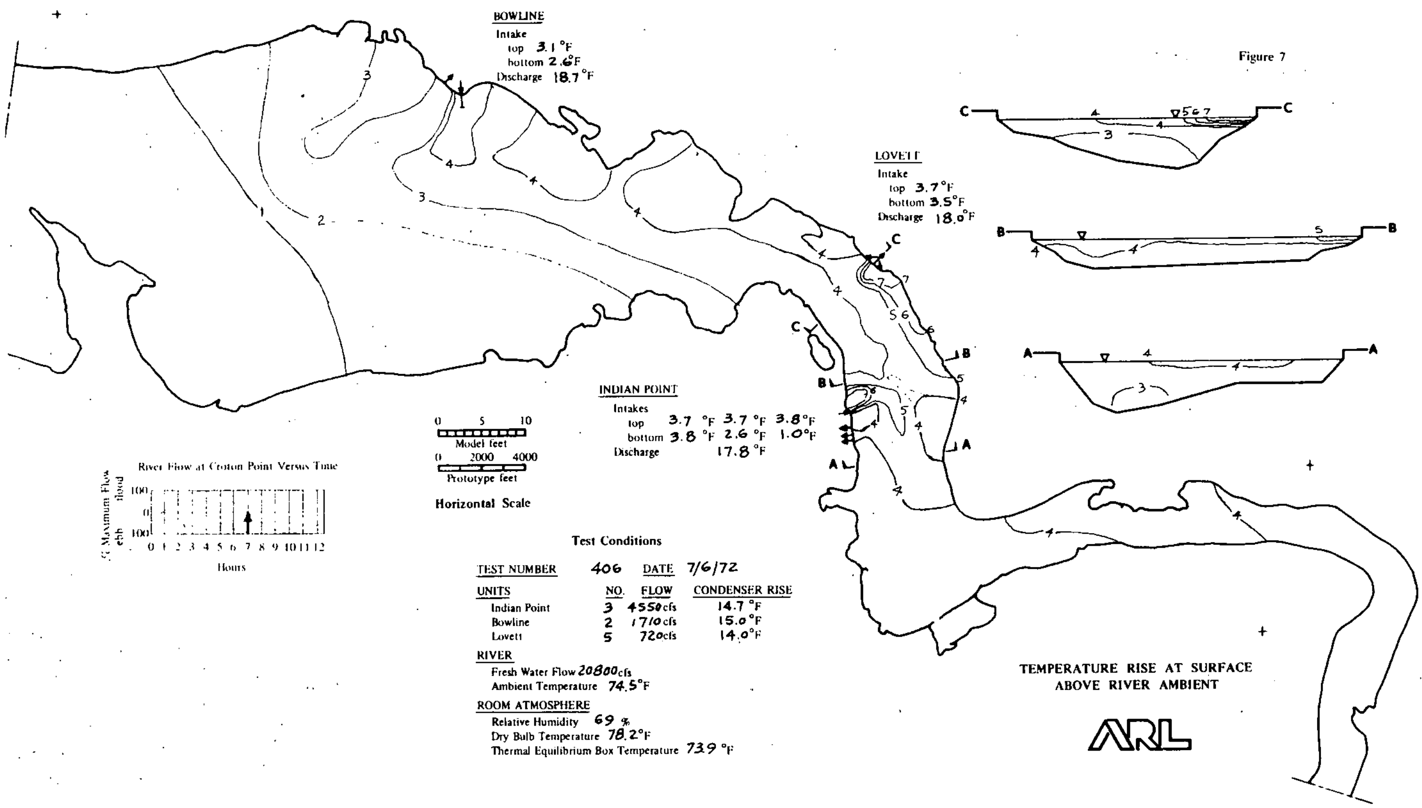


Figure 6





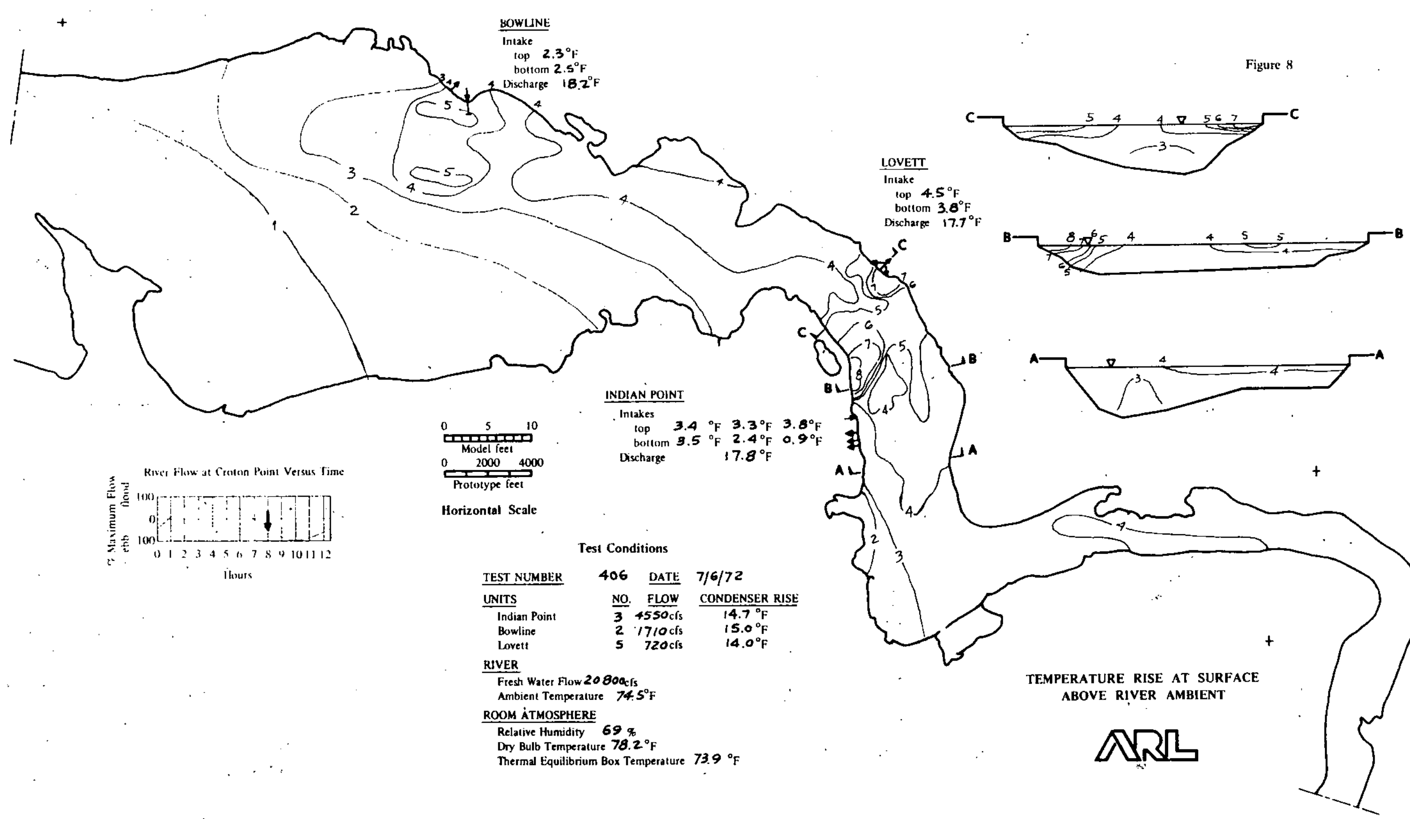
Test Conditions

TEST NUMBER 406 DATE 7/6/72

UNITS	NO.	FLOW	CONDENSER RISE
Indian Point	3	4550cfs	14.7 °F
Bowline	2	1710cfs	15.0 °F
Lovett	5	720cfs	14.0°F

RIVER
Fresh Water Flow 20800cfs
Ambient Temperature 74.5°F

ROOM ATMOSPHERE
Relative Humidity 69 %
Dry Bulb Temperature 78.2°F
Thermal Equilibrium Box Temperature 73.9 °F



Test Conditions

TEST NUMBER 406 DATE 7/6/72

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Lovett	5	720cfs	14.0°F

RIVER
Fresh Water Flow 20800cfs
Ambient Temperature 74.5°F

ROOM ATMOSPHERE
Relative Humidity 69 %
Dry Bulb Temperature 78.2°F
Thermal Equilibrium Box Temperature 73.9 °F

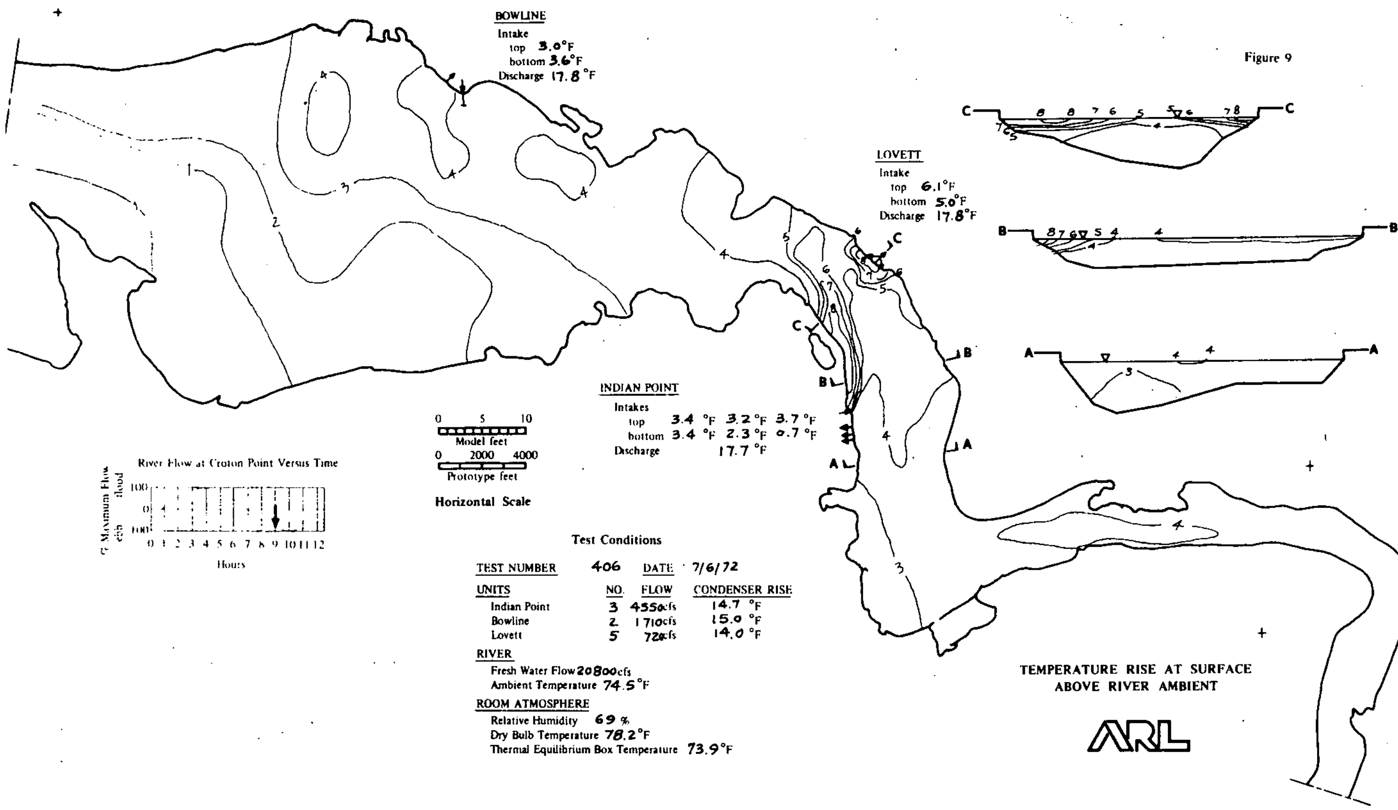


Figure 9

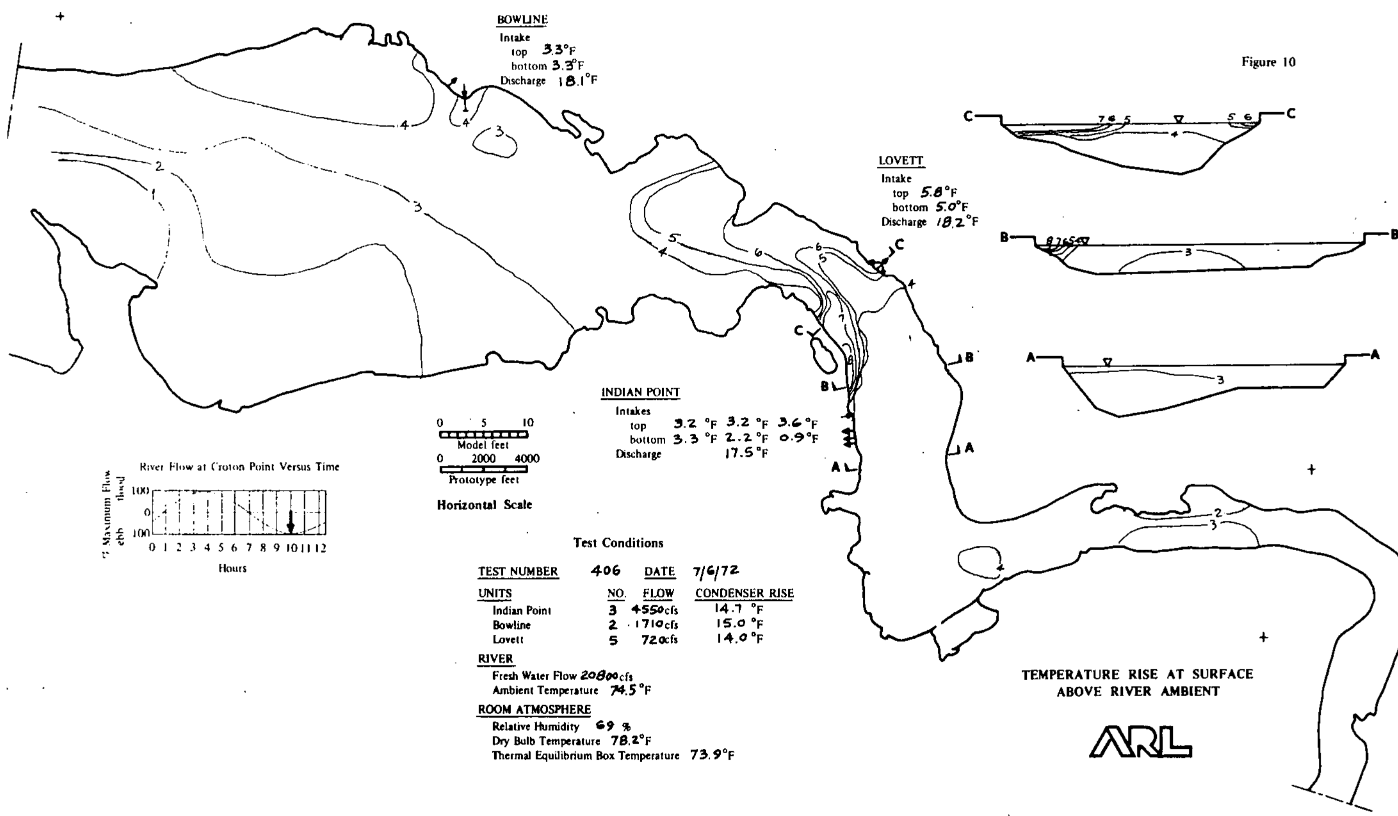


Figure 10

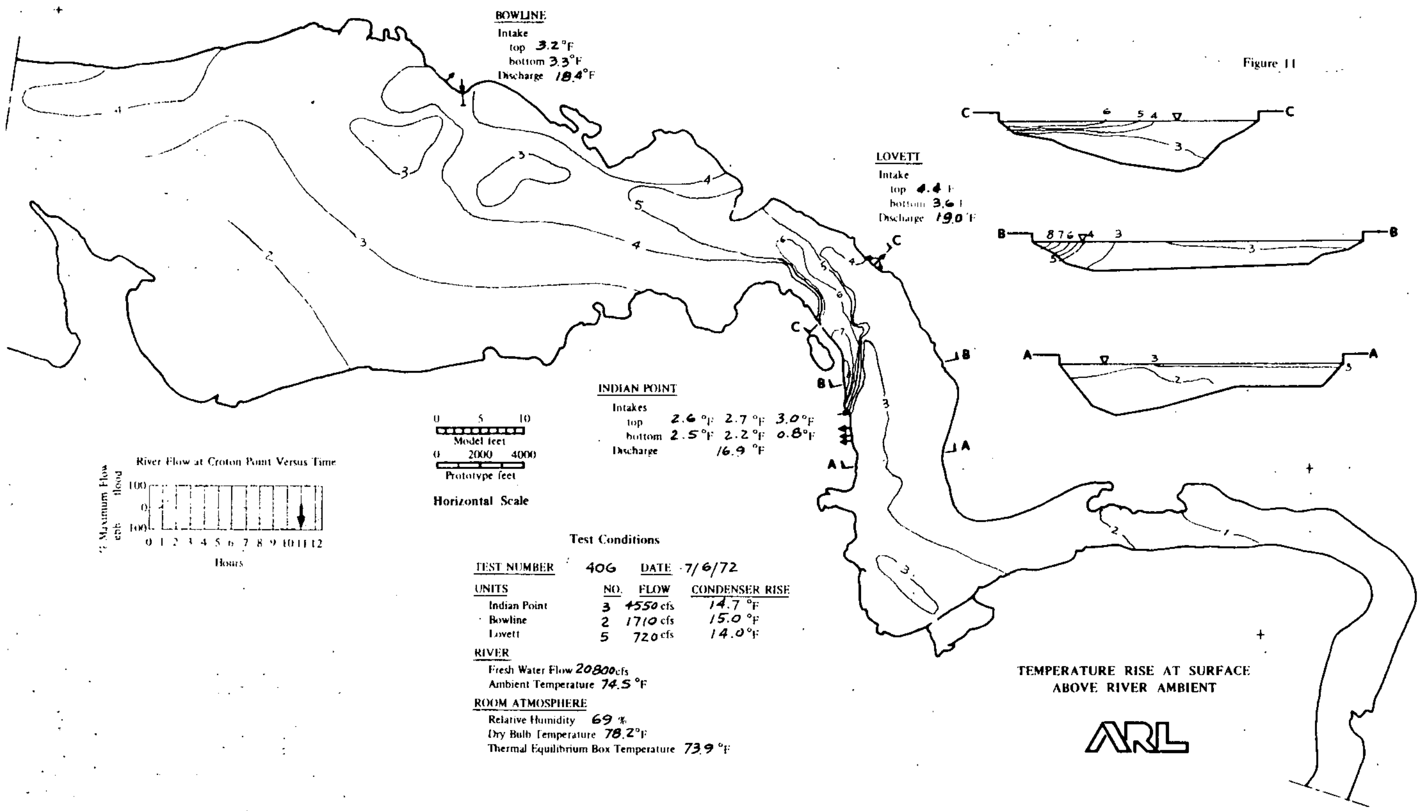


Figure 11
BOWLINE
Intake
top 3.2 °F
bottom 3.3 °F
Discharge 18.4 °F
LOVETT
Intake
top 4.4 °F
bottom 3.6 °F
Discharge 19.0 °F
INDIAN POINT
Intakes
top 2.6 °F 2.7 °F 3.0 °F
bottom 2.5 °F 2.2 °F 0.8 °F
Discharge 16.9 °F
Model feet
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
% Maximum Flow
ebb flood
Hours
Test Conditions
TEST NUMBER 406 DATE 7/6/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550 cfs 14.7 °F
Bowline 2 1710 cfs 15.0 °F
Lovett 5 720 cfs 14.0 °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 74.5 °F
ROOM ATMOSPHERE
Relative Humidity 69 %
Dry Bulb Temperature 78.2 °F
Thermal Equilibrium Box Temperature 73.9 °F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

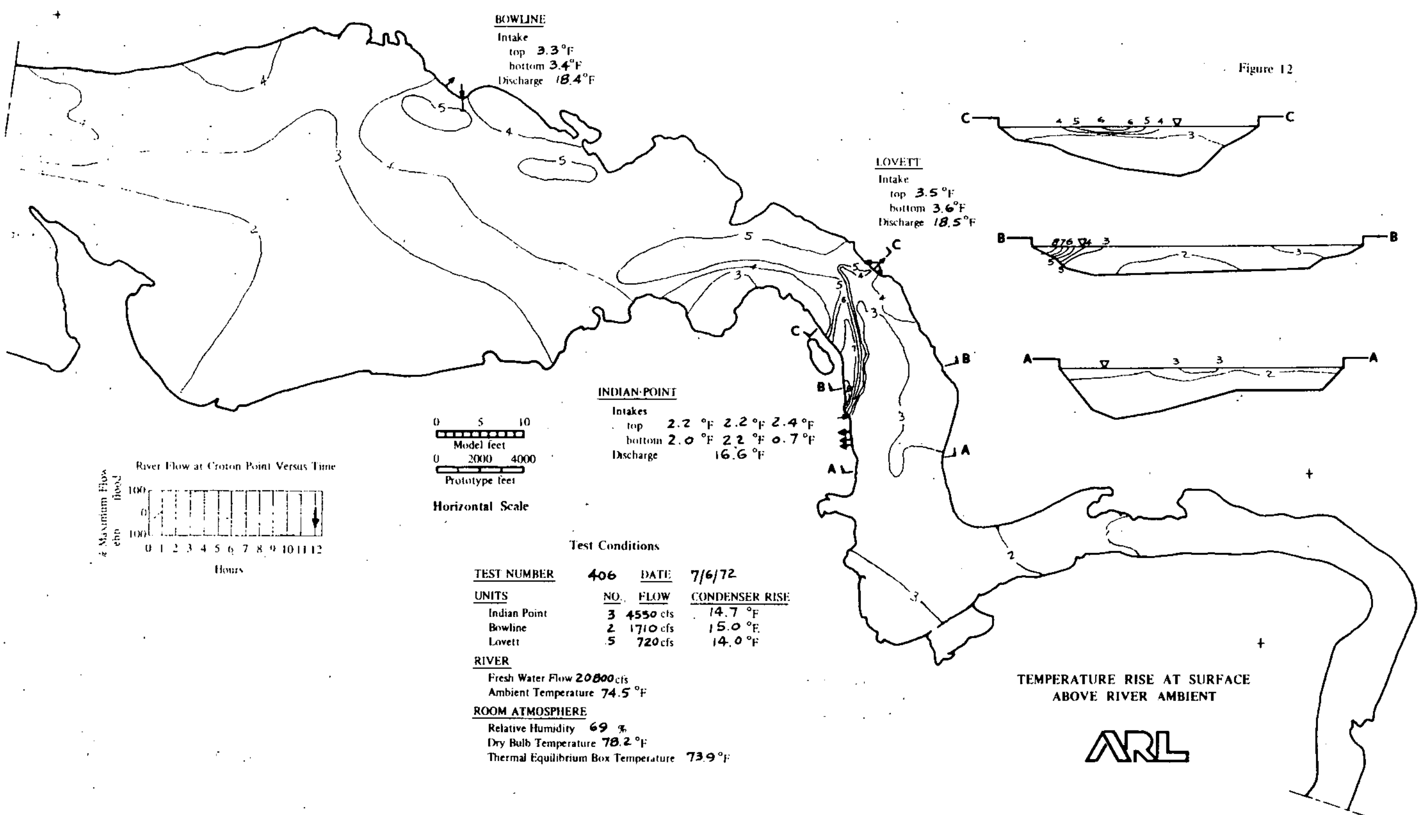
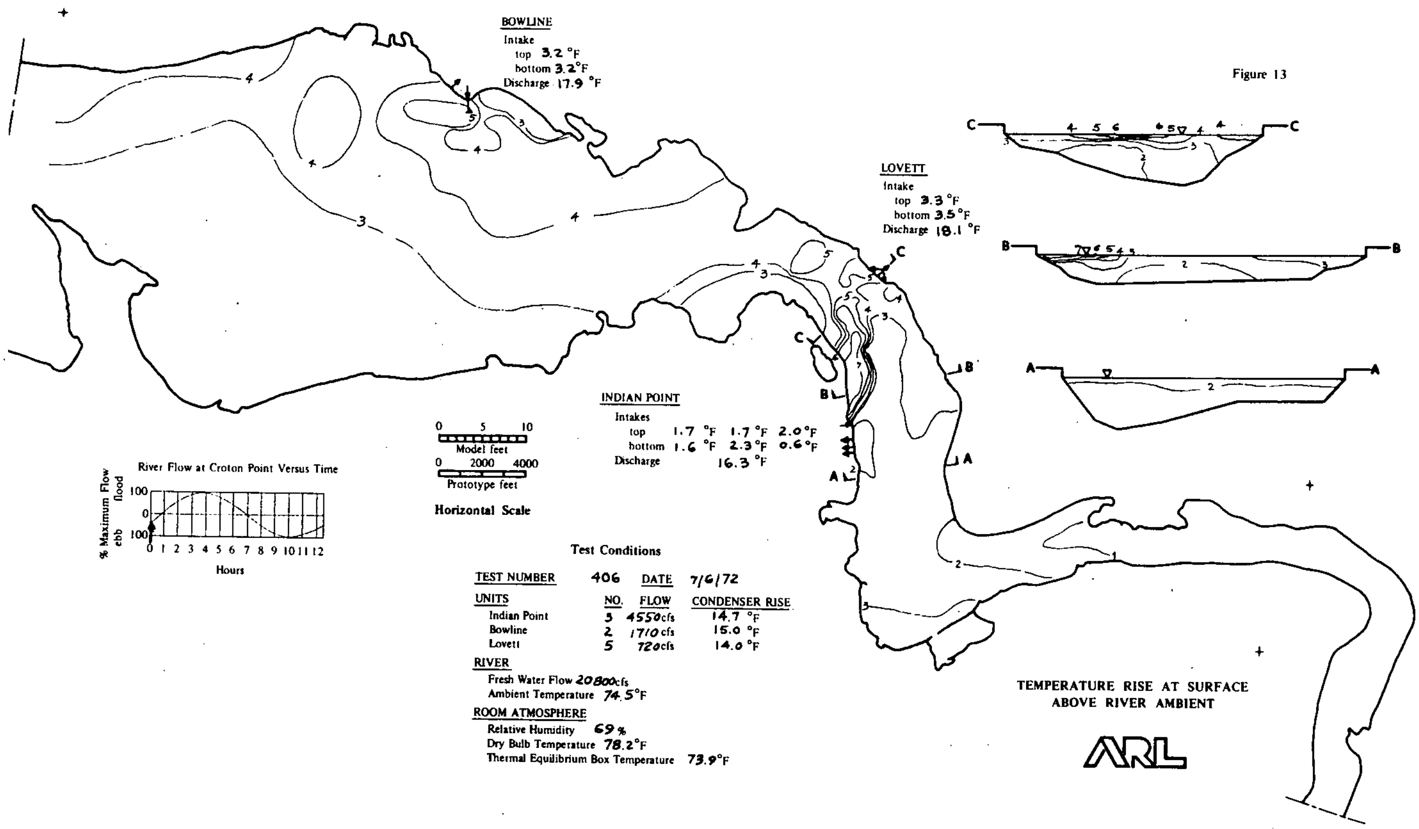


Figure 12
BOWLINE
Intake
top 3.3 °F
bottom 3.4 °F
Discharge 18.4 °F
LOVETT
Intake
top 3.5 °F
bottom 3.6 °F
Discharge 18.5 °F
INDIAN POINT
Intakes
top 2.2 °F 2.2 °F 2.4 °F
bottom 2.0 °F 2.2 °F 0.7 °F
Discharge 16.6 °F
Model feet
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
% Maximum Flow
ebb flood
Hours
Test Conditions
TEST NUMBER 406 DATE 7/6/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550 cfs 14.7 °F
Bowline 2 1710 cfs 15.0 °F
Lovett 5 720 cfs 14.0 °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 74.5 °F
ROOM ATMOSPHERE
Relative Humidity 69 %
Dry Bulb Temperature 78.2 °F
Thermal Equilibrium Box Temperature 73.9 °F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

Figure 13



TEMPERATURE RISE AT SURFACE ABOVE RIVER AMBIENT

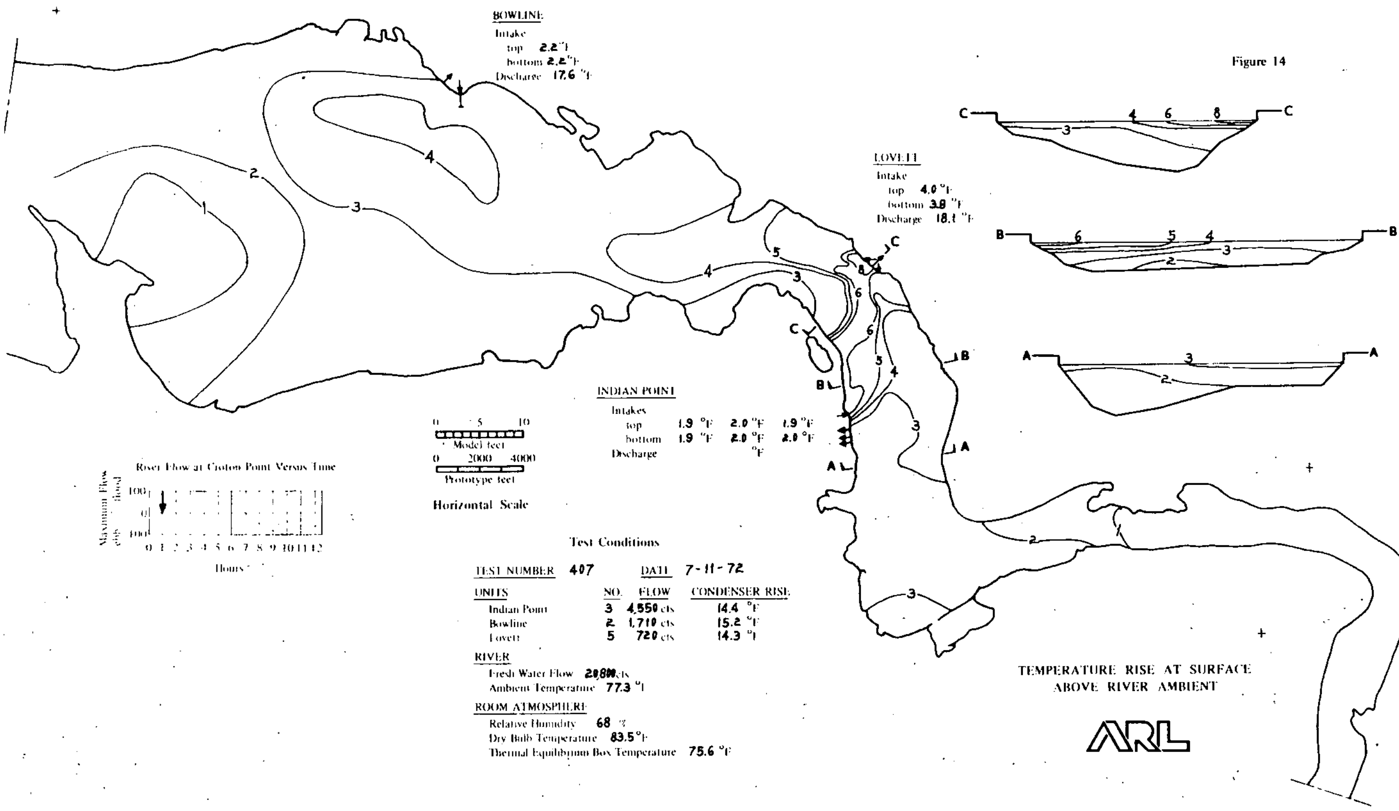


Figure 14

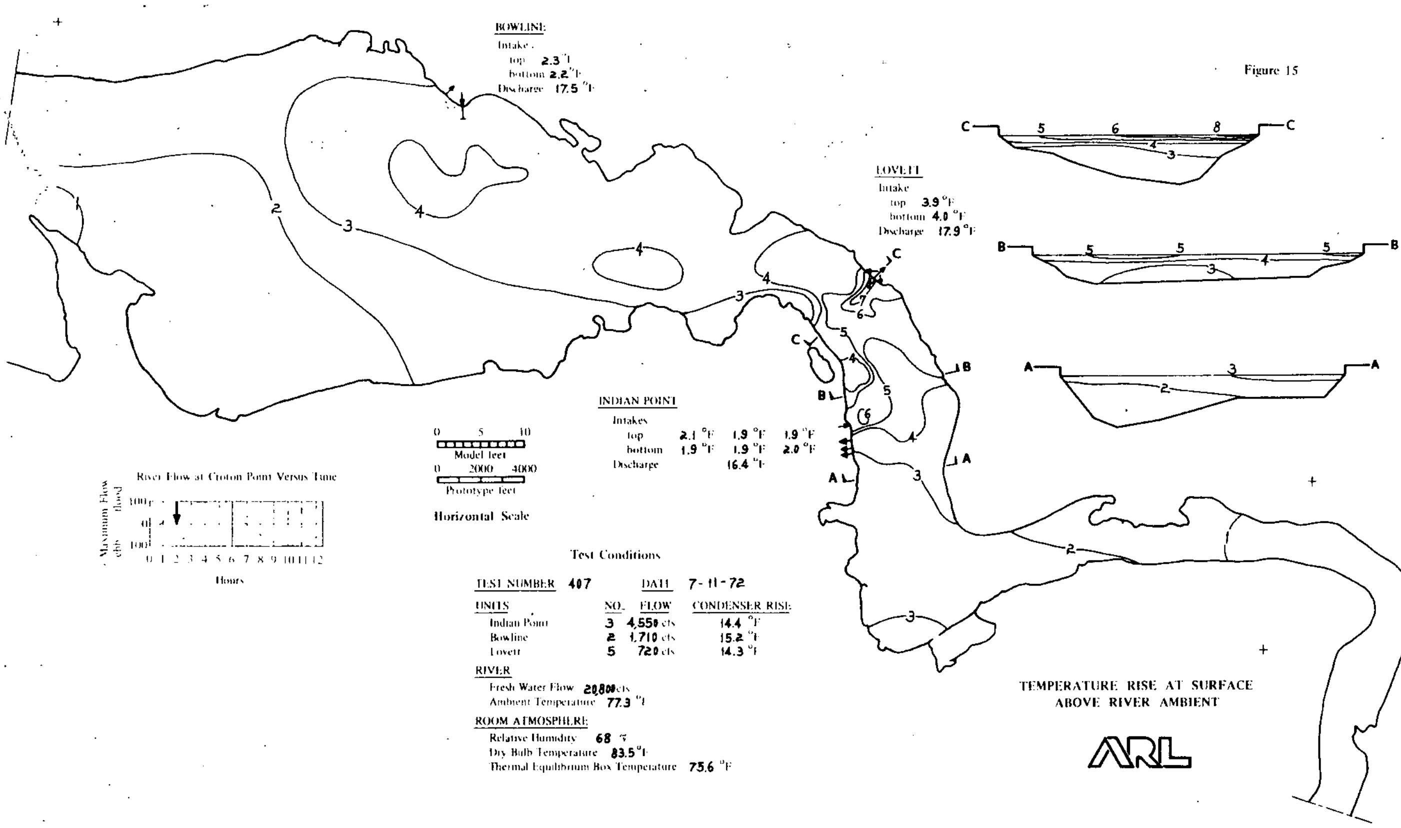


Figure 15

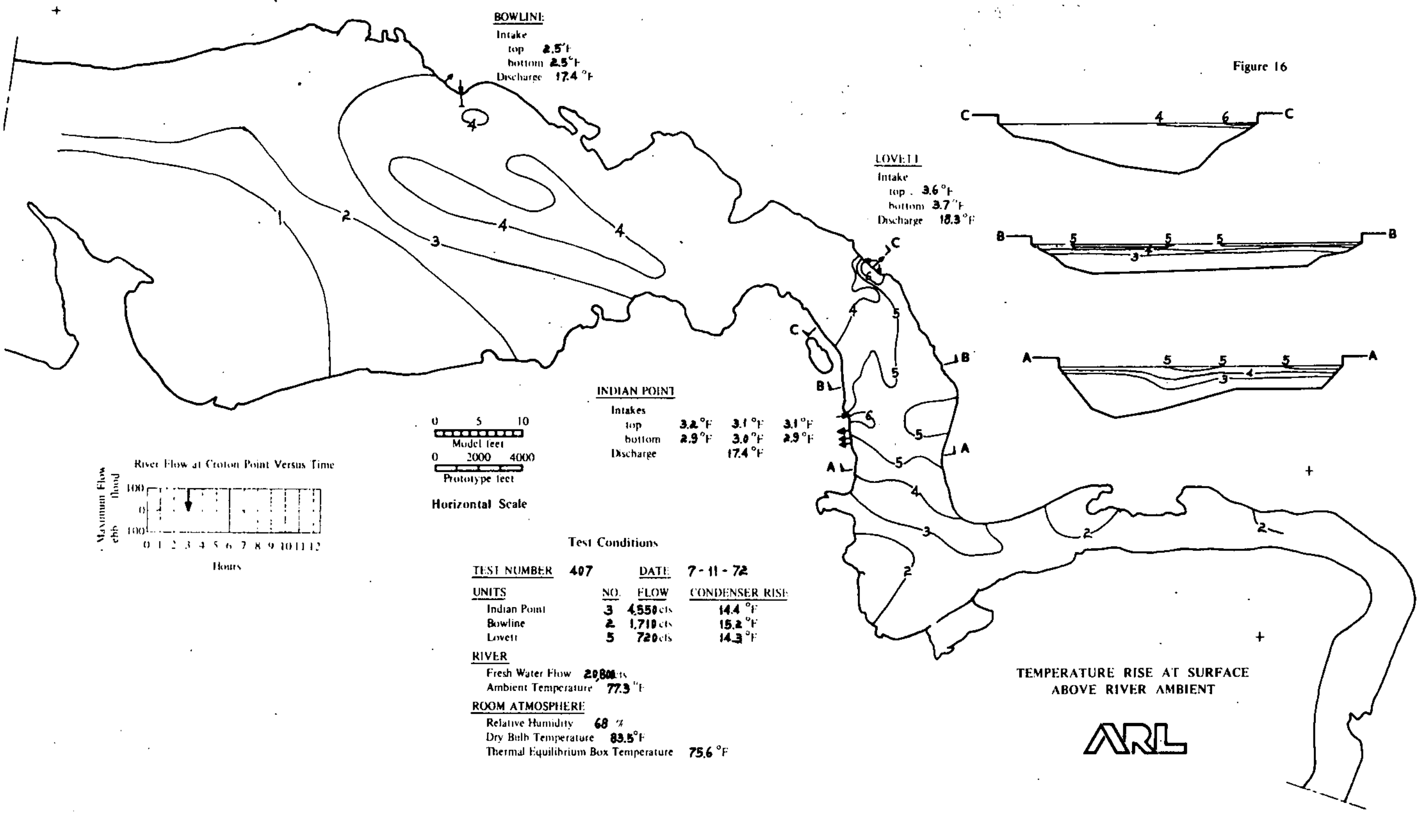


Figure 16

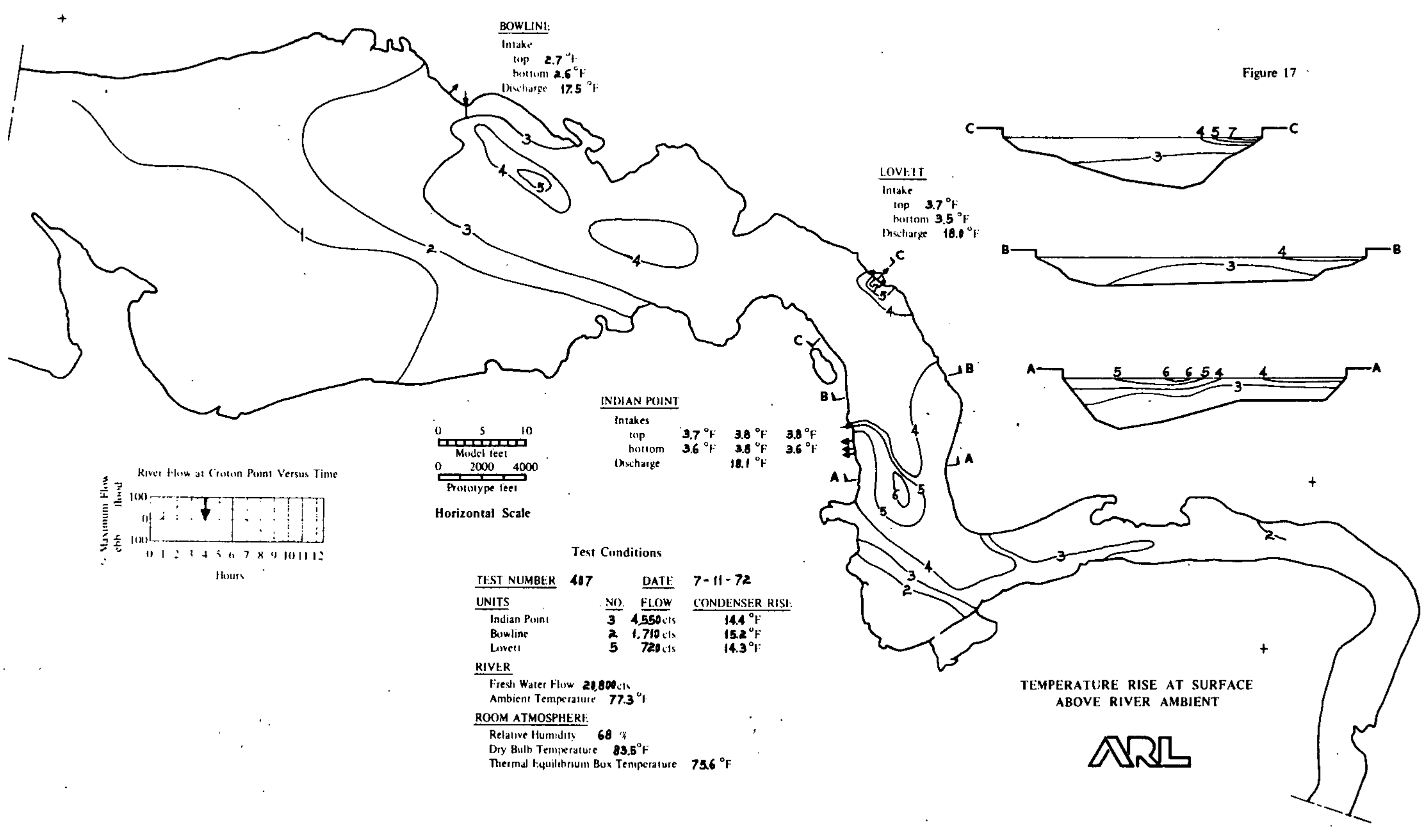
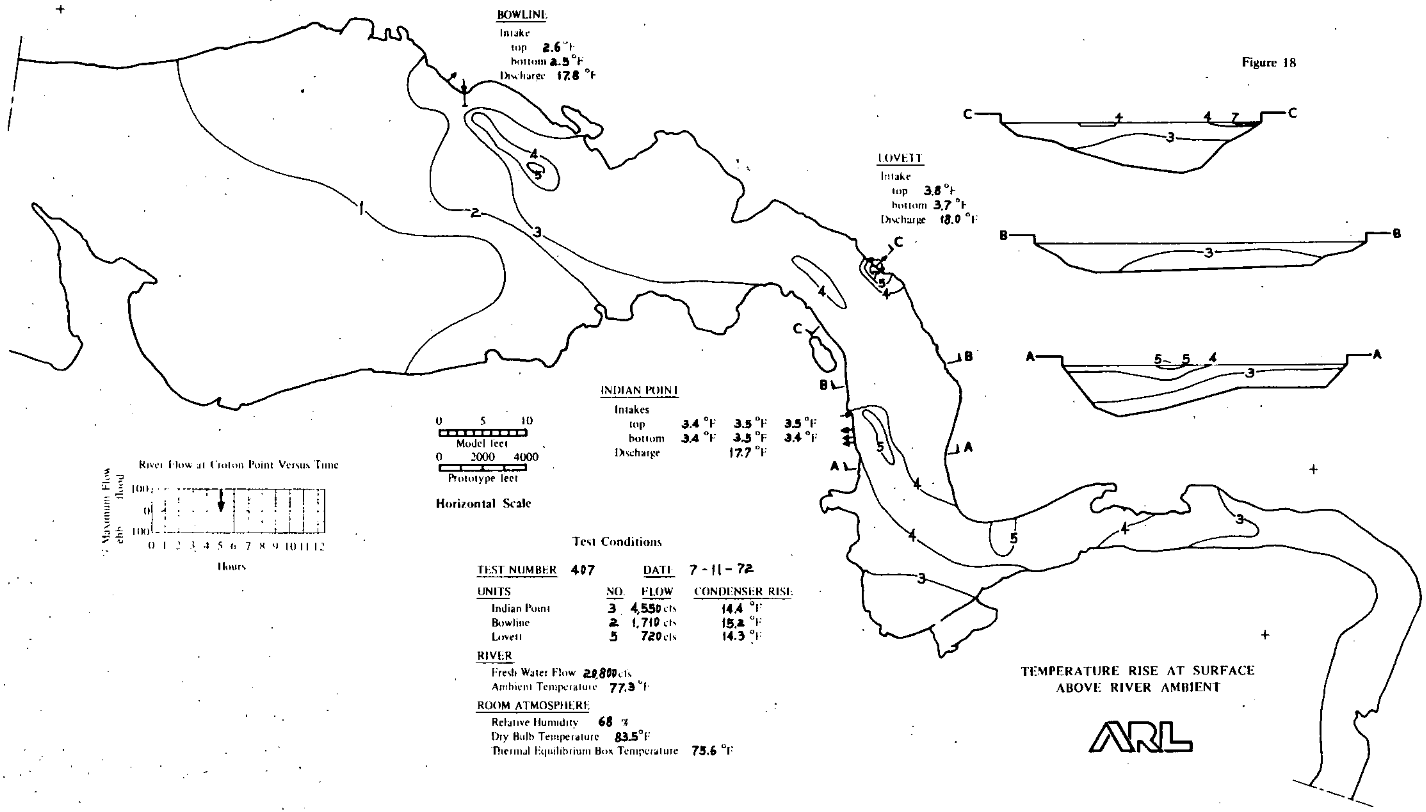


Figure 17



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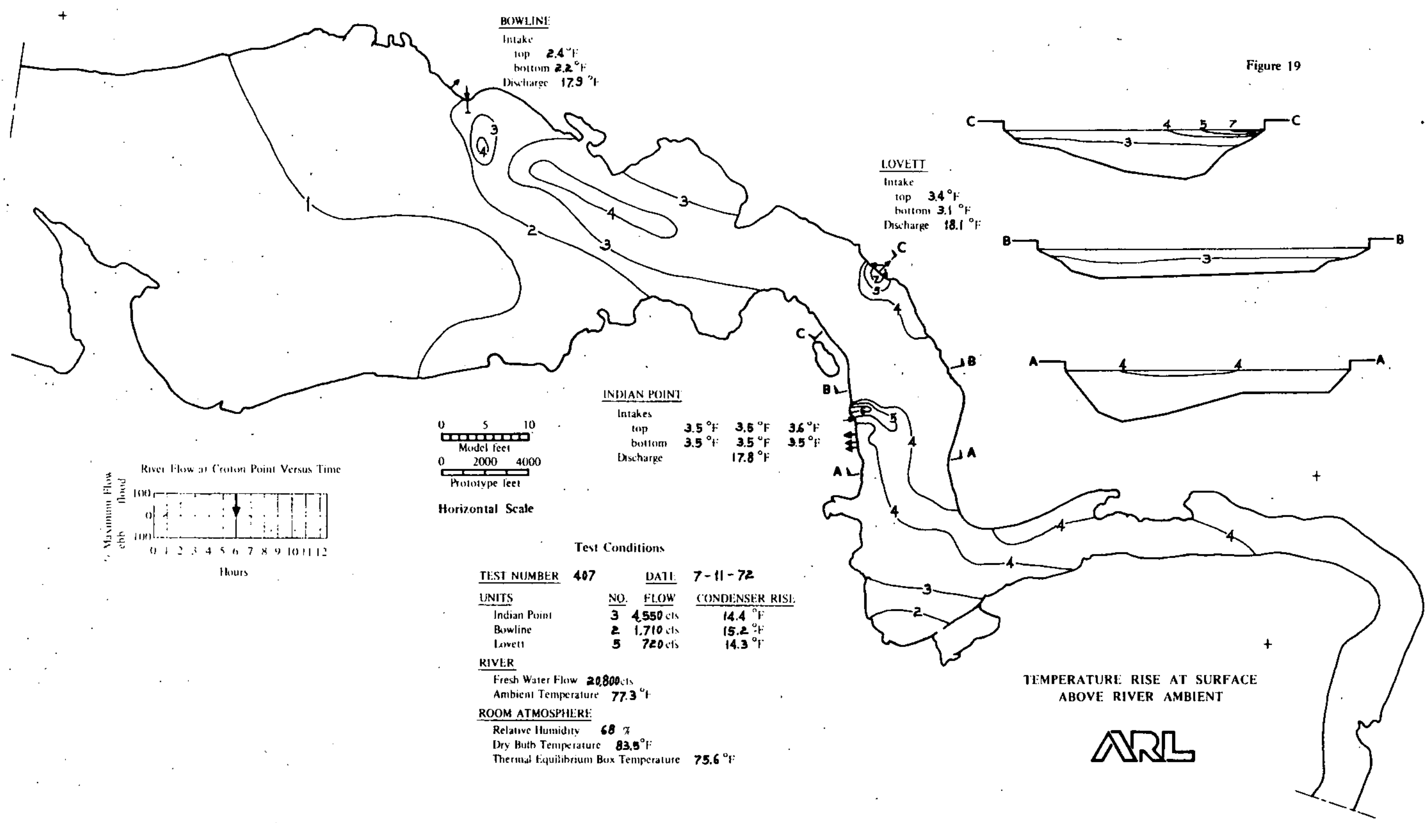
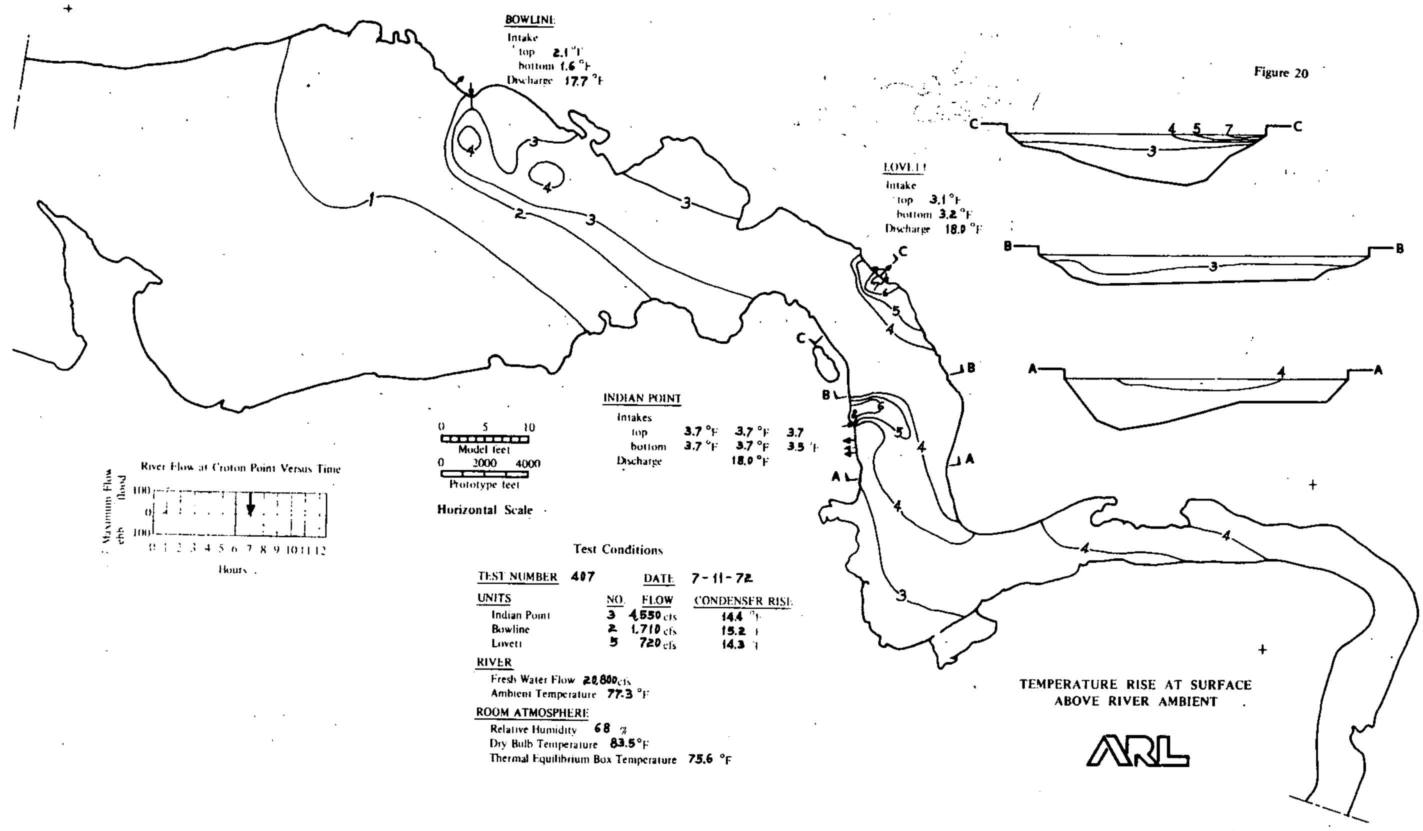


Figure 19

Figure 20



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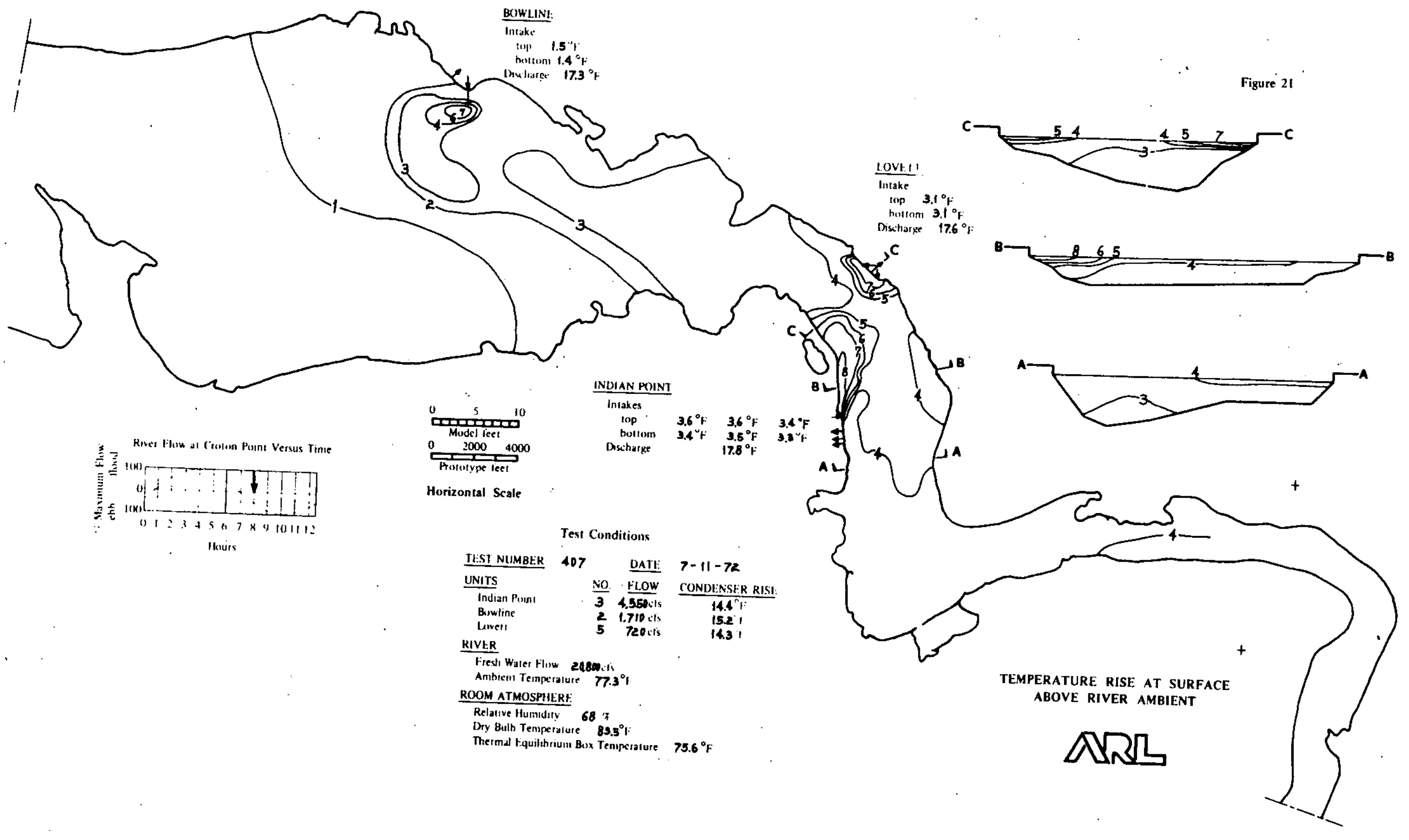

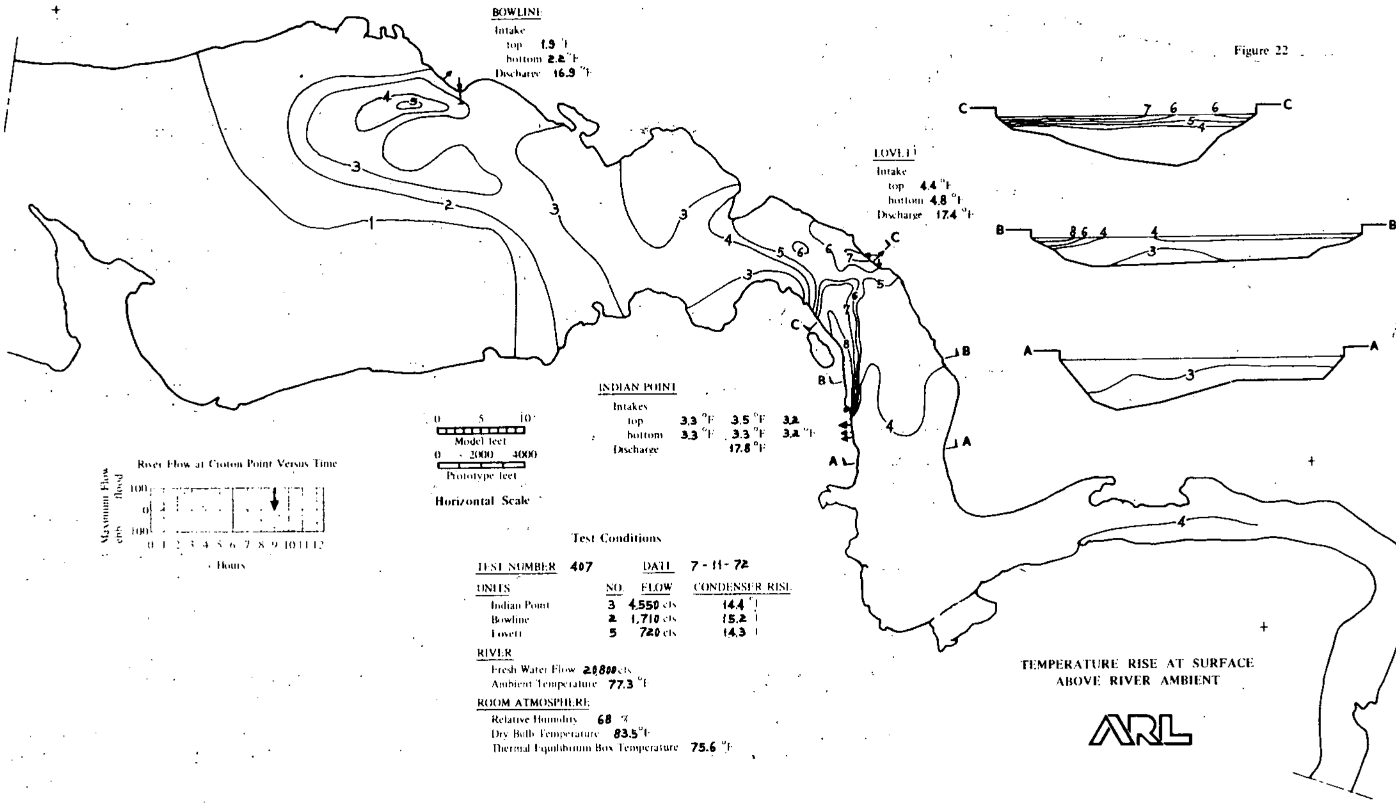

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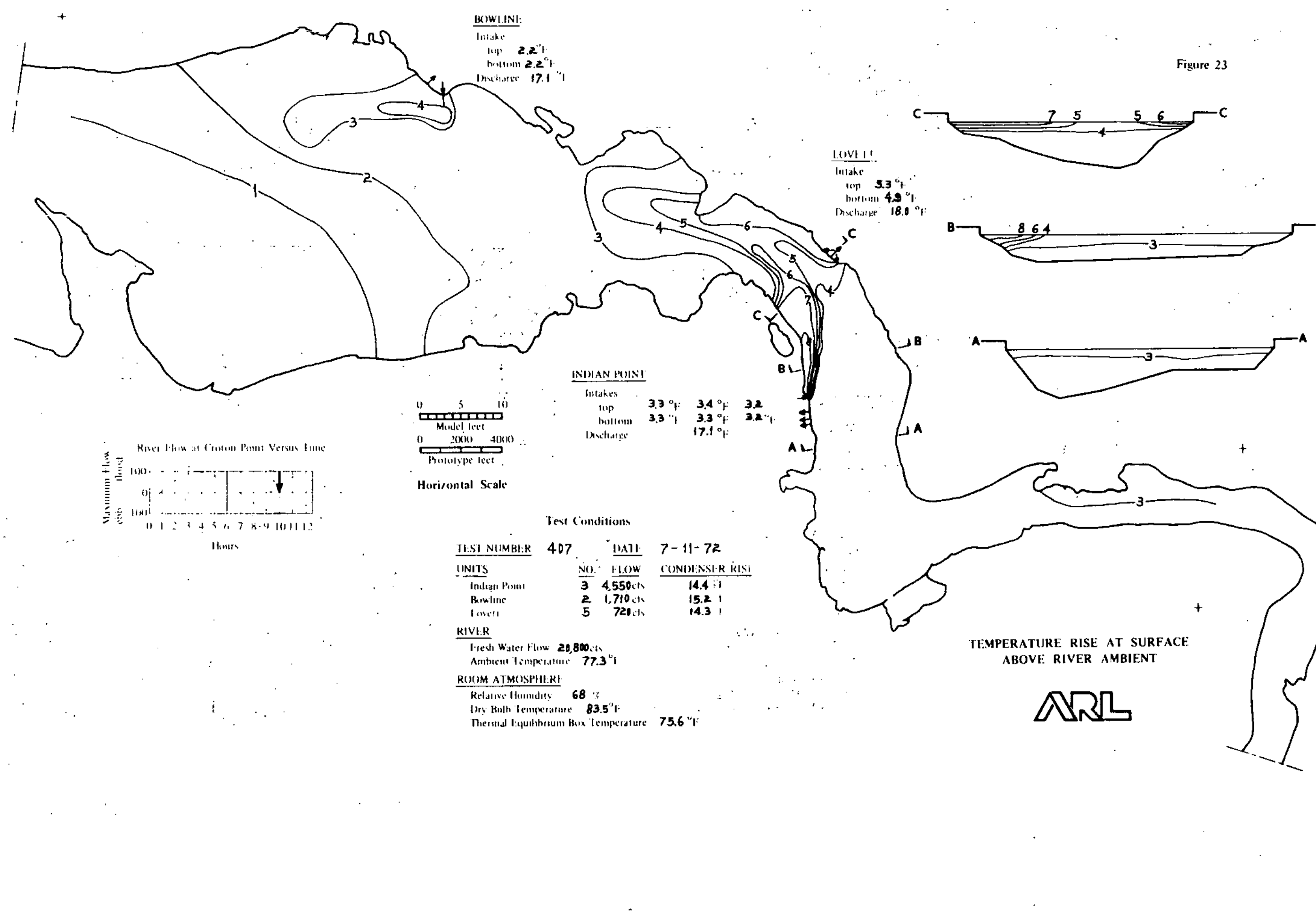


Figure 23

Figure 24

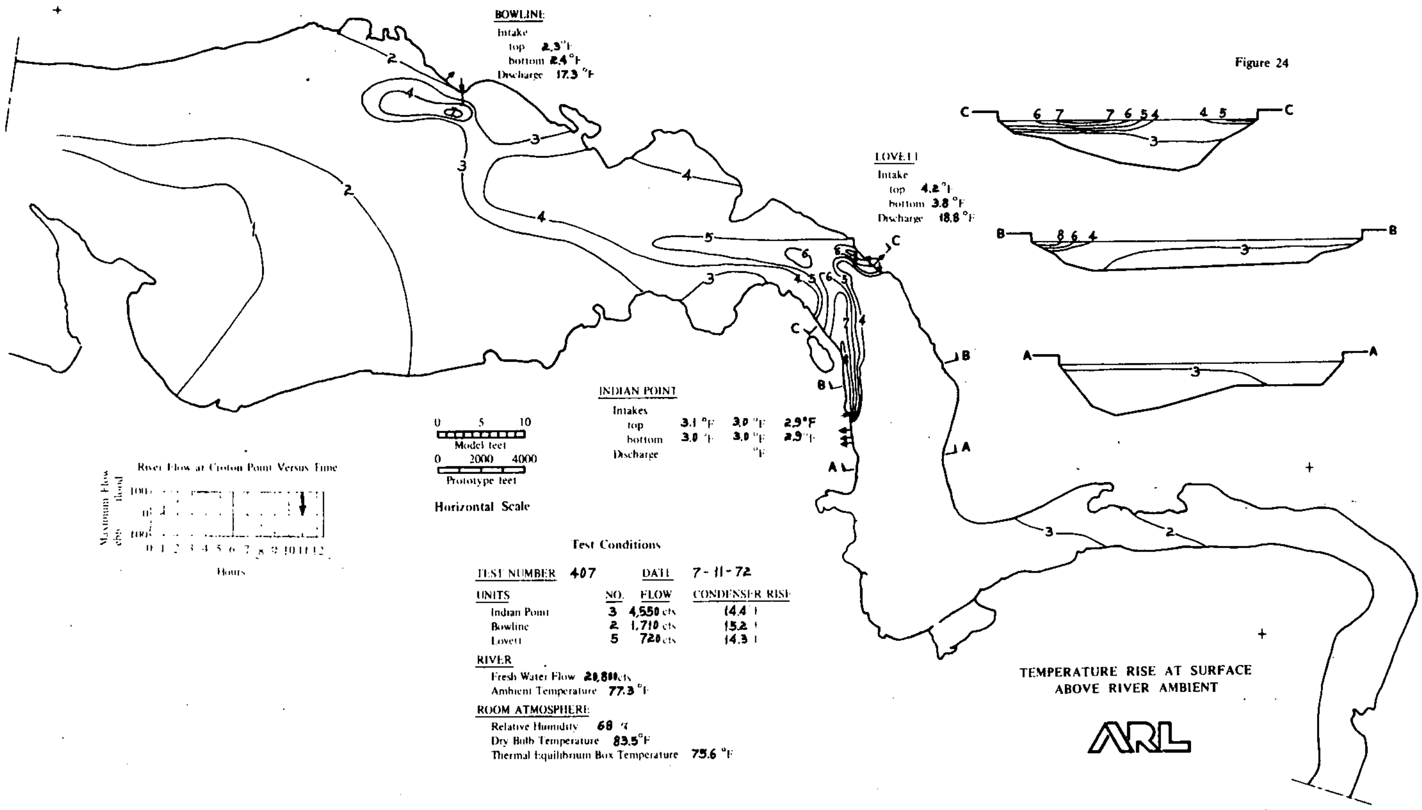


Figure 25

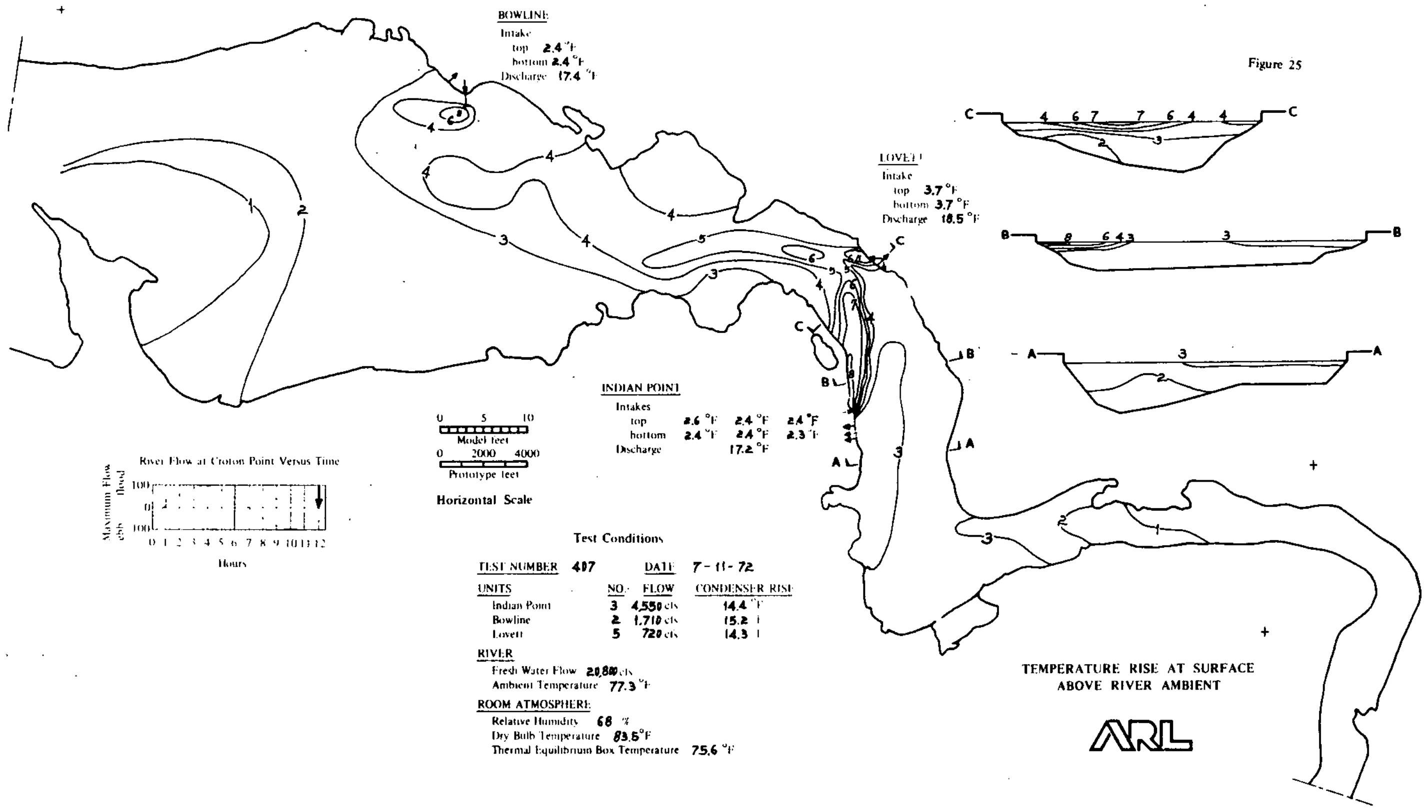
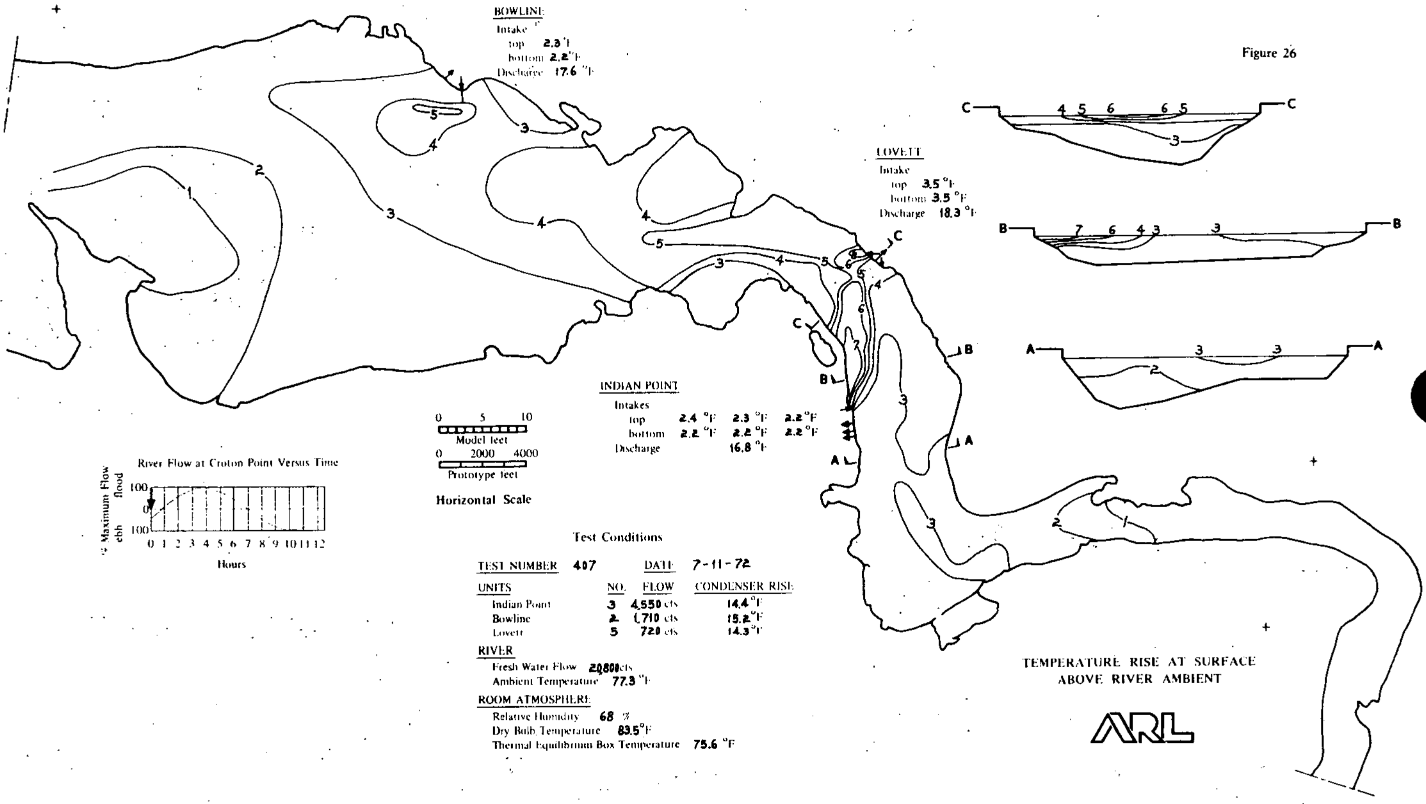


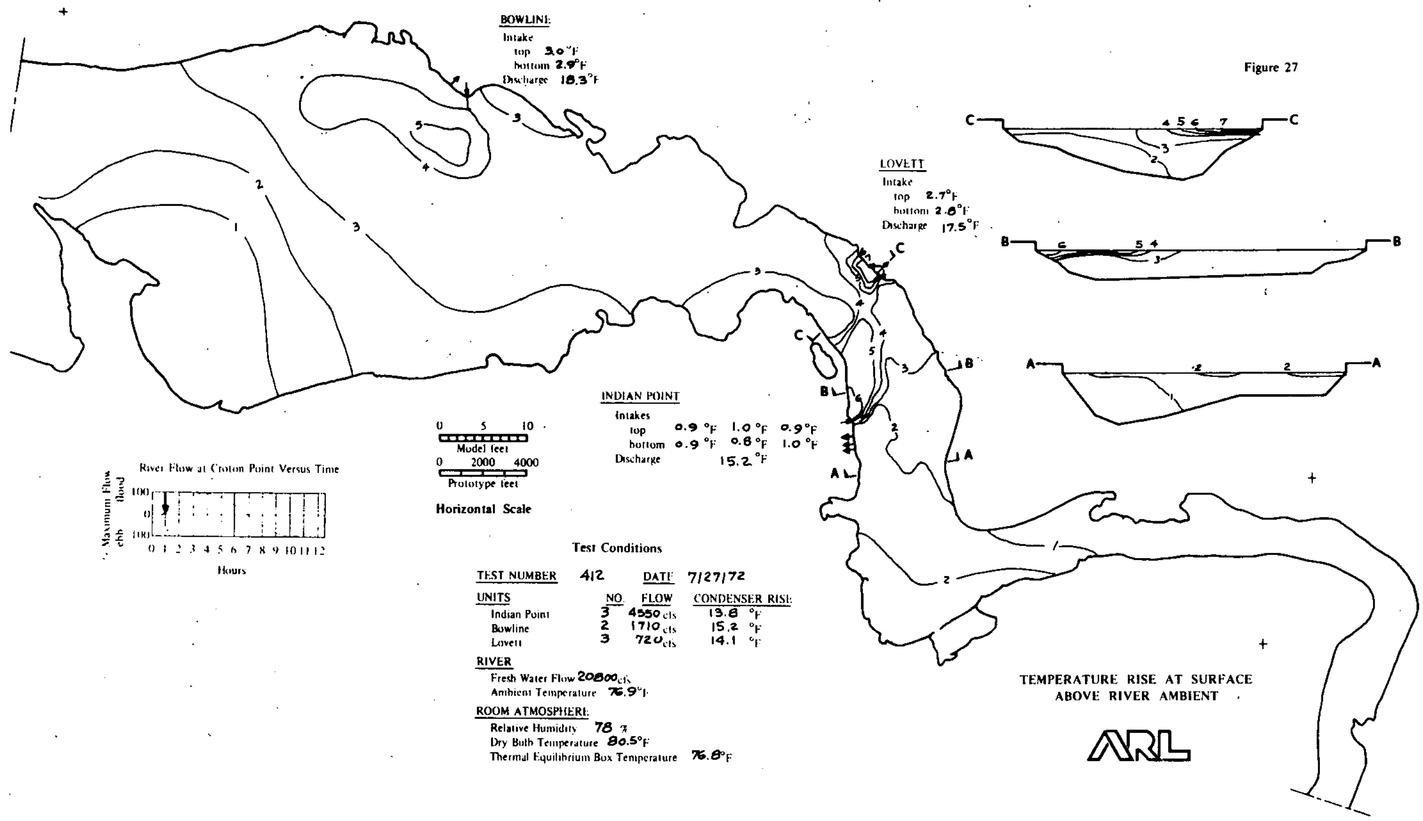
Figure 26



TEMPERATURE RISE AT SURFACE ABOVE RIVER AMBIENT

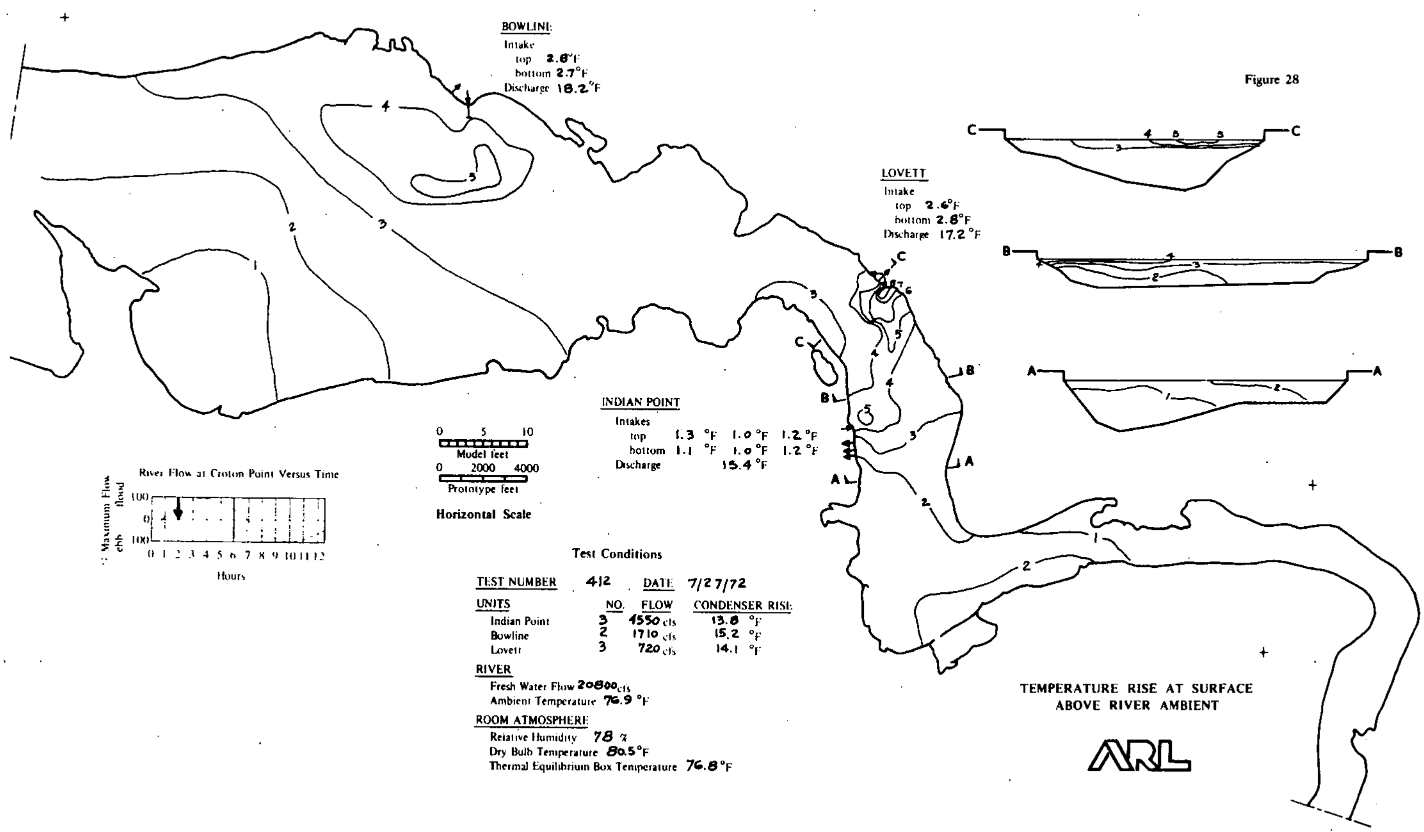
ARL

Figure 27



TEMPERATURE RISE AT SURFACE ABOVE RIVER AMBIENT

Figure 28



TEMPERATURE RISE AT SURFACE ABOVE RIVER AMBIENT

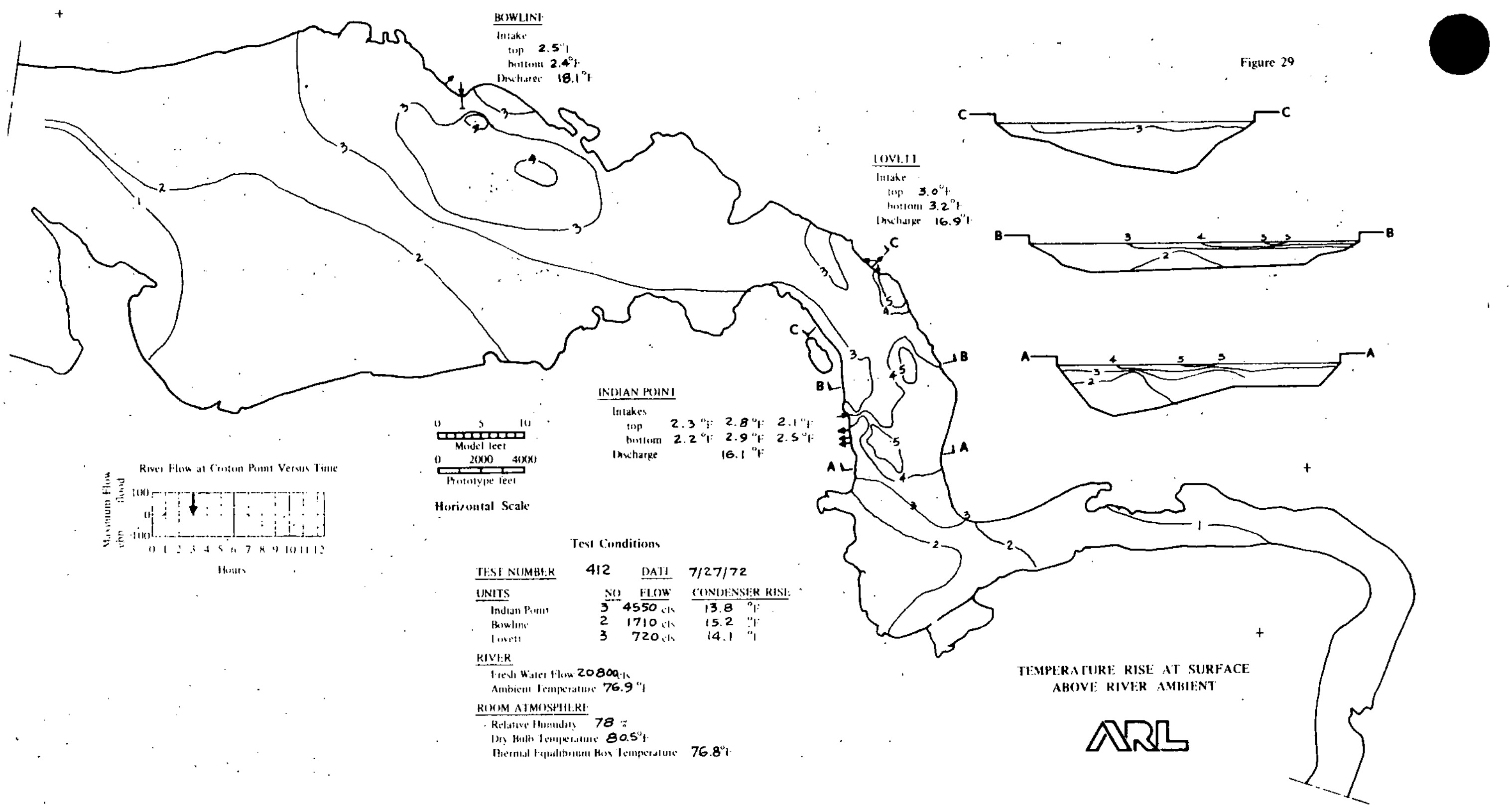


Figure 29

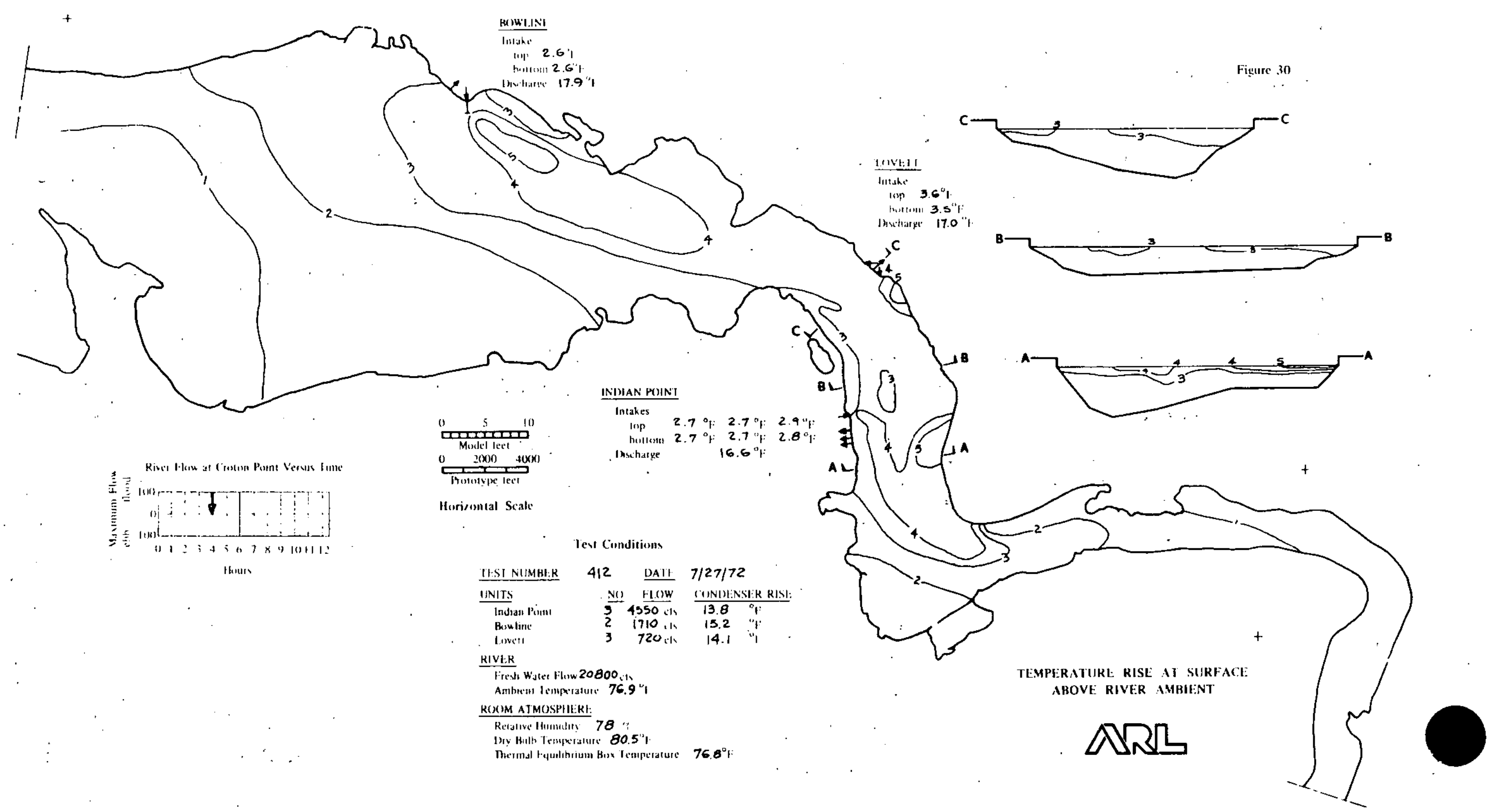
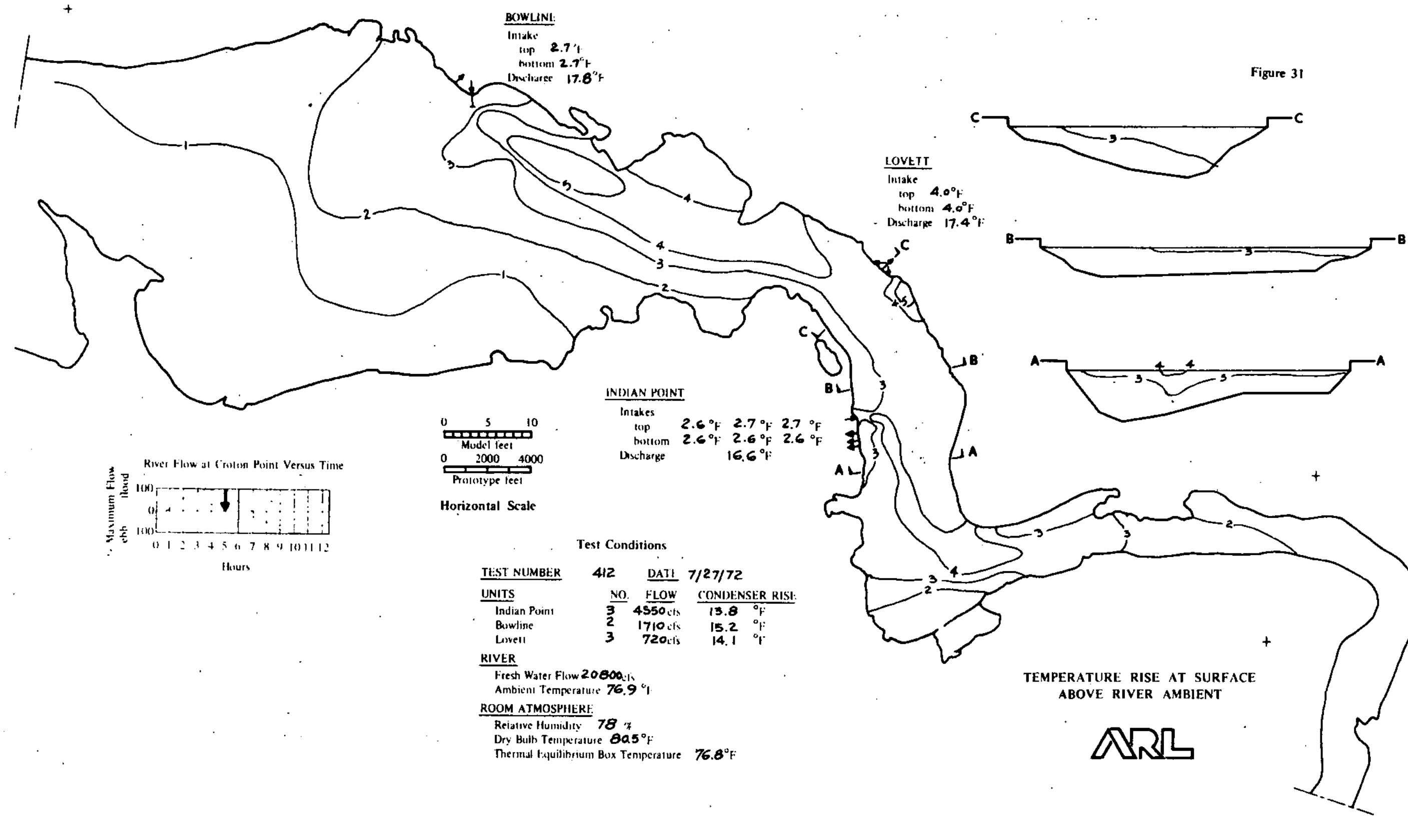


Figure 30

Figure 31



Test Conditions

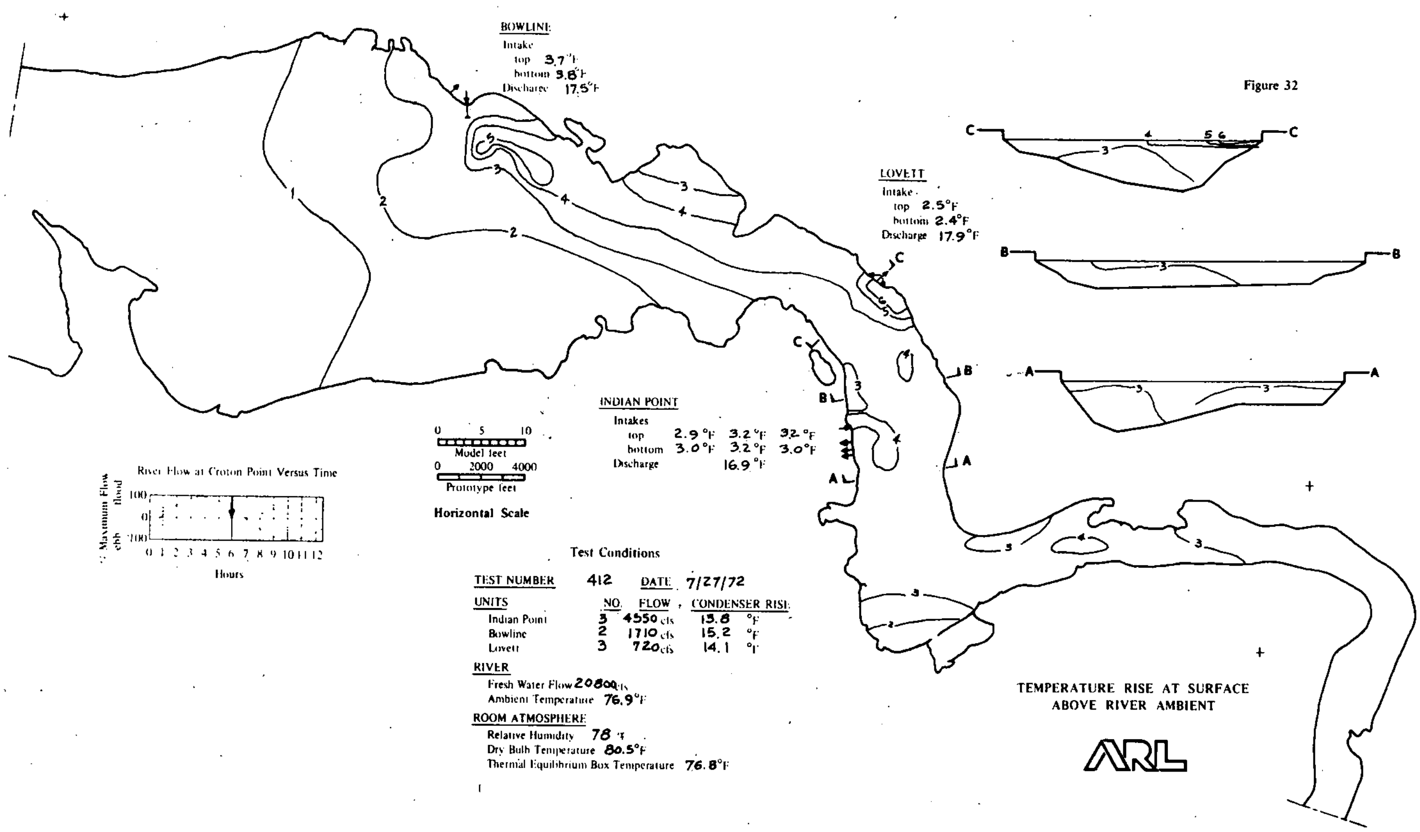
TEST NUMBER 412 DATE 7/27/72

UNITS	NO.	FLOW	CONDENSER RISE
Indian Point	3	4550 cfs	13.8 °F
Bowline	2	1710 cfs	15.2 °F
Lovett	3	720 cfs	14.1 °F

RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 76.9 °F

ROOM ATMOSPHERE
Relative Humidity 78 %
Dry Bulb Temperature 80.5°F
Thermal Equilibrium Box Temperature 76.8°F

Figure 32



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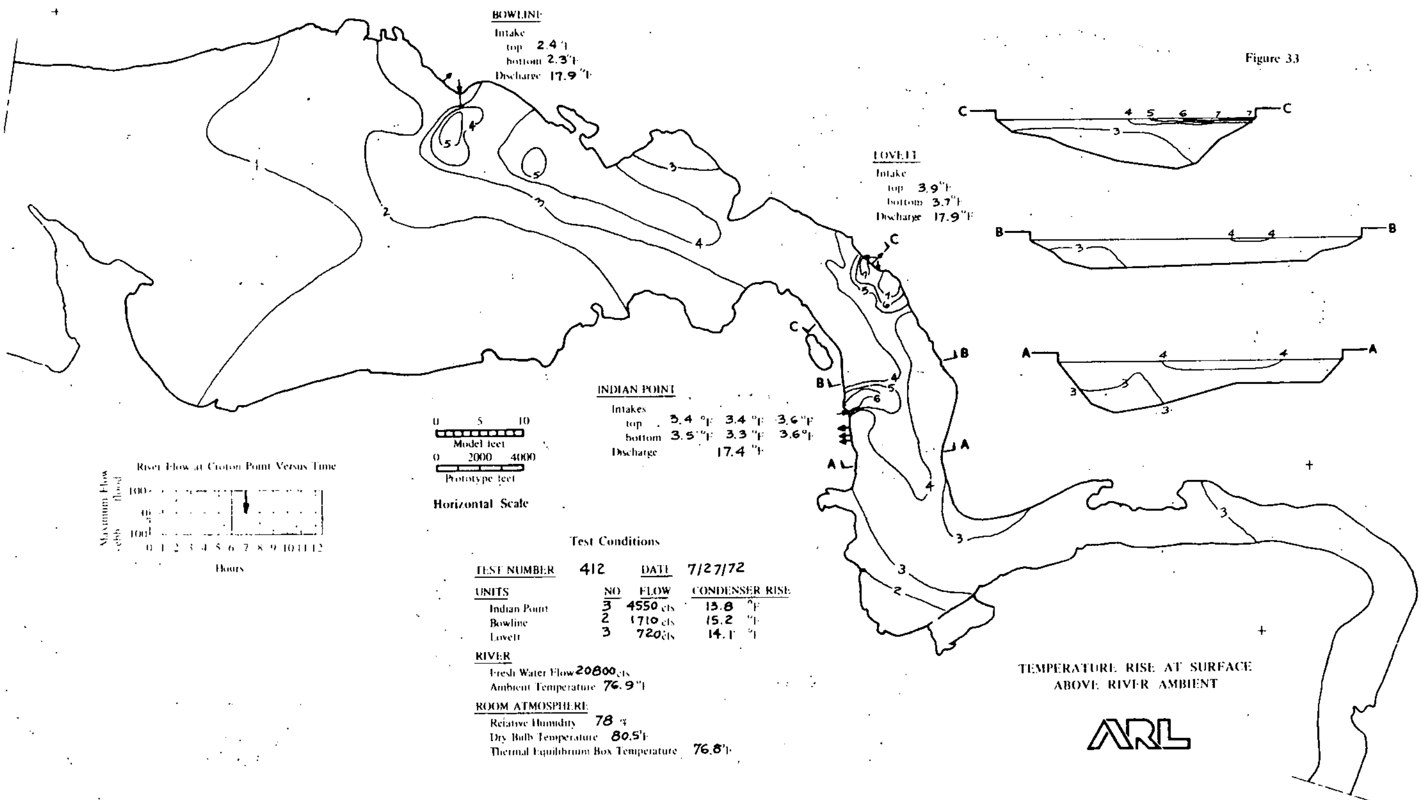


Figure 33
BOWLINE
Intake
top 2.4 °F
bottom 2.3°F
Discharge 17.9 °F
LOVETT
Intake
top 3.9°F
bottom 3.7°F
Discharge 17.9°F
INDIAN POINT
Intakes
top 3.4 °F 3.4 °F 3.6 °F
bottom 3.5 °F 3.3 °F 3.6 °F
Discharge 17.4 °F
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
Maximum Flow cfs
flood
ebb
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
Test Conditions
TEST NUMBER 412 DATE 7/27/72
UNITS NO FLOW CONDENSER RISE
Indian Point 3 4550 cfs 13.8 °F
Bowline 2 1710 cfs 15.2 °F
Lovett 3 720 cfs 14.1 °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 76.9 °F
ROOM ATMOSPHERE
Relative Humidity 78 %
Dry Bulb Temperature 80.5°F
Thermal Equilibrium Box Temperature 76.8°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

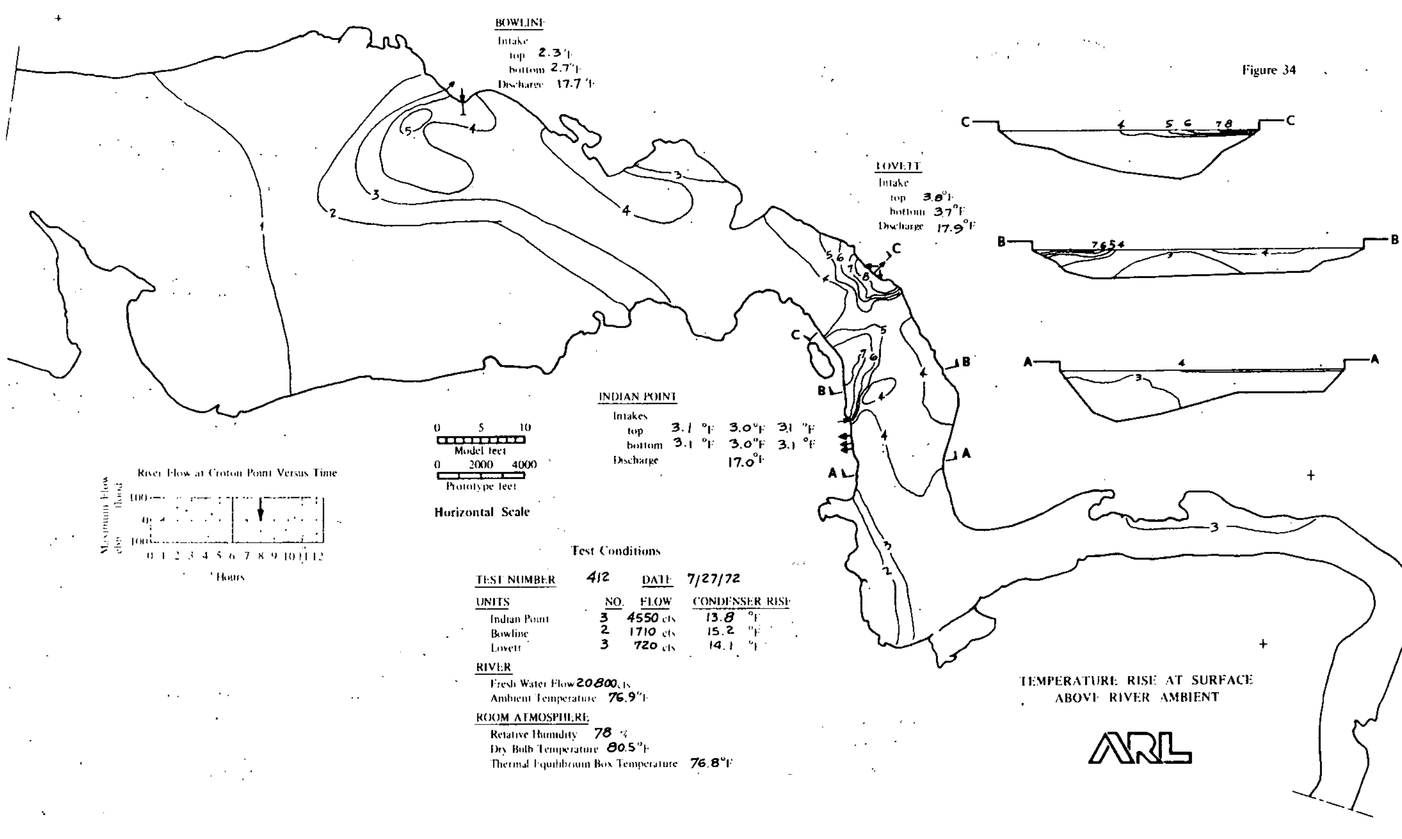
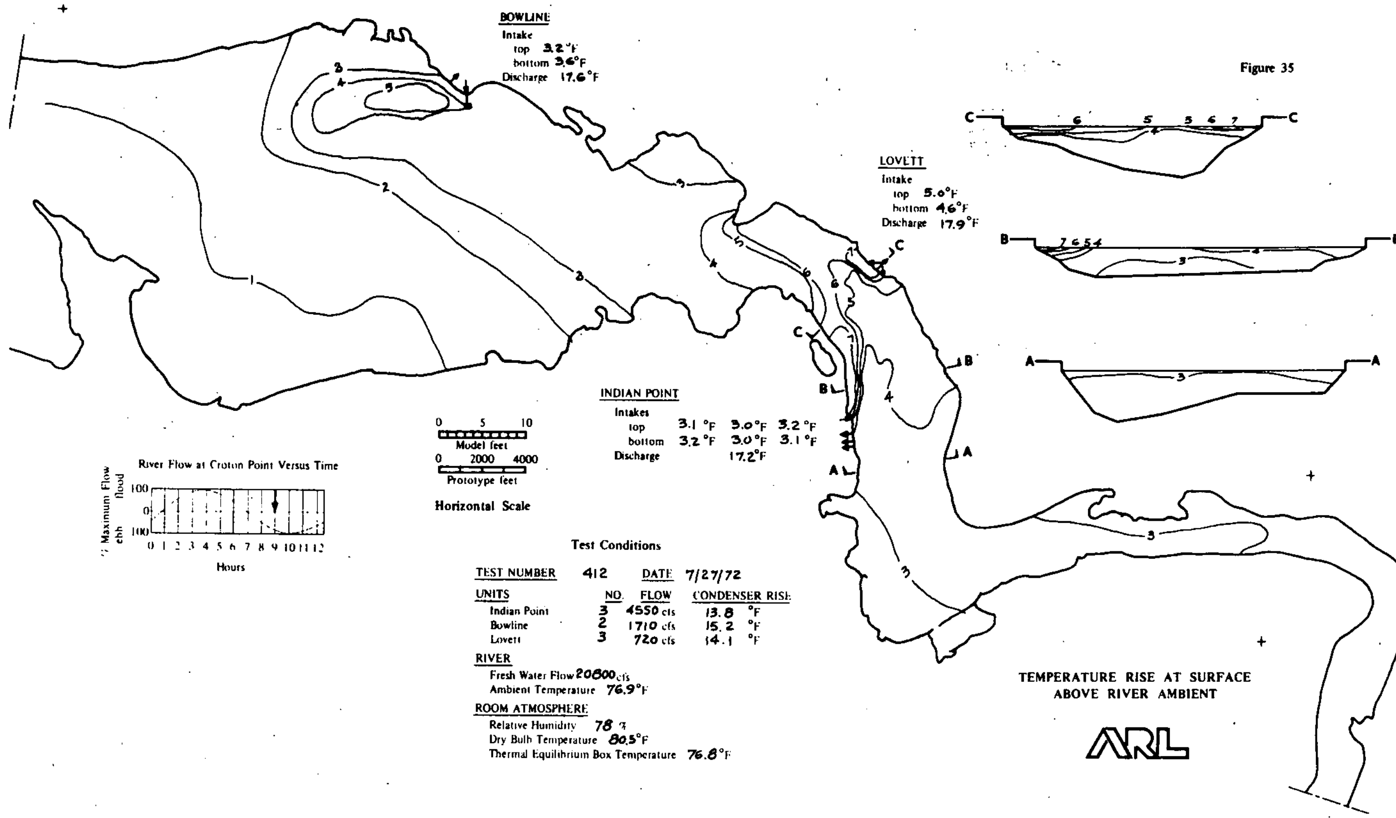


Figure 34
BOWLINE
Intake
top 2.3°F
bottom 2.7°F
Discharge 17.7 °F
LOVETT
Intake
top 3.8°F
bottom 3.7°F
Discharge 17.9°F
INDIAN POINT
Intakes
top 3.1 °F 3.0°F 3.1 °F
bottom 3.1 °F 3.0°F 3.1 °F
Discharge 17.0°F
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
Maximum Flow cfs
flood
ebb
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
Test Conditions
TEST NUMBER 412 DATE 7/27/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550 cfs 13.8 °F
Bowline 2 1710 cfs 15.2 °F
Lovett 3 720 cfs 14.1 °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 76.9°F
ROOM ATMOSPHERE
Relative Humidity 78 %
Dry Bulb Temperature 80.5°F
Thermal Equilibrium Box Temperature 76.8°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

Figure 35



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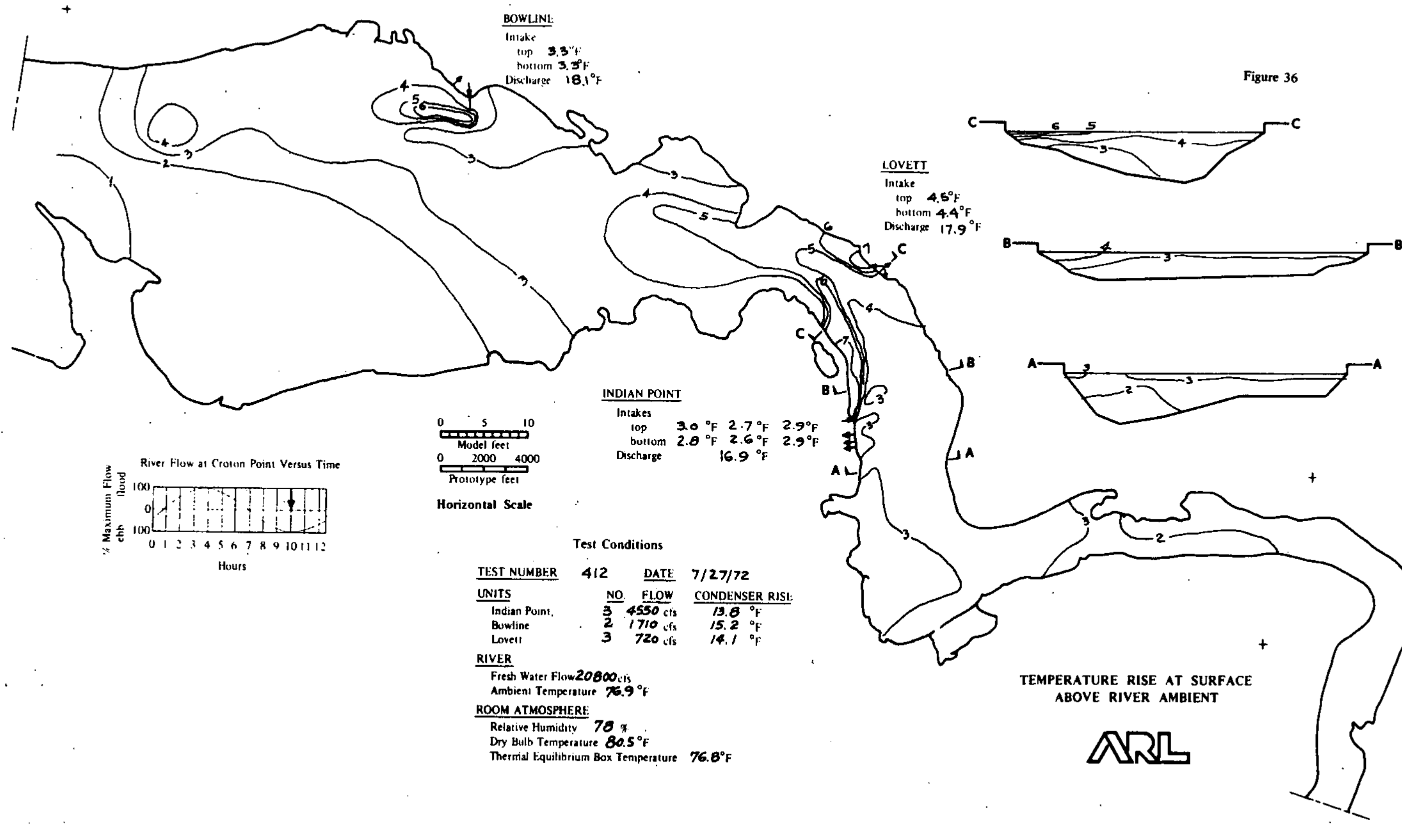
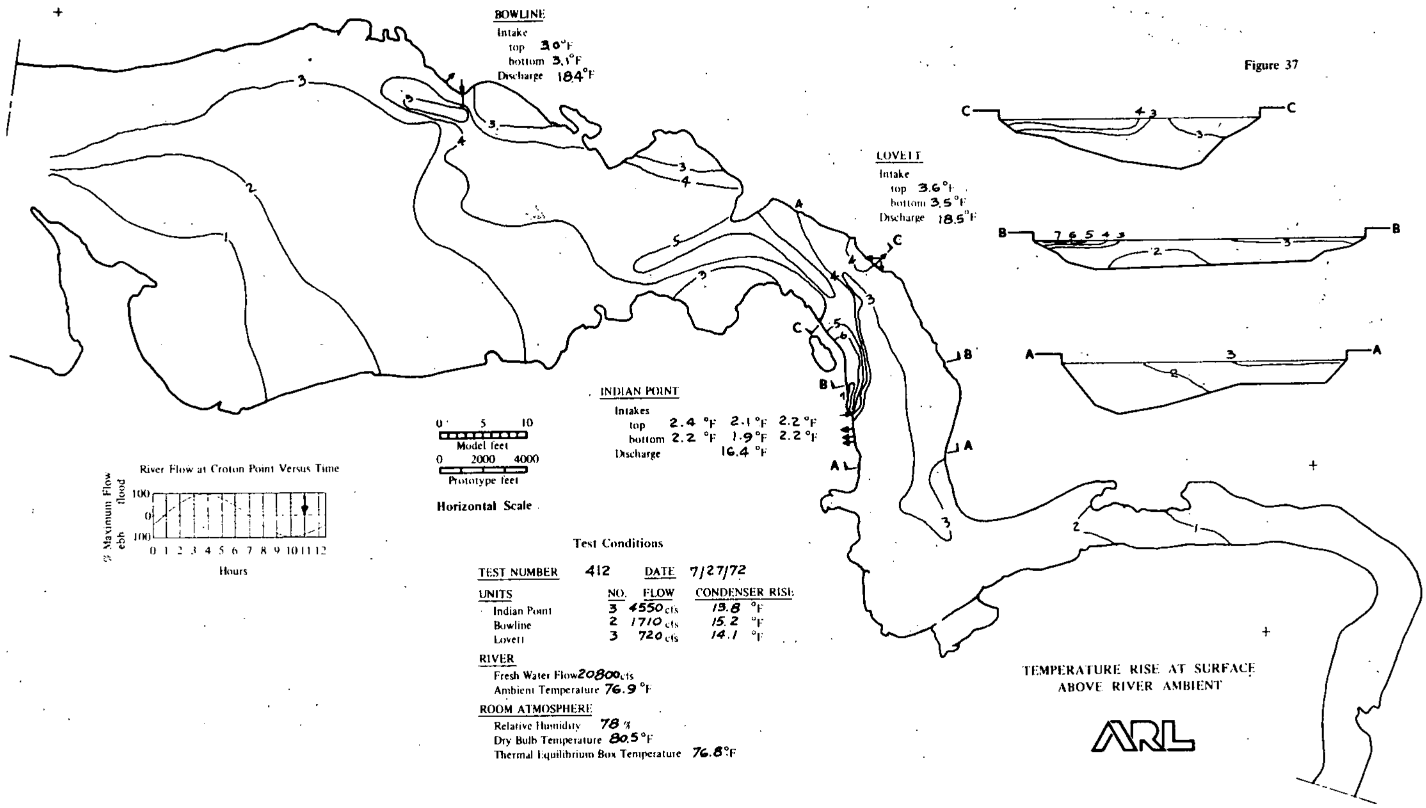


Figure 37



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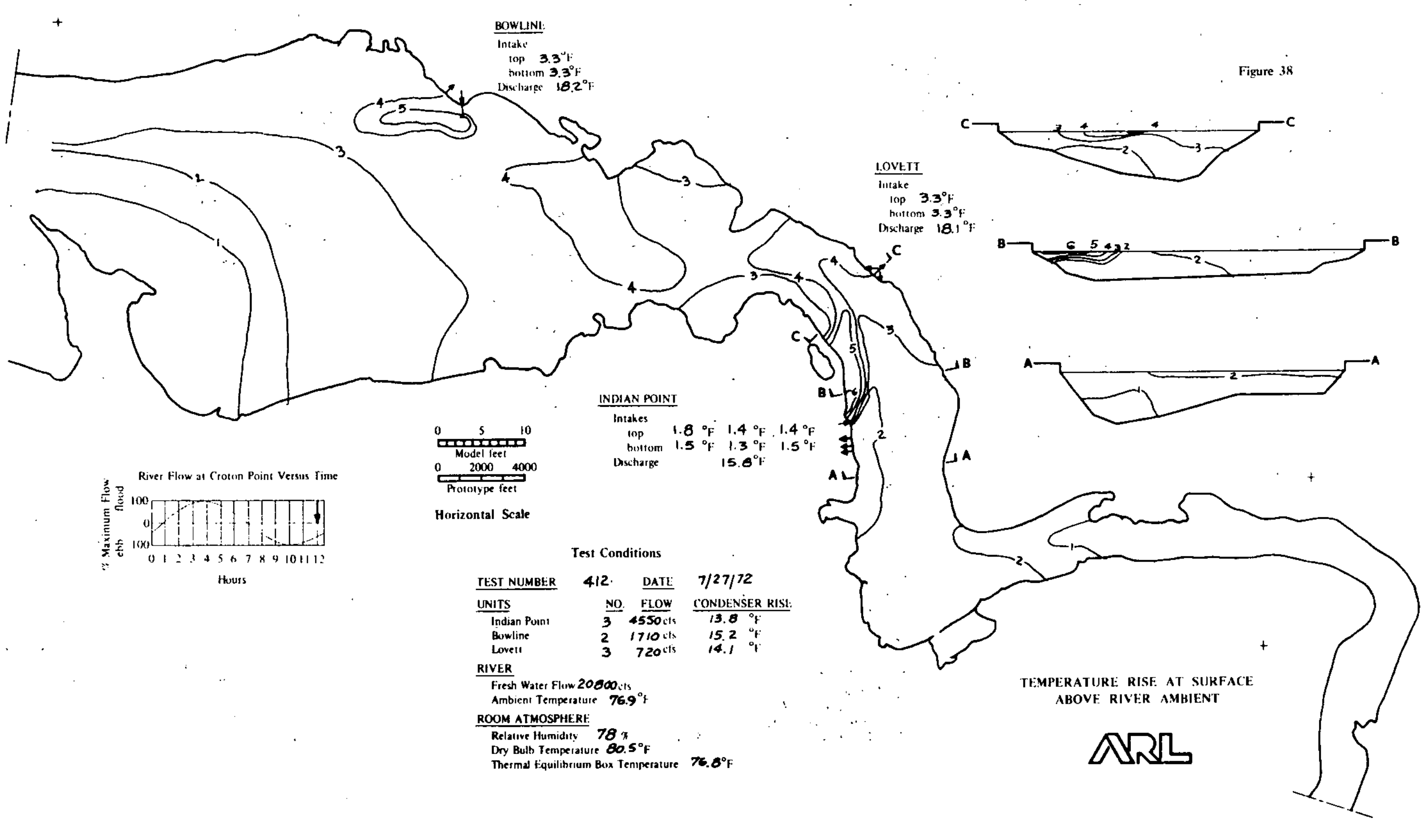

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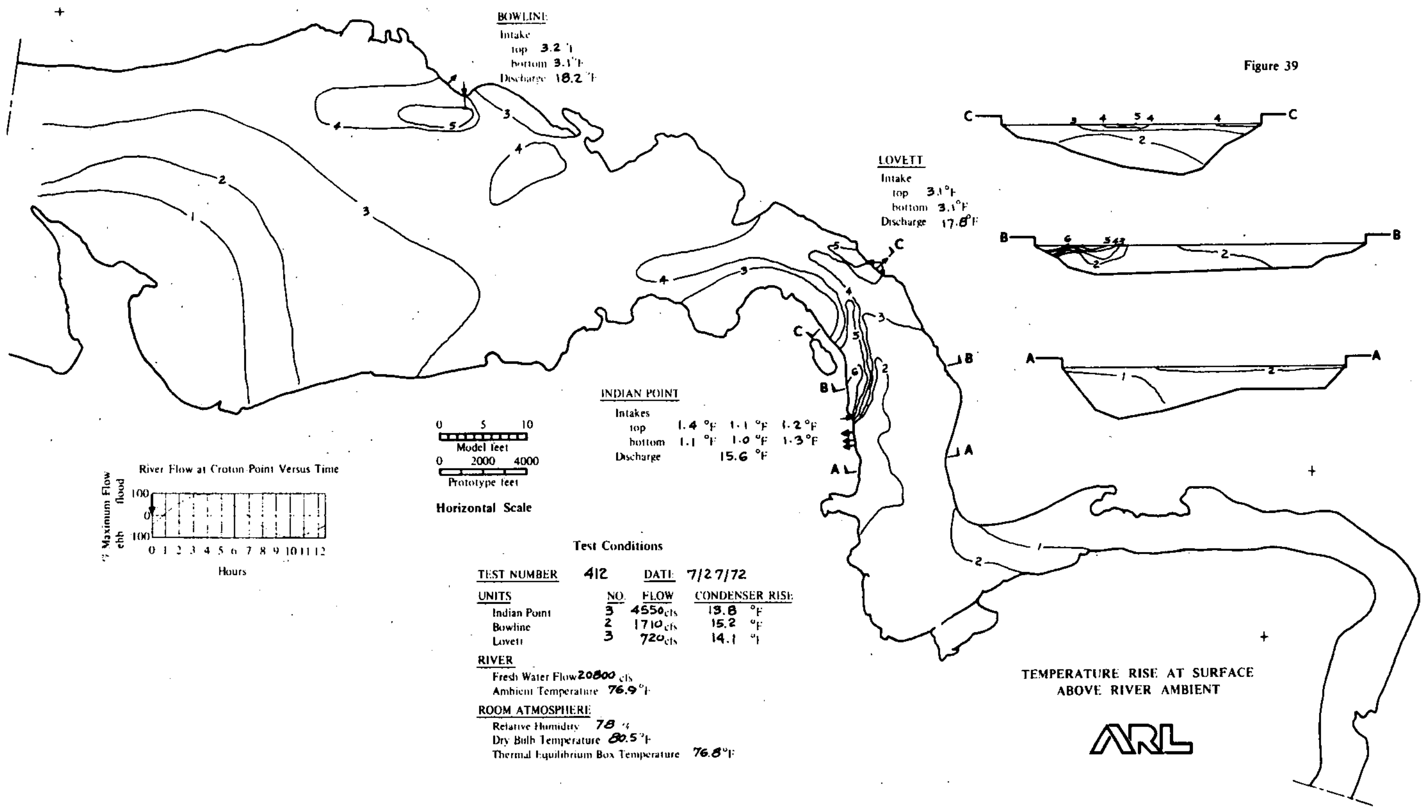
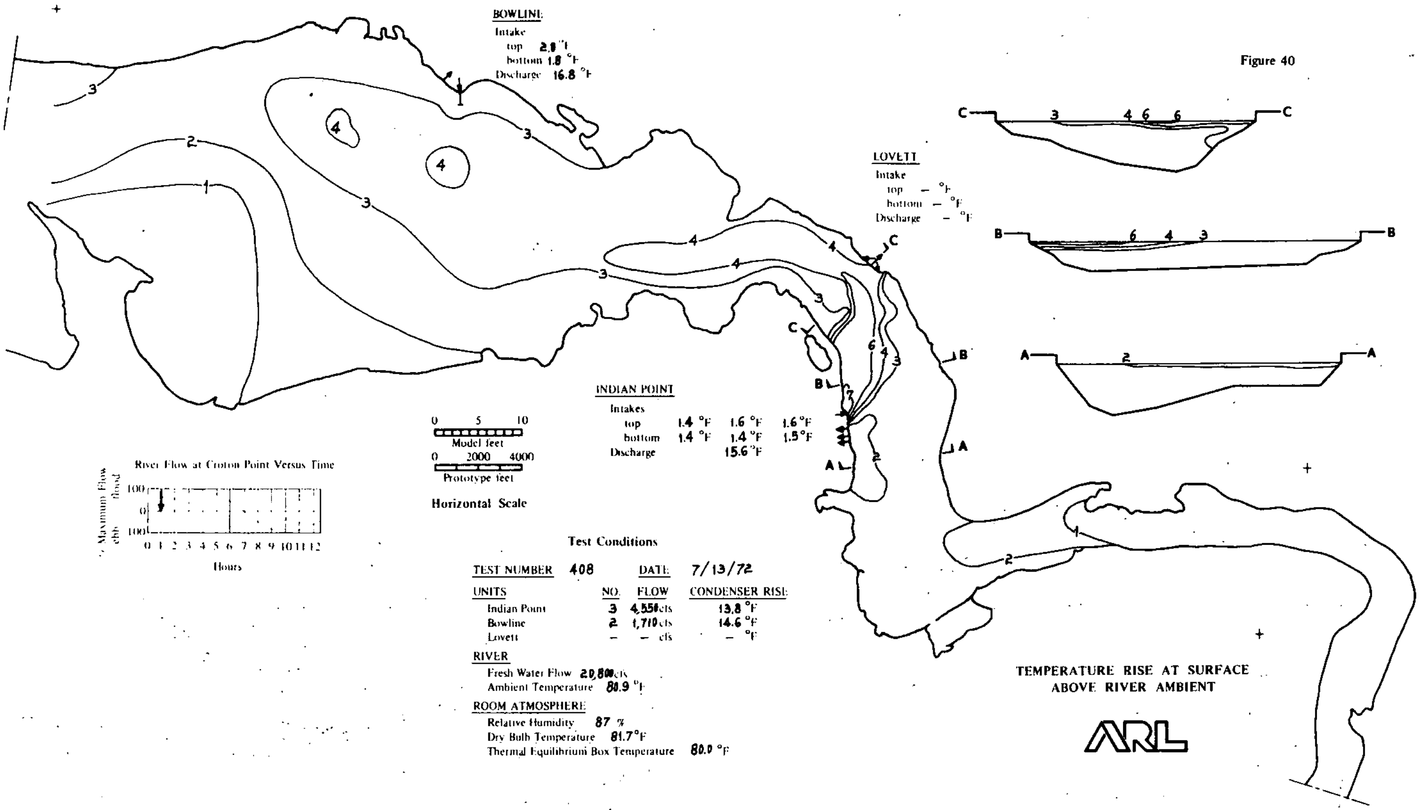

BOWLINE
Intake
top 3.2 °F
bottom 3.1°F
Discharge 18.2 °F
LOVETT
Intake
top 3.1°F
bottom 3.1°F
Discharge 17.8°F
INDIAN POINT
Intakes
top 1.4 °F 1.1 °F 1.2 °F
bottom 1.1 °F 1.0 °F 1.3 °F
Discharge 15.6 °F
River Flow at Croton Point Versus Time
% Maximum Flow
ebb flood
100
0
100
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
Test Conditions
TEST NUMBER 412 DATE 7/27/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550cfs 13.8 °F
Bowline 2 1710cfs 15.2 °F
Lovett 3 720cfs 14.1 °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 76.9°F
ROOM ATMOSPHERE
Relative Humidity 78 %
Dry Bulb Temperature 80.5°F
Thermal Equilibrium Box Temperature 76.8°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT



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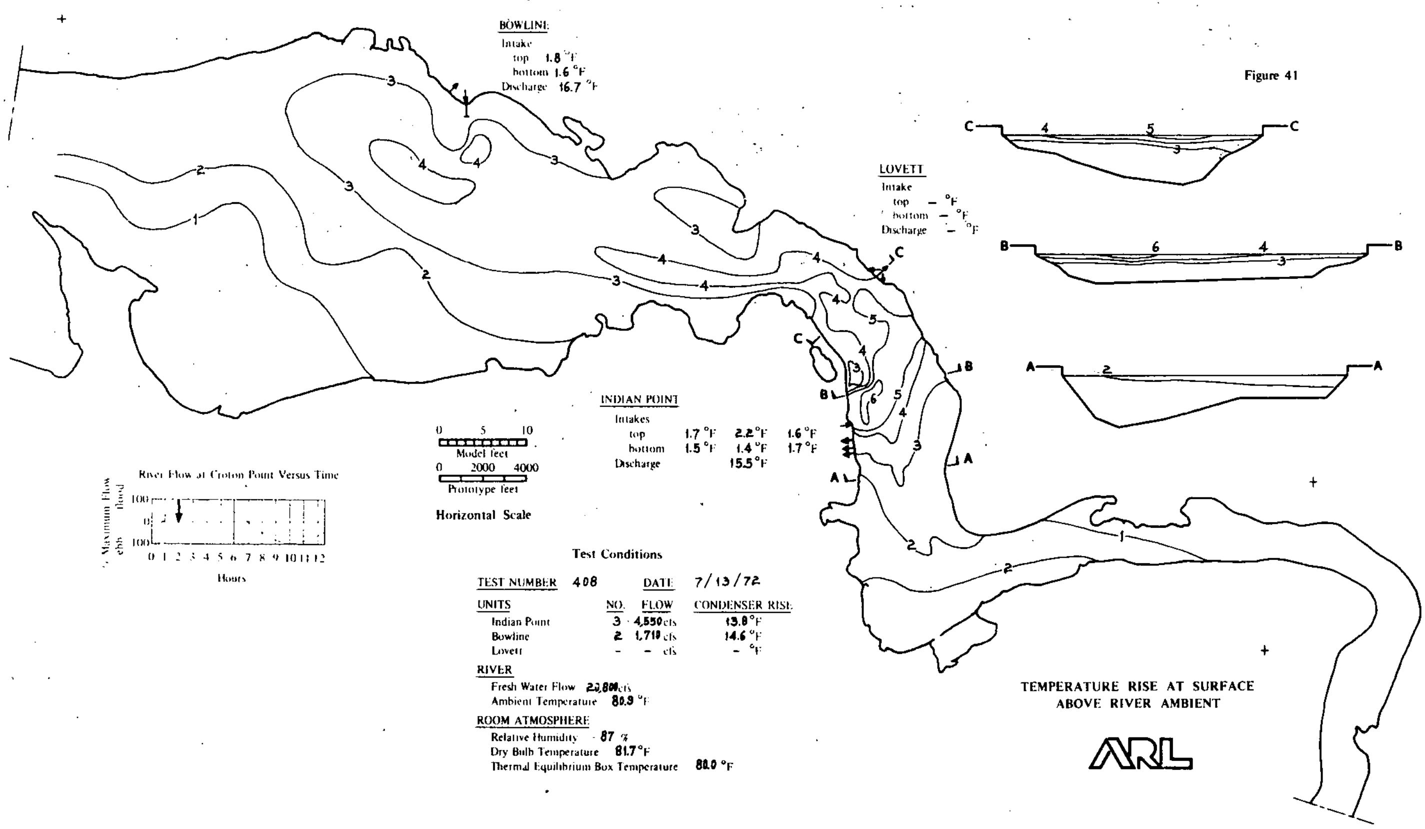

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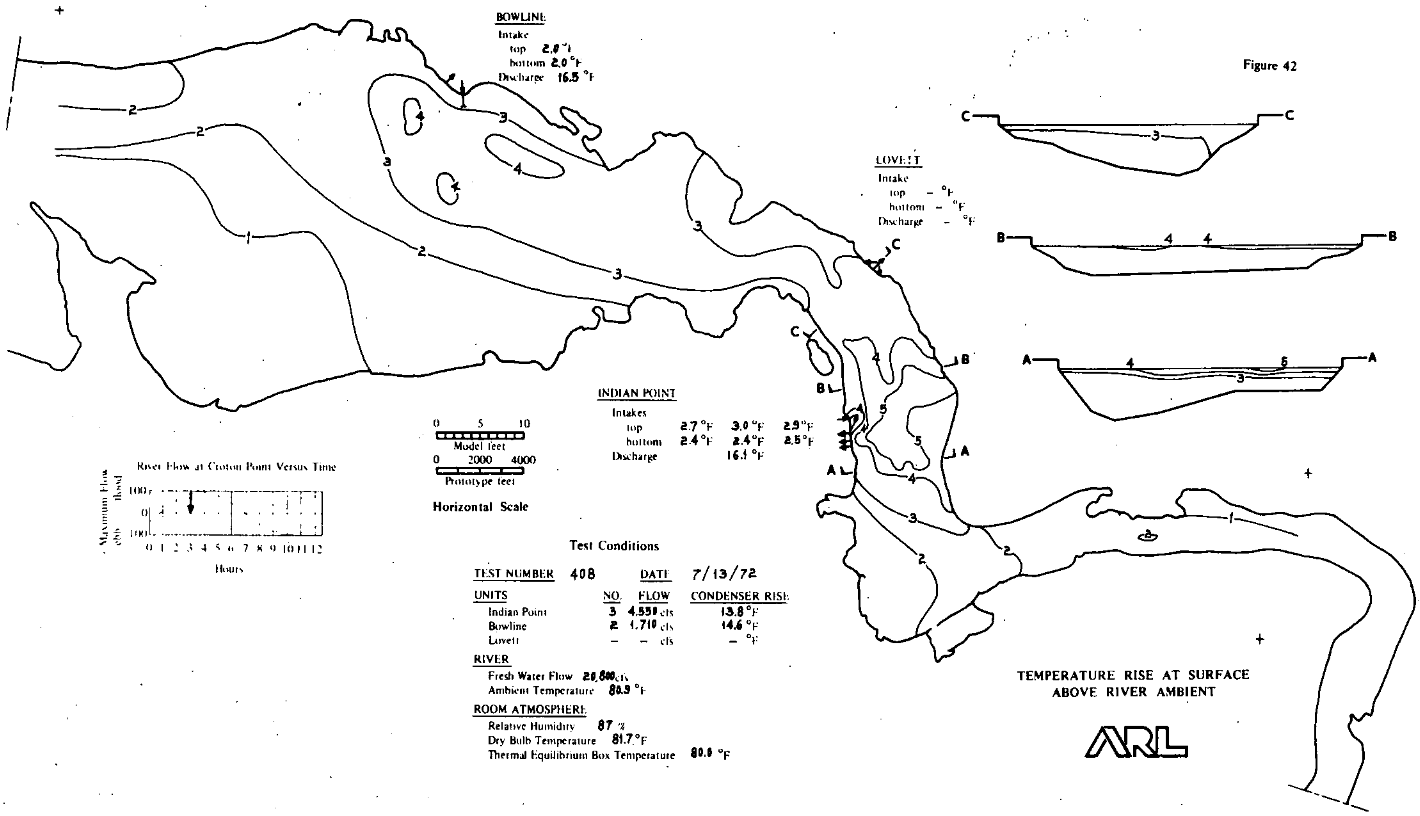

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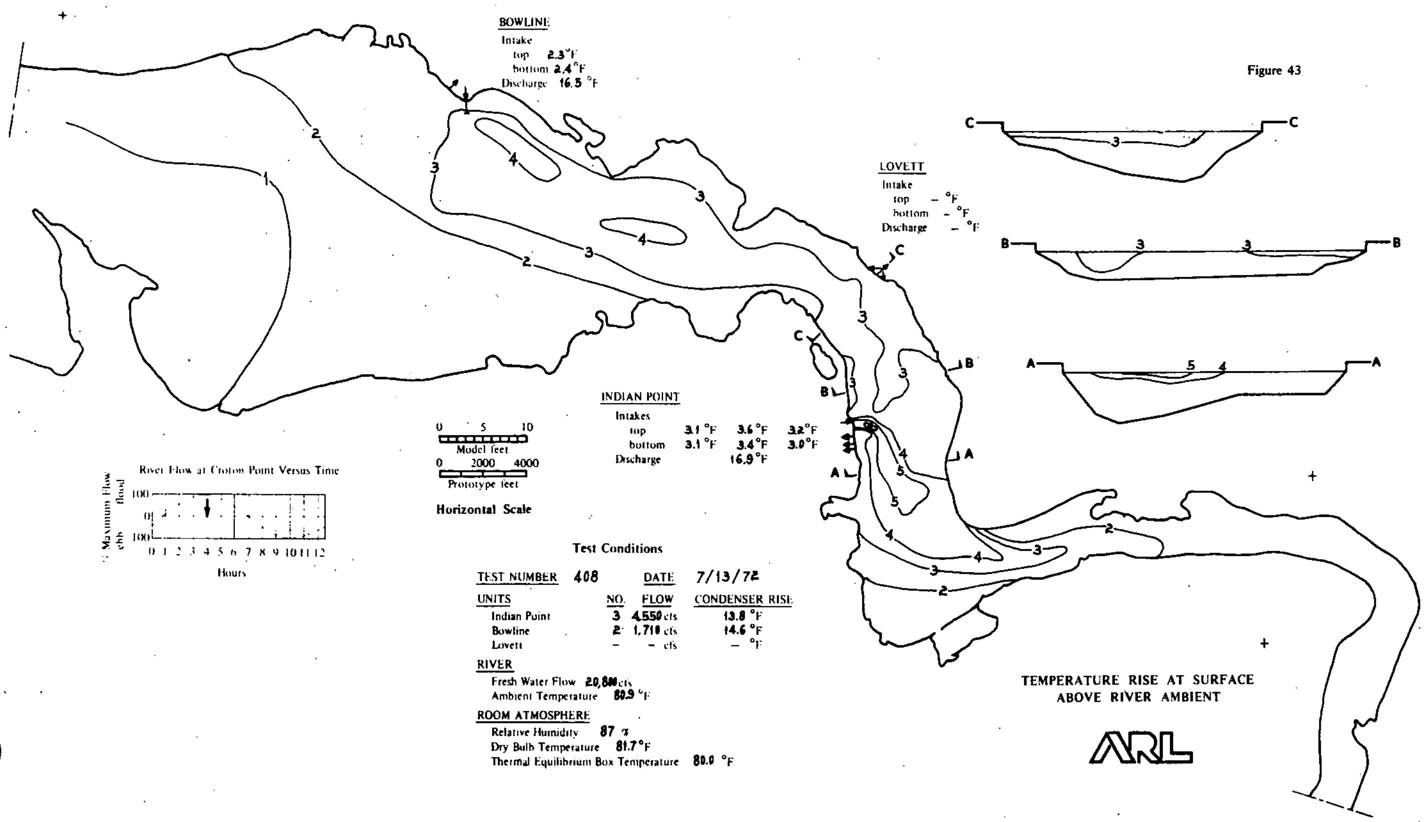
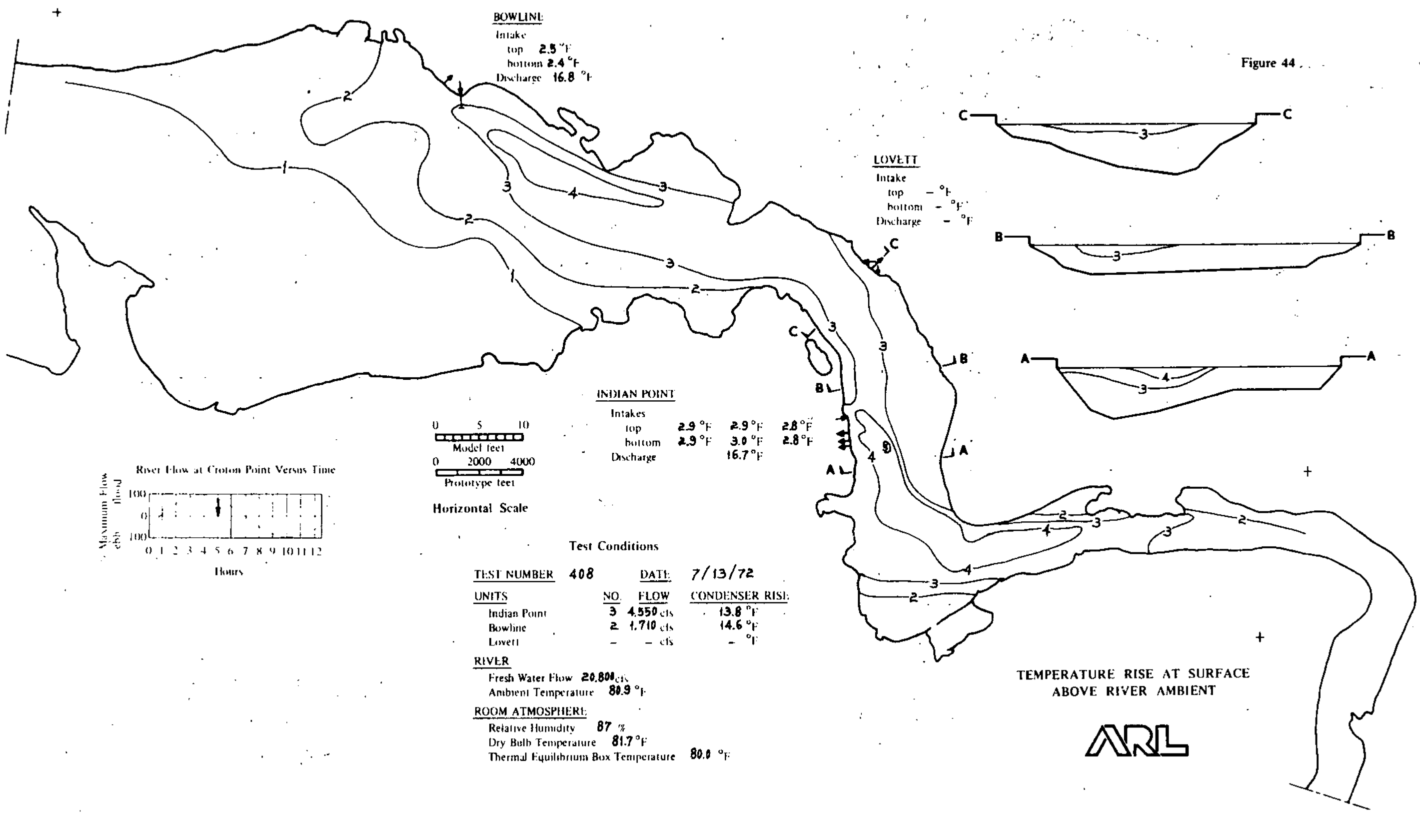


Figure 43

Figure 44



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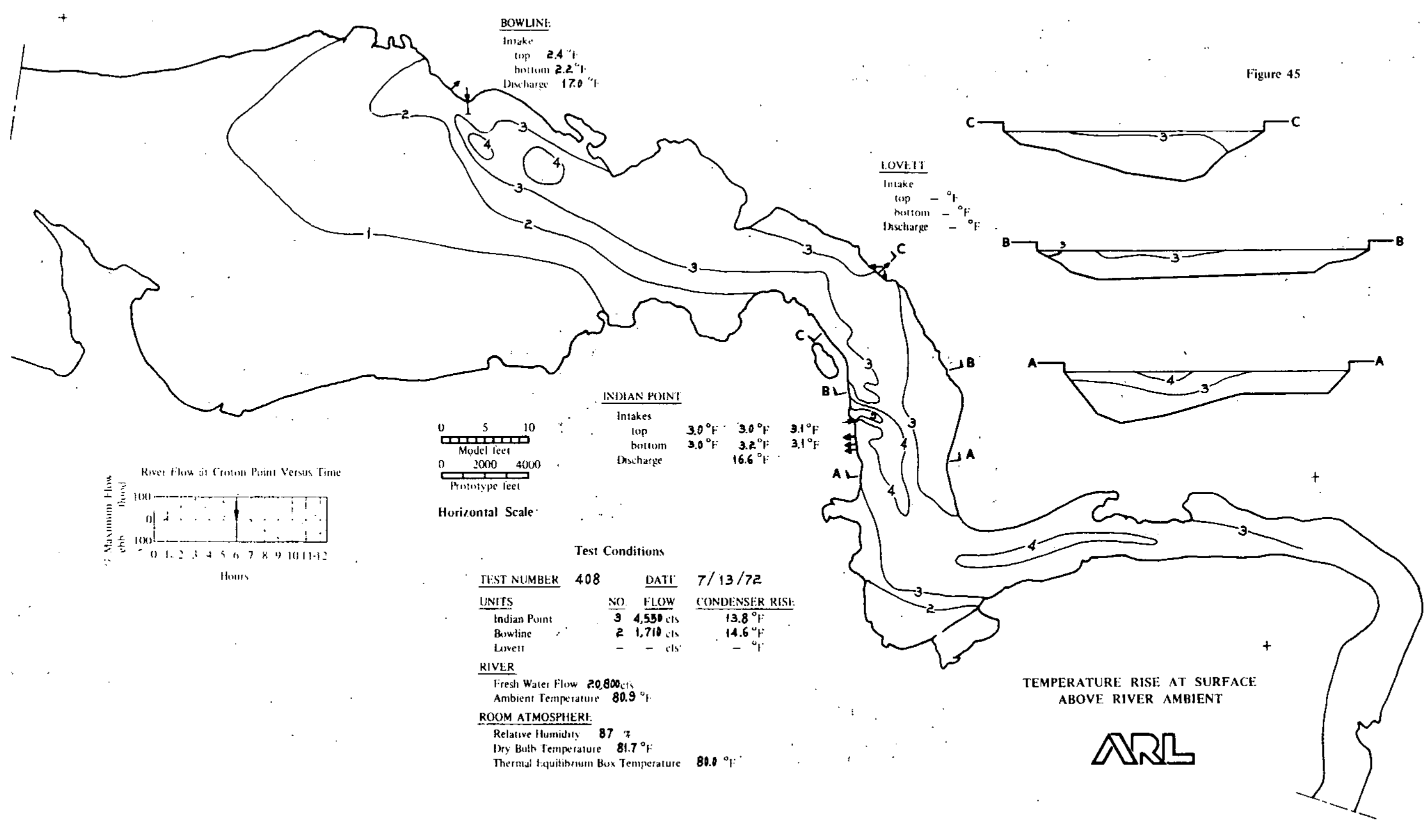

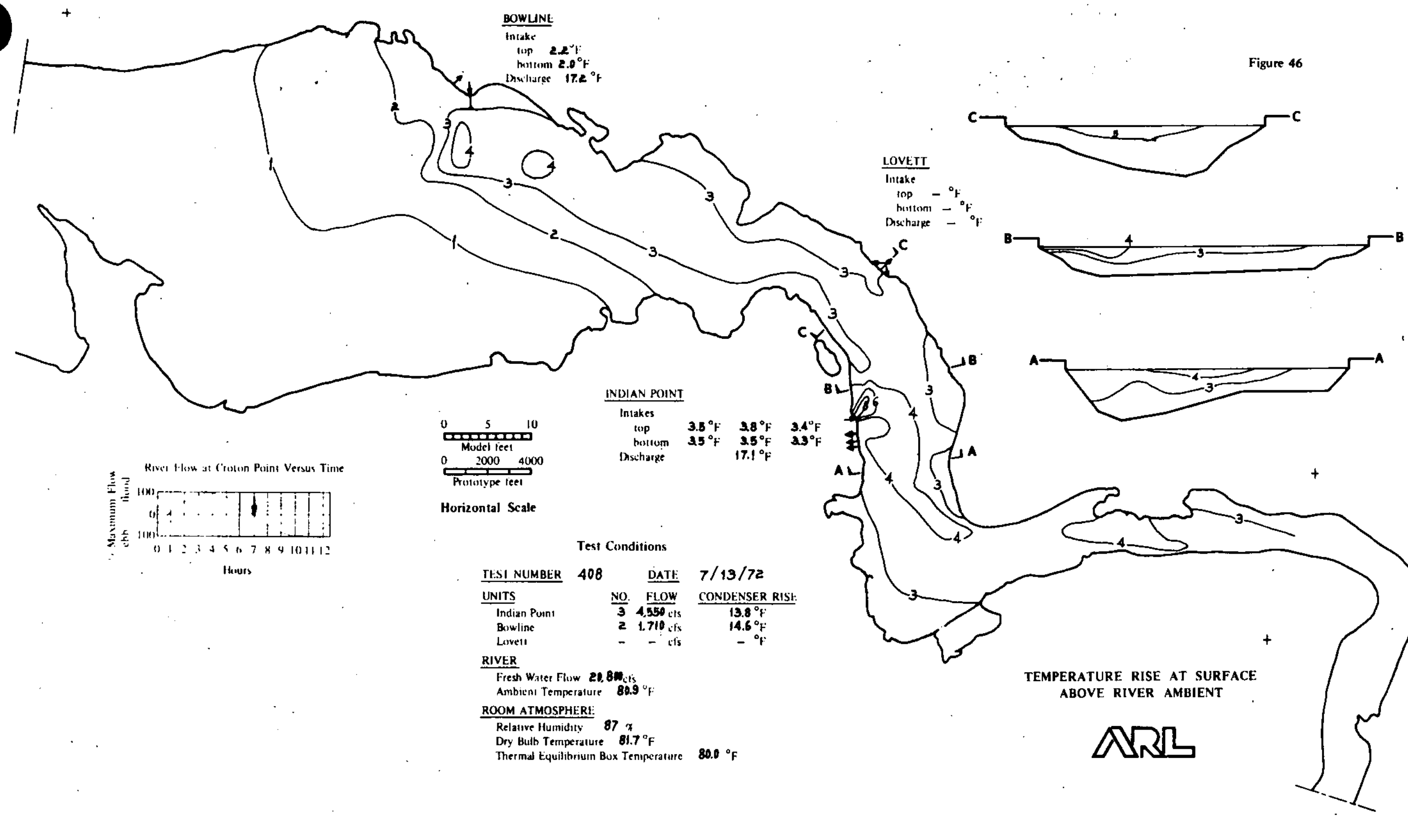

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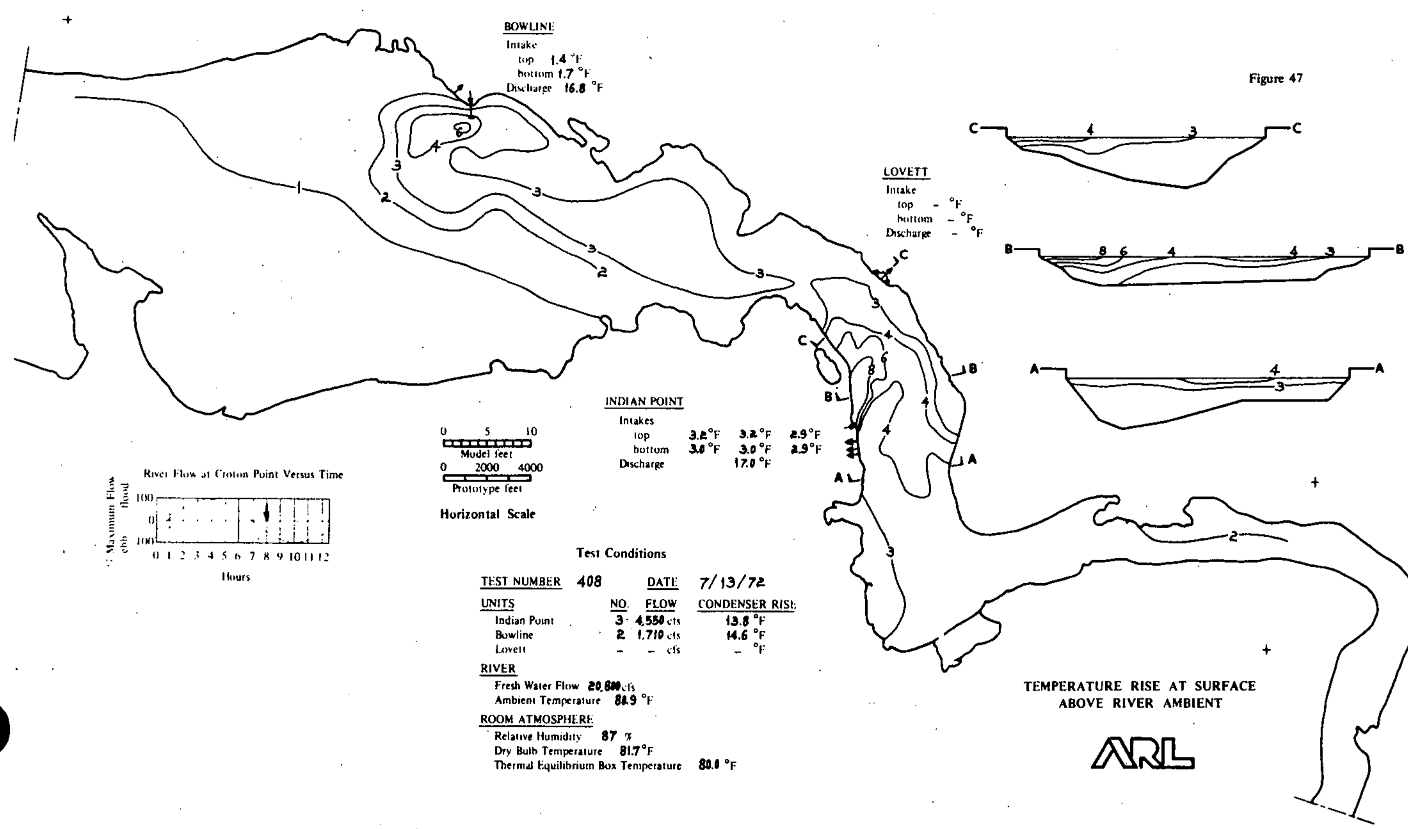
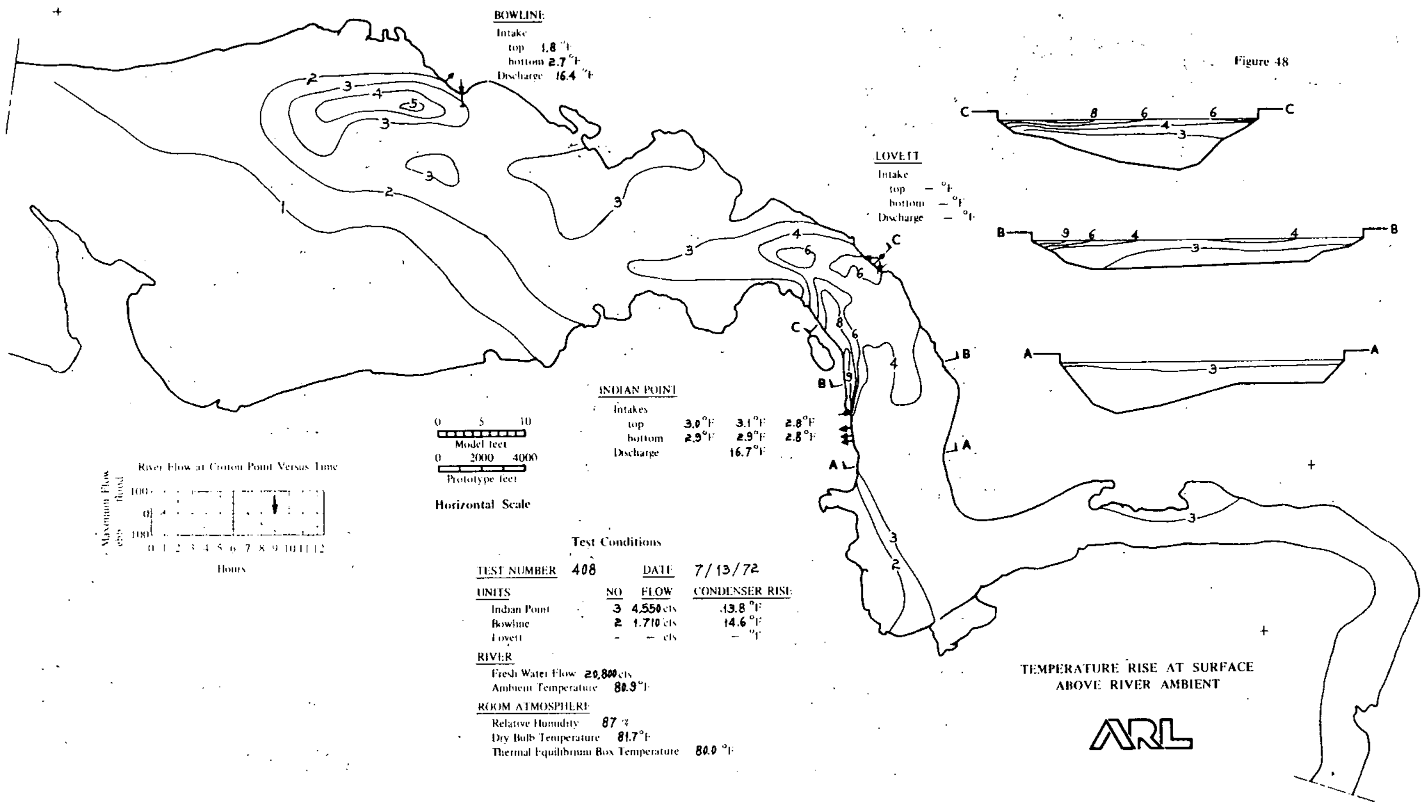


Figure 47

Figure 48



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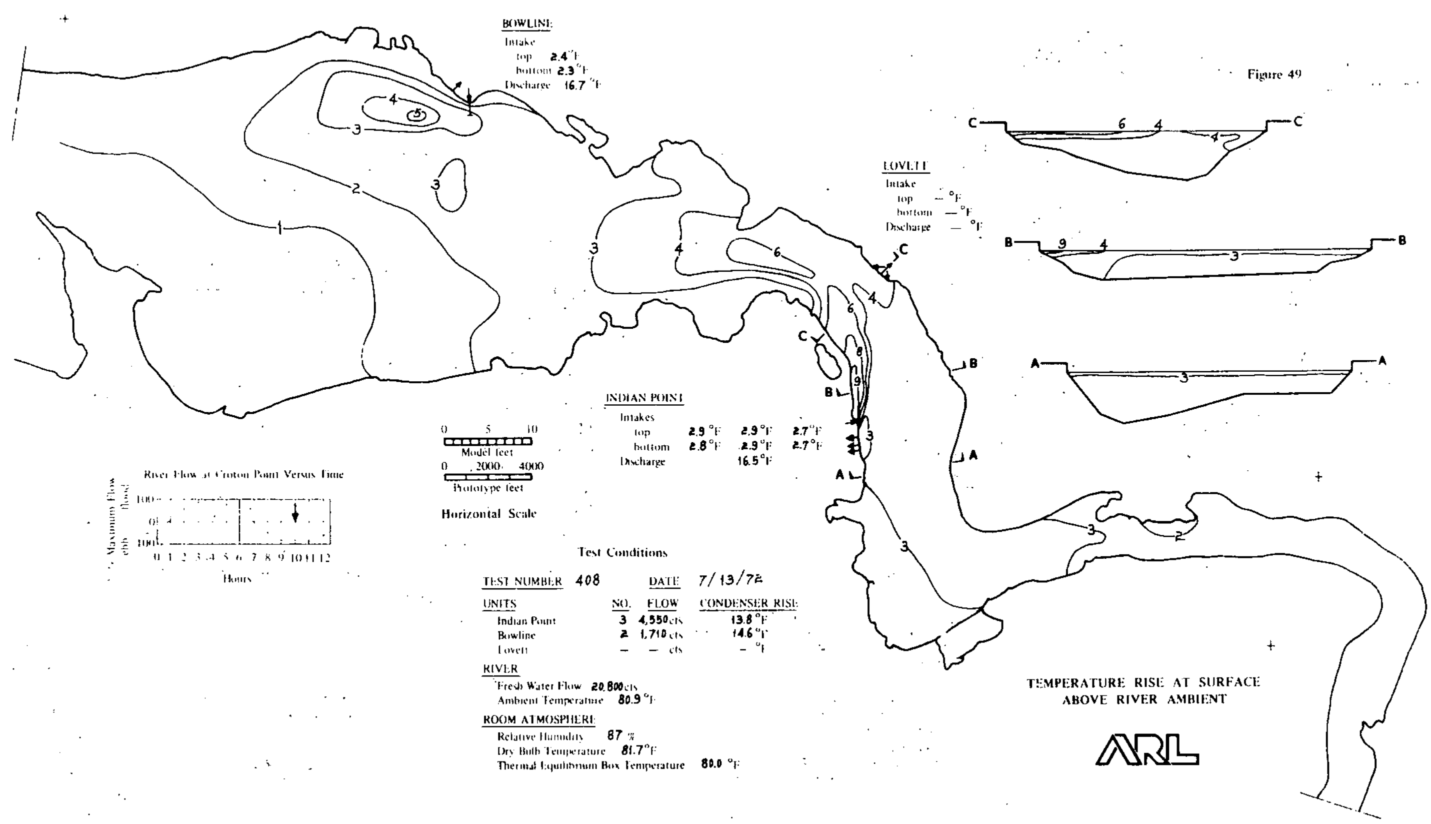

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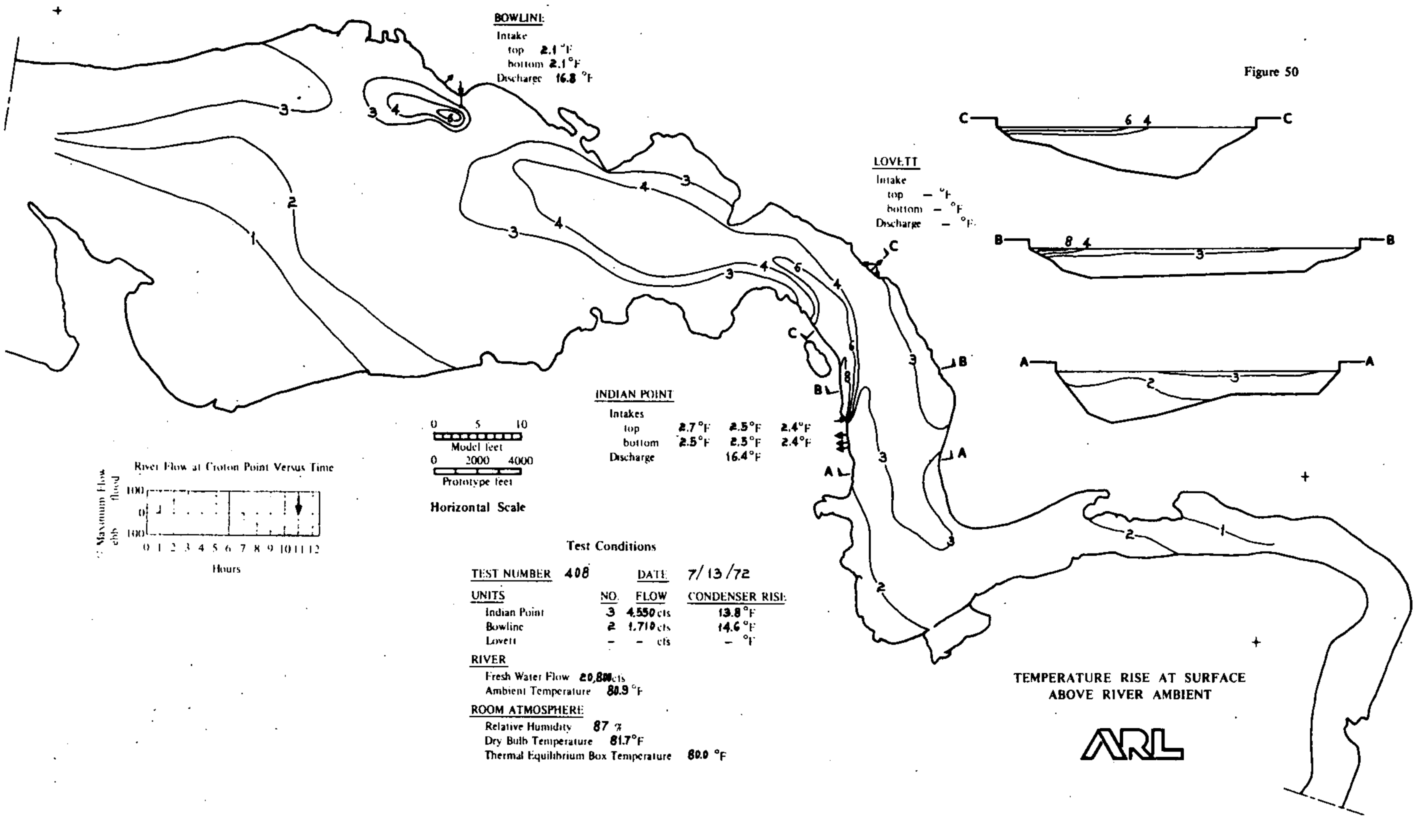
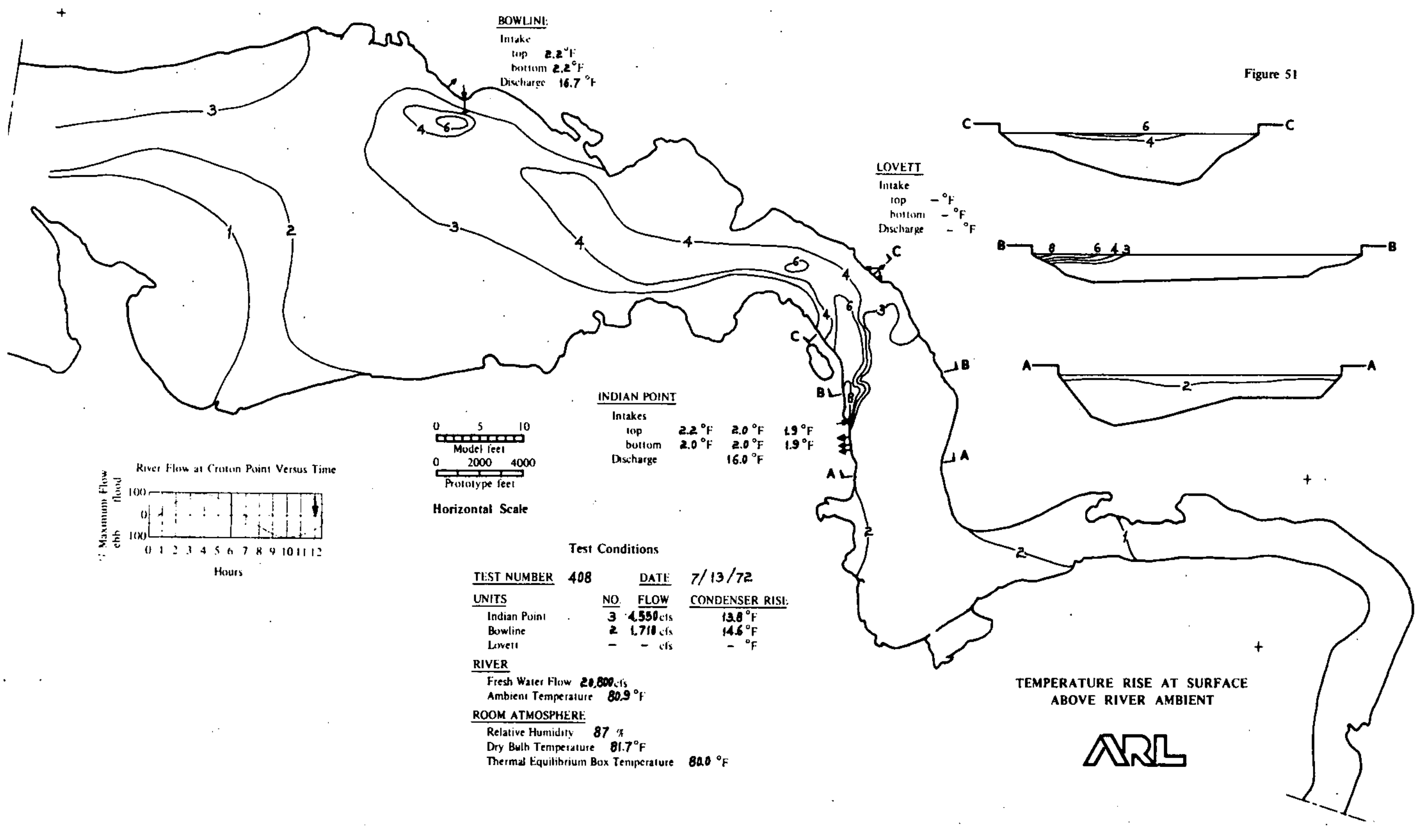


Figure 51



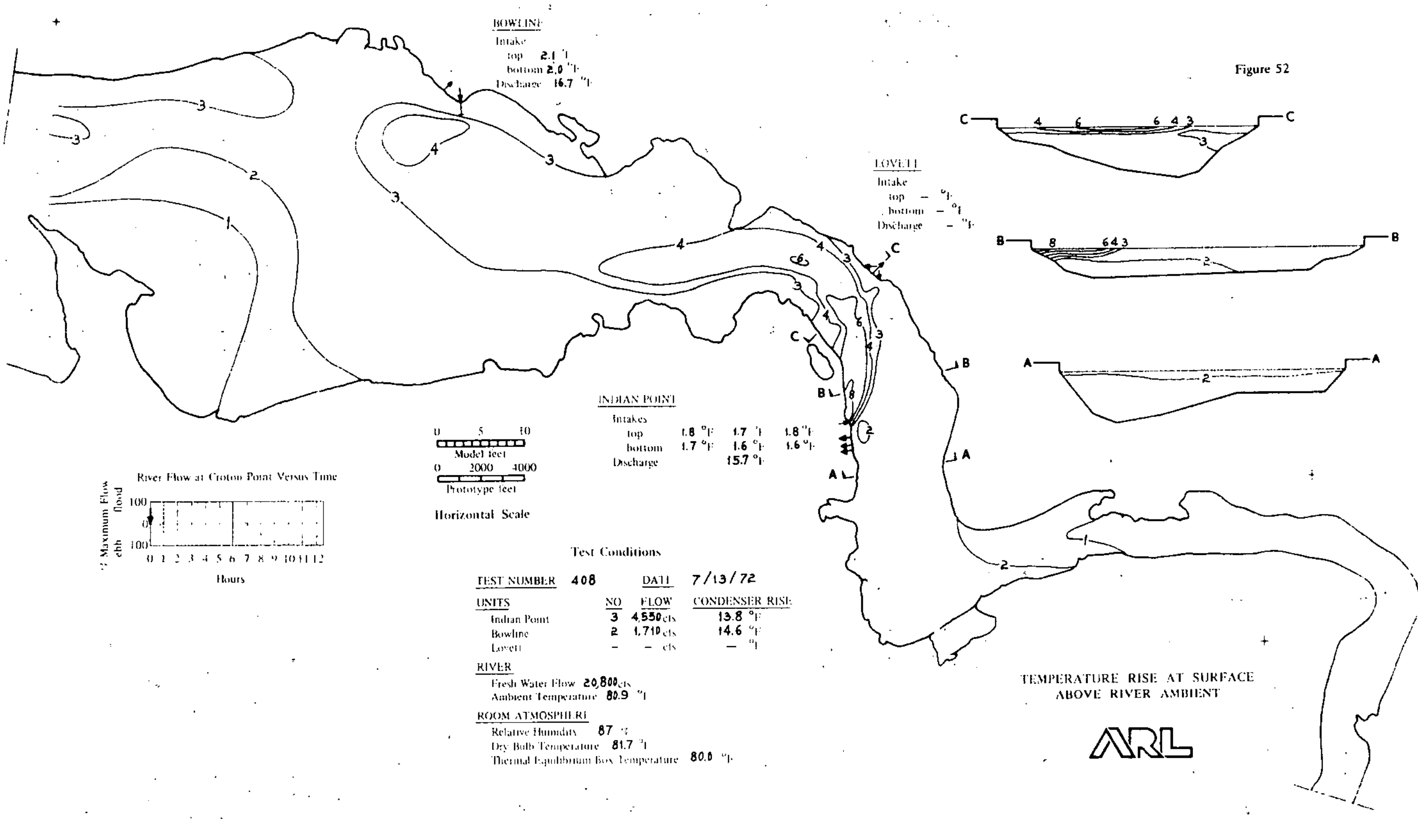
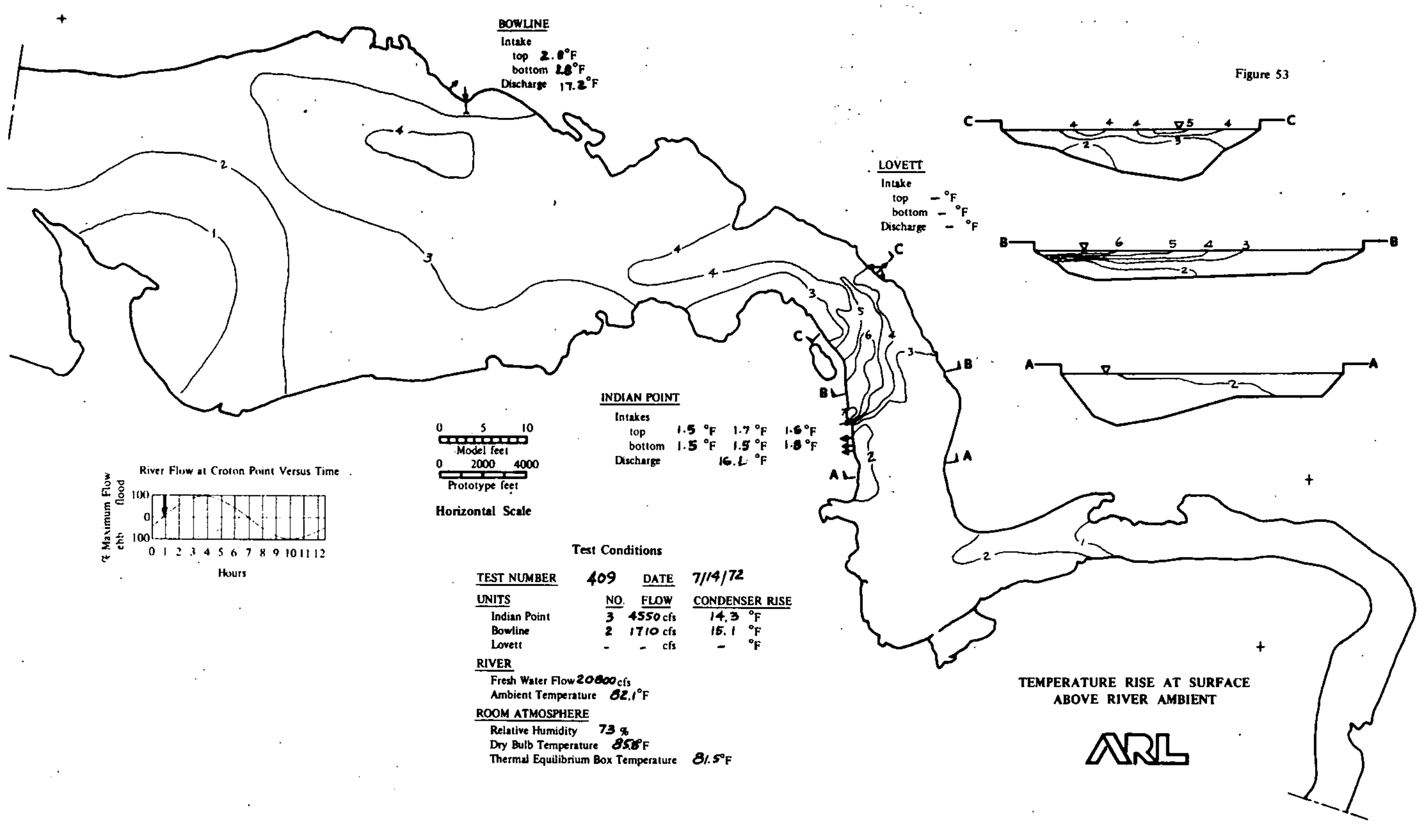


Figure 52

TEMPERATURE RISE AT SURFACE ABOVE RIVER AMBIENT

Figure 53



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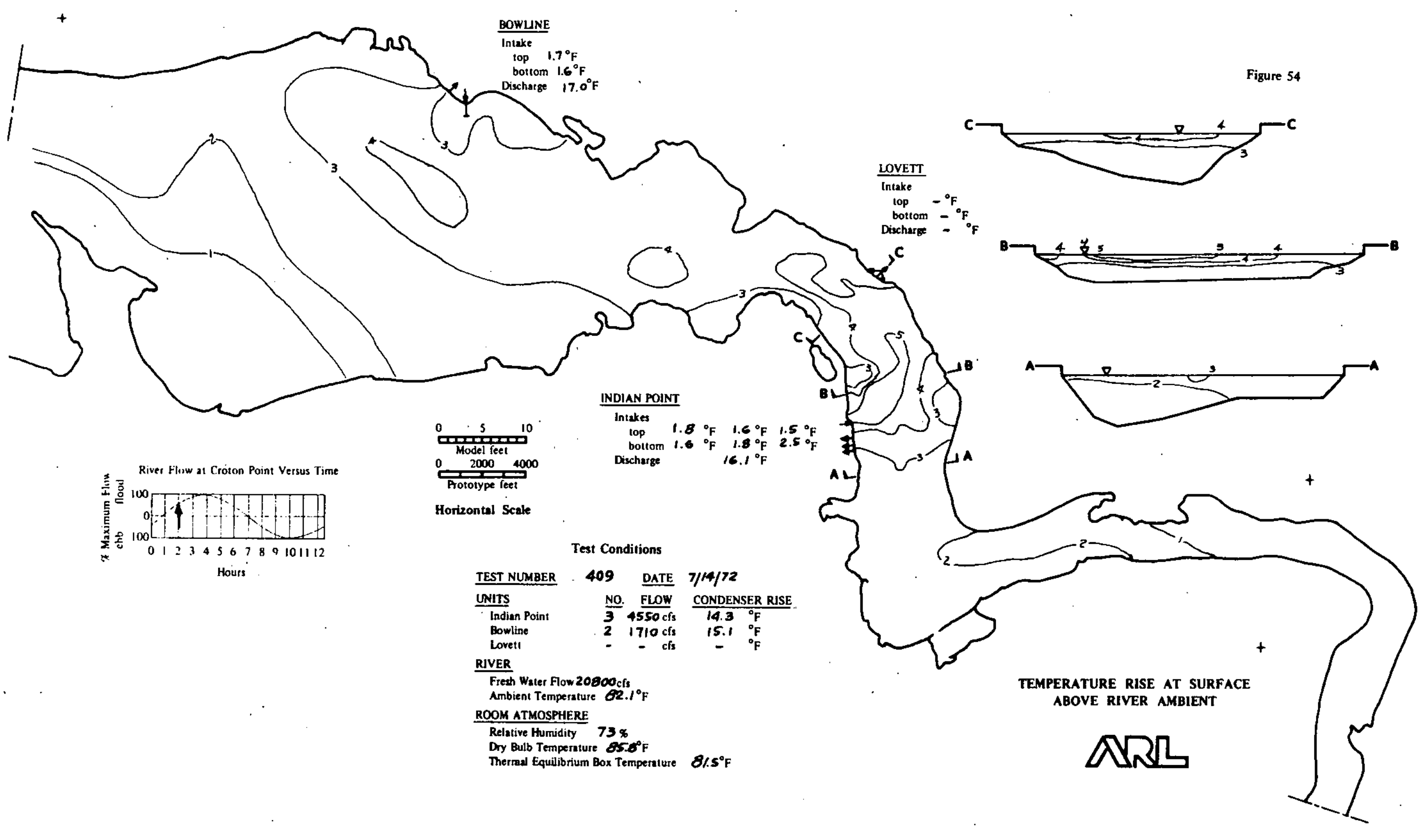


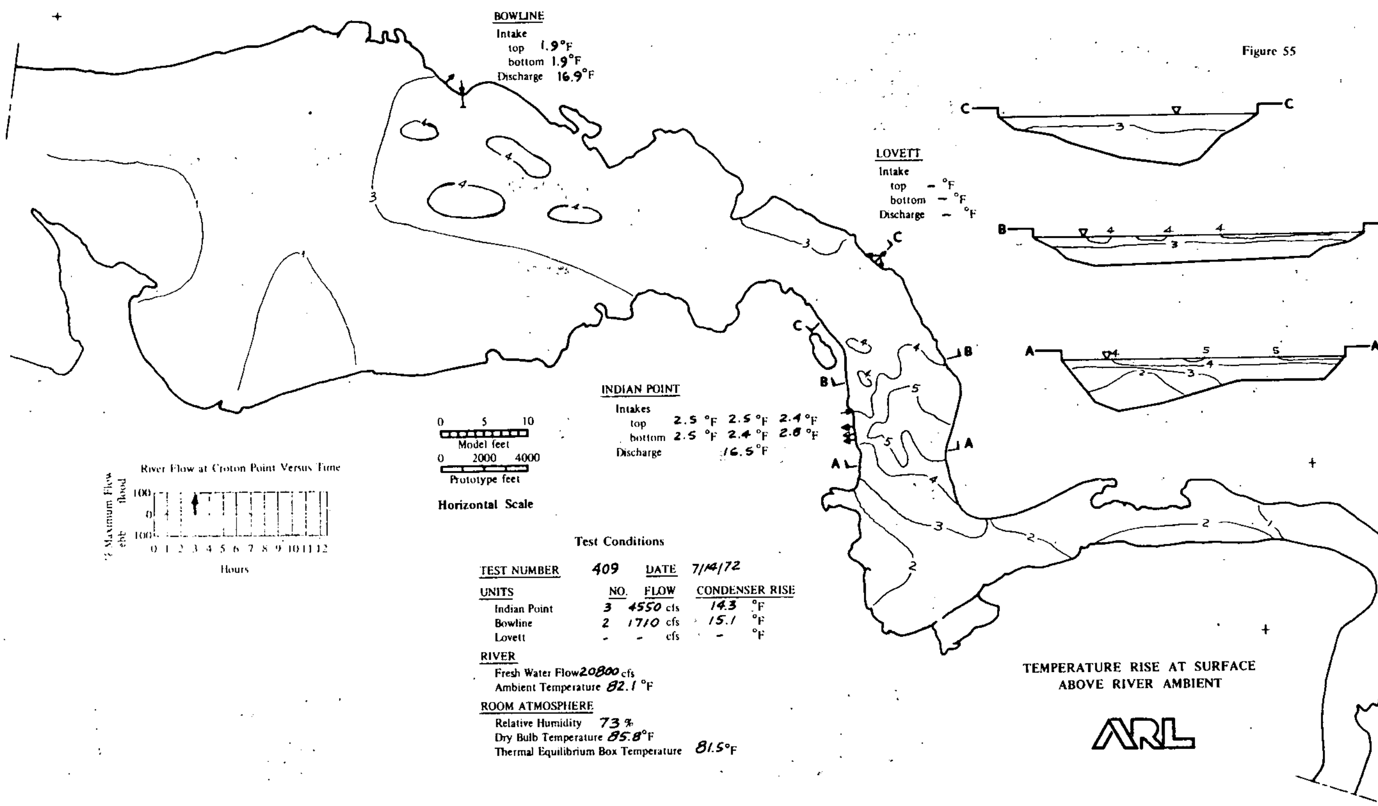


Figure 55
BOWLINE
Intake
top 1.9°F
bottom 1.9°F
Discharge 16.9°F
LOVETT
Intake
top – °F
bottom – °F
Discharge – °F
INDIAN POINT
Intakes
top 2.5 °F 2.5 °F 2.4 °F
bottom 2.5 °F 2.4 °F 2.8 °F
Discharge 16.5°F
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
% Maximum Flow
flood
ebb
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
Test Conditions
TEST NUMBER 409 DATE 7/14/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550 cfs 14.3 °F
Bowline 2 1710 cfs 15.1 °F
Lovett - - cfs - °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 82.1 °F
ROOM ATMOSPHERE
Relative Humidity 73 %
Dry Bulb Temperature 85.8°F
Thermal Equilibrium Box Temperature 81.5°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

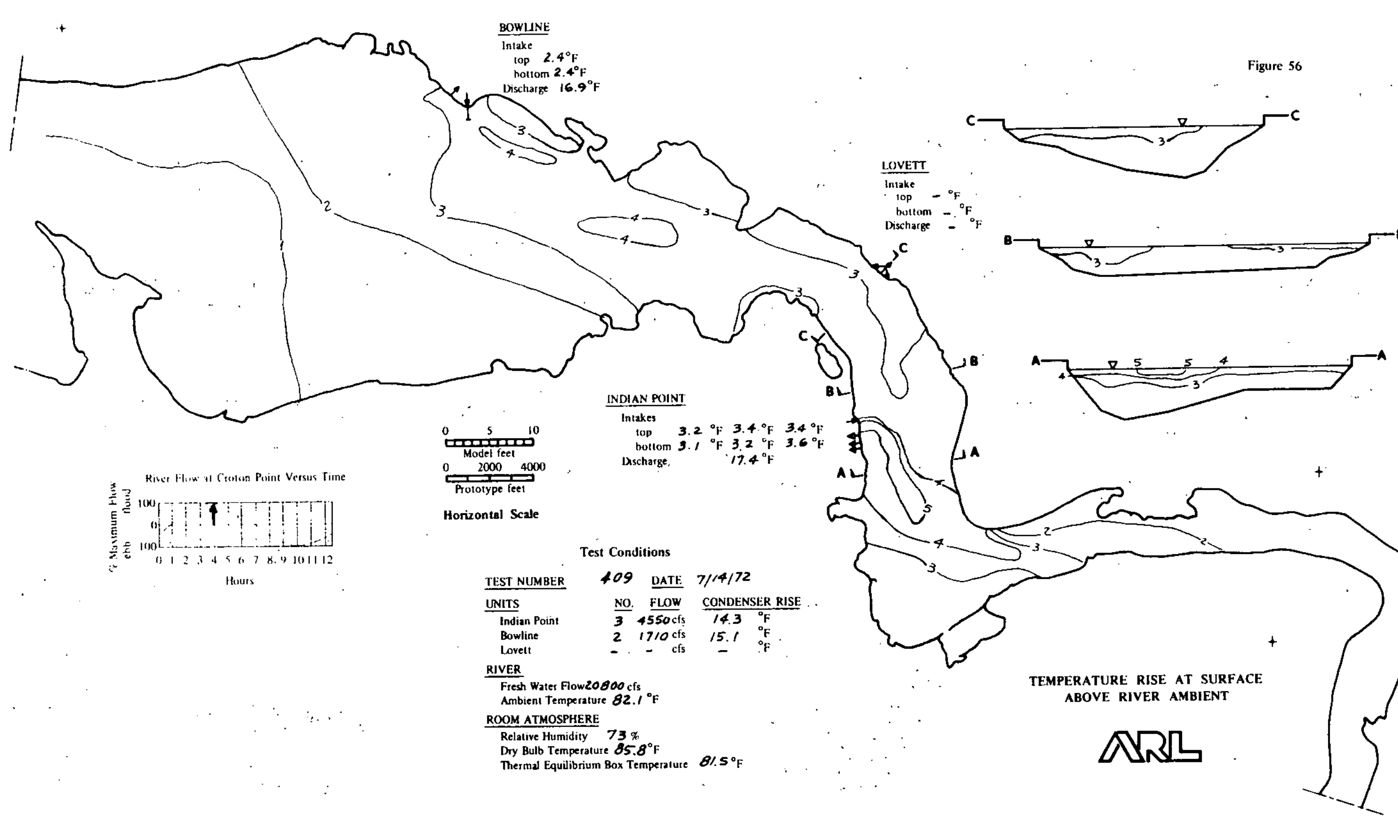
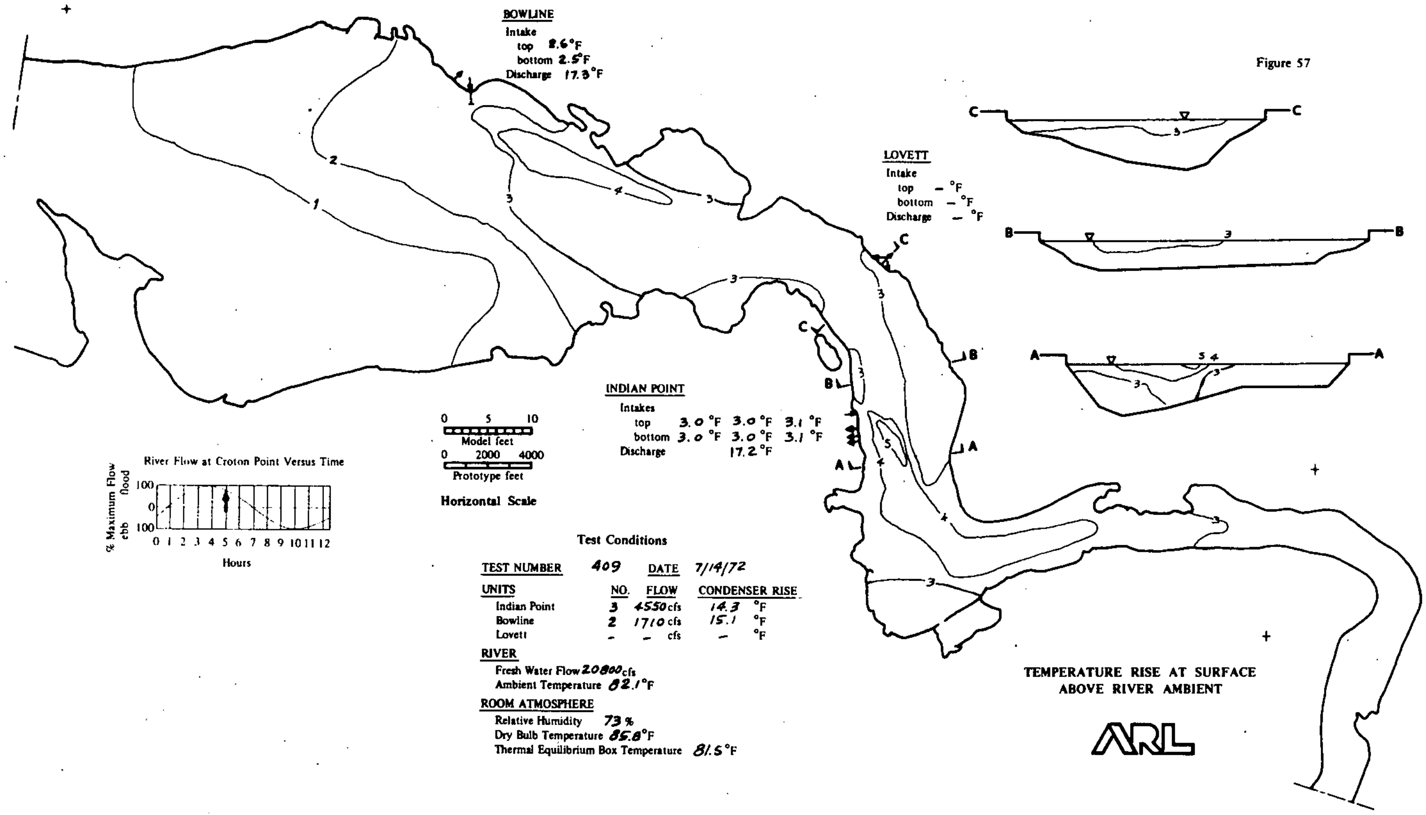


Figure 56
BOWLINE
Intake
top 2.4°F
bottom 2.4°F
Discharge 16.9°F
LOVETT
Intake
top – °F
bottom – °F
Discharge – °F
INDIAN POINT
Intakes
top 3.2 °F 3.4 °F 3.4 °F
bottom 3.1 °F 3.2 °F 3.6 °F
Discharge 17.4°F
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
% Maximum Flow
flood
ebb
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
Test Conditions
TEST NUMBER 409 DATE 7/14/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550 cfs 14.3 °F
Bowline 2 1710 cfs 15.1 °F
Lovett - - cfs – °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 82.1 °F
ROOM ATMOSPHERE
Relative Humidity 73 %
Dry Bulb Temperature 85.8°F
Thermal Equilibrium Box Temperature 81.5°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

Figure 57



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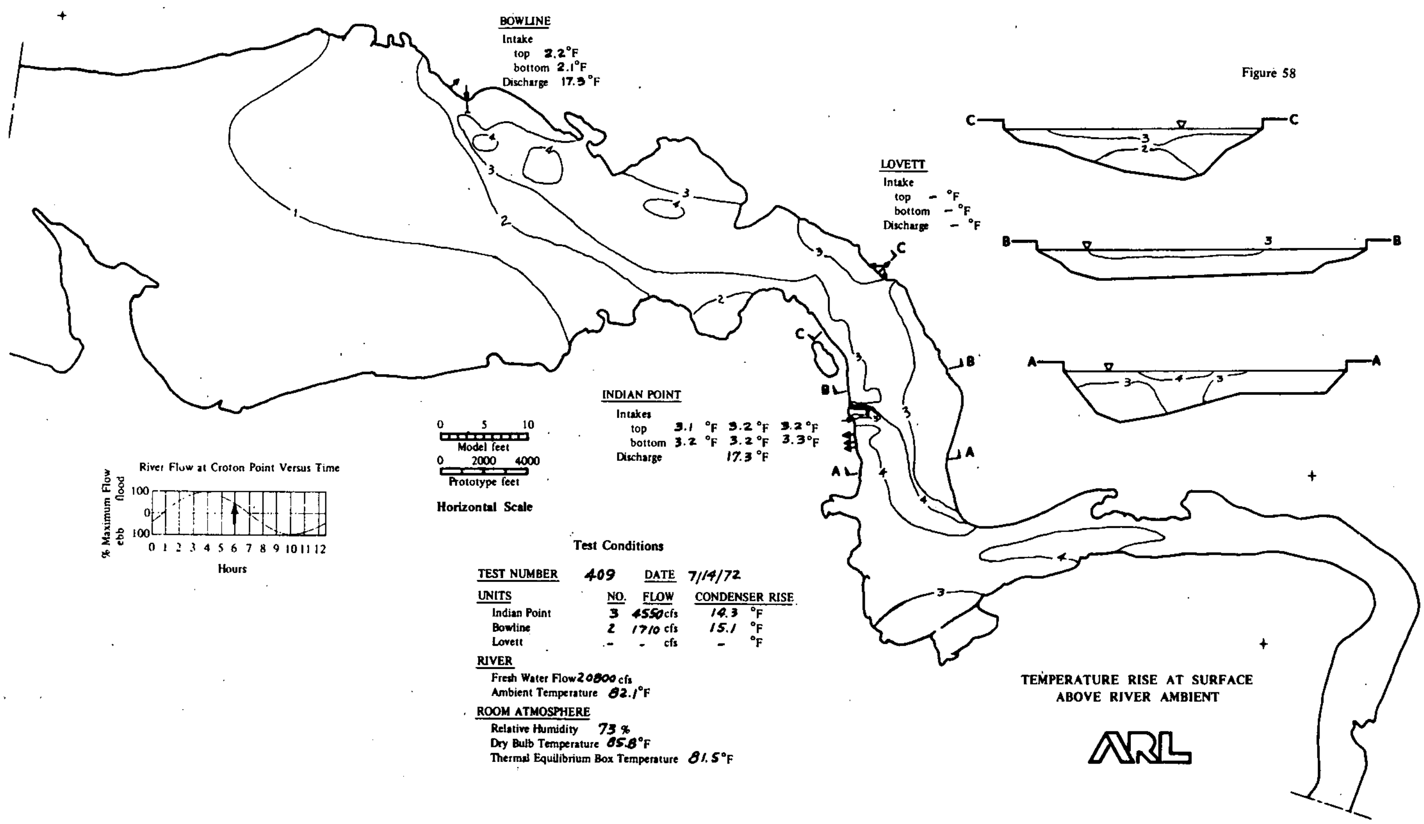

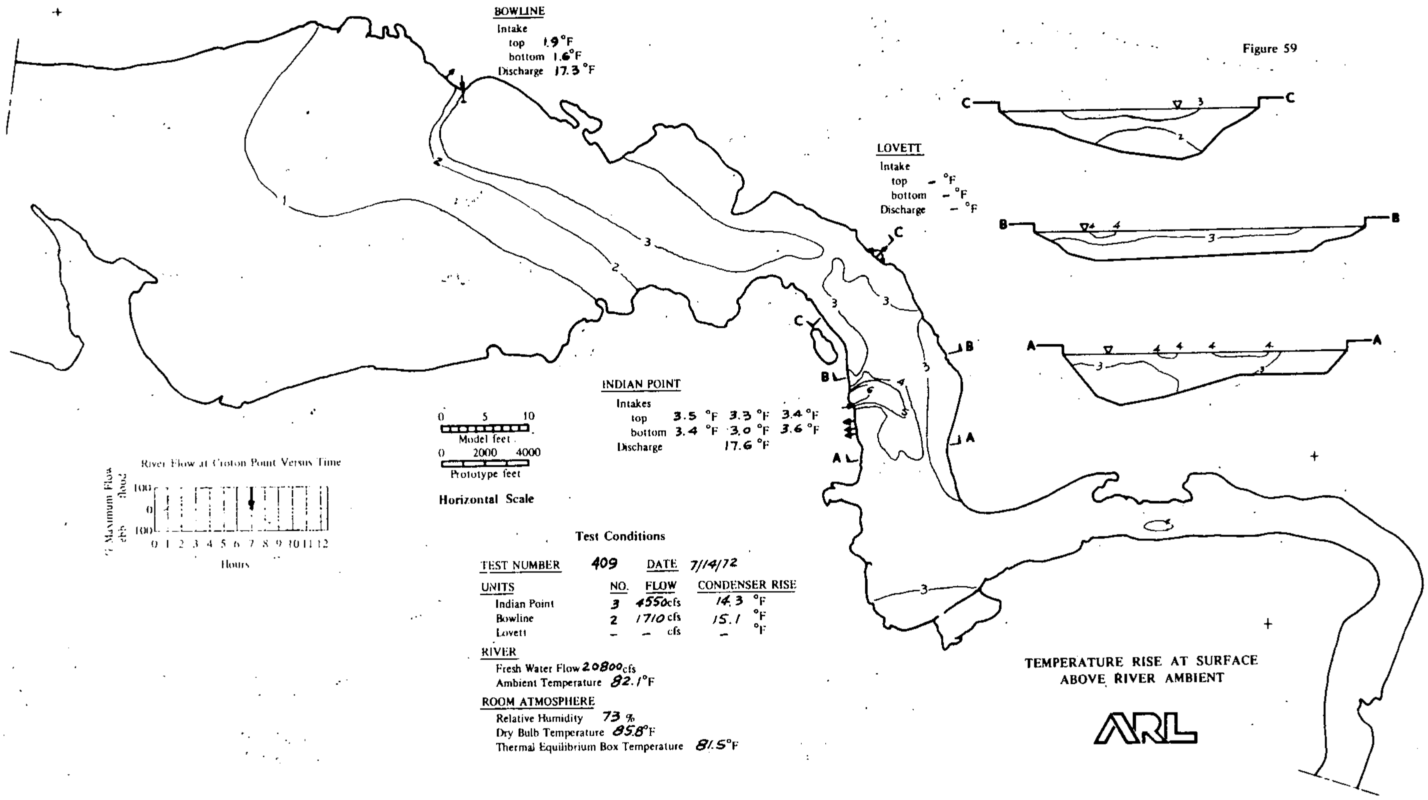
Figure 59
BOWLINE
Intake
top 1.9°F
bottom 1.6°F
Discharge 17.3°F
LOVETT
Intake
top - °F
bottom - °F
Discharge - °F
INDIAN POINT
Intakes
top 3.5 °F 3.3 °F 3.4 °F
bottom 3.4 °F 3.0 °F 3.6 °F
Discharge 17.6 °F
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
% Maximum Flow
ebb flood
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
Test Conditions
TEST NUMBER 409 DATE 7/14/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550cfs 14.3 °F
Bowline 2 1710cfs 15.1 °F
Lovett - - cfs - °F
RIVER
Fresh Water Flow 20800cfs
Ambient Temperature 82.1°F
ROOM ATMOSPHERE
Relative Humidity 73 %
Dry Bulb Temperature 85.8°F
Thermal Equilibrium Box Temperature 81.5°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

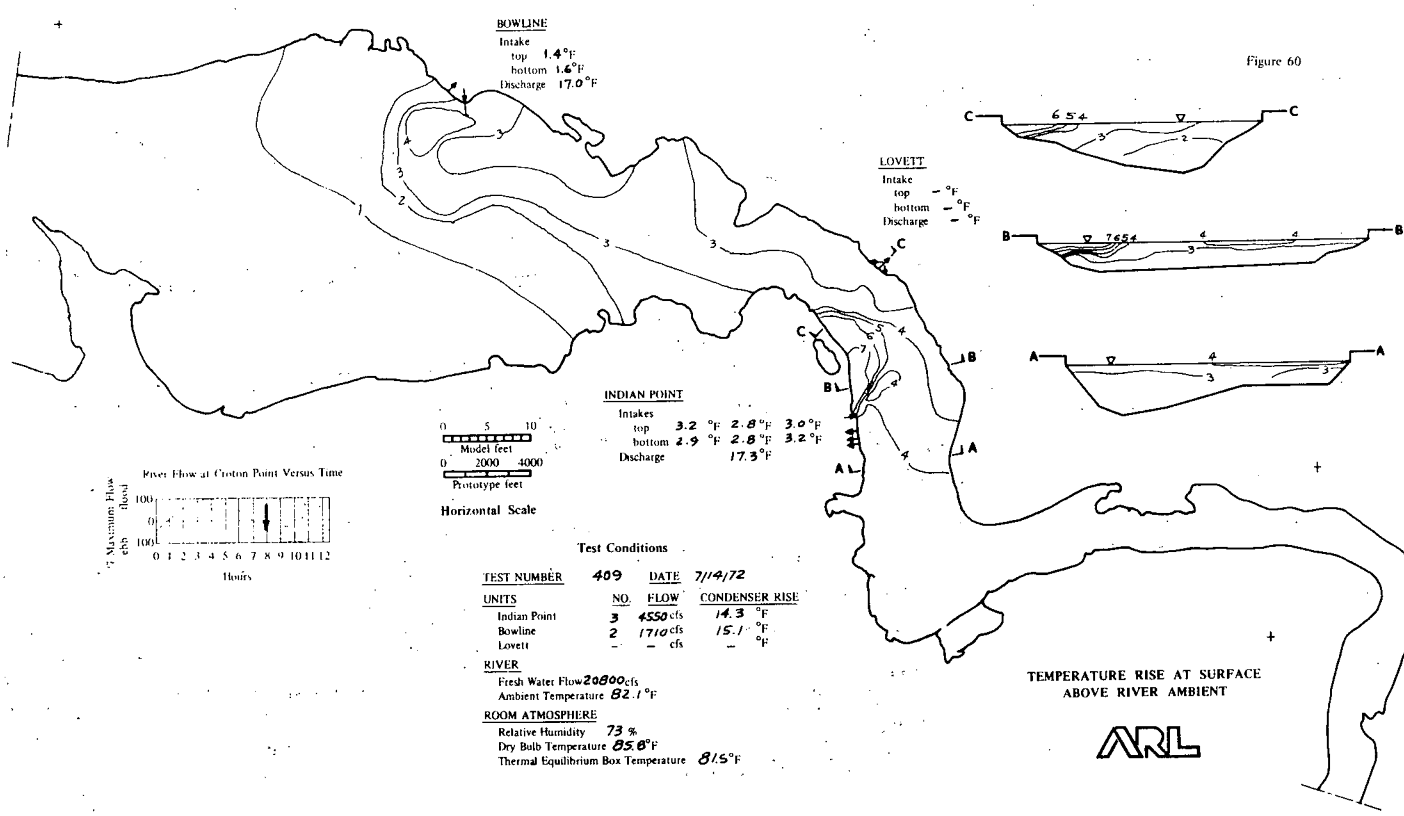
Figure 60
BOWLINE
Intake
top 1.4°F
bottom 1.6°F
Discharge 17.0°F
LOVETT
Intake
top - °F
bottom - °F
Discharge - °F
INDIAN POINT
Intakes
top 3.2 °F 2.8 °F 3.0 °F
bottom 2.9 °F 2.8 °F 3.2 °F
Discharge 17.3°F
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
% Maximum Flow
ebb flood
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
Test Conditions
TEST NUMBER 409 DATE 7/14/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550cfs 14.3 °F
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Lovett - - cfs - °F
RIVER
Fresh Water Flow 20800cfs
Ambient Temperature 82.1°F
ROOM ATMOSPHERE
Relative Humidity 73 %
Dry Bulb Temperature 85.6°F
Thermal Equilibrium Box Temperature 81.5°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

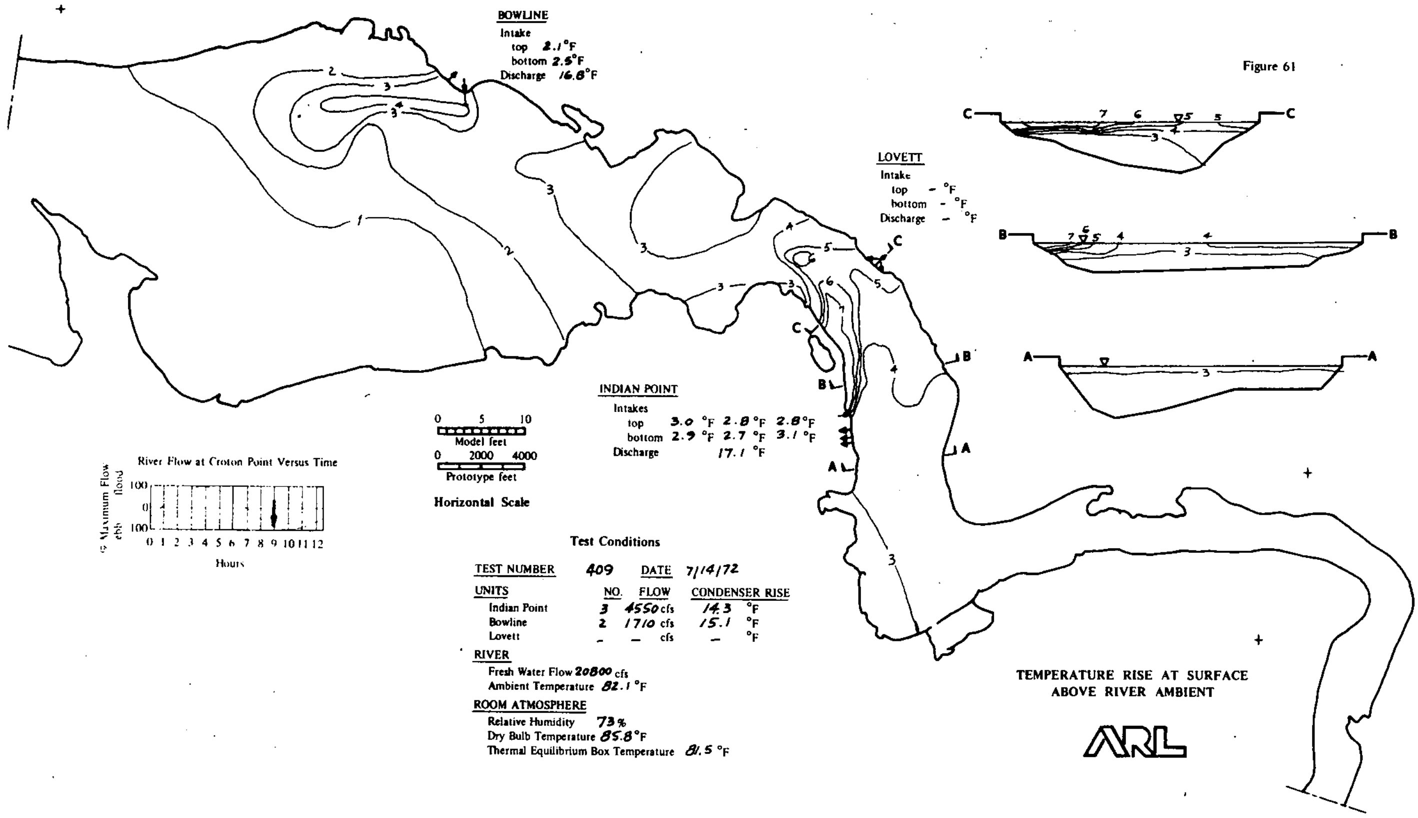


Figure 61

Test Conditions

TEST NUMBER 409 DATE 7/14/72

UNITS	NO.	FLOW	CONDENSER RISE
Indian Point	3	4550 cfs	14.3 °F
Bowline	2	1710 cfs	15.1 °F
Lovett	-	- cfs	- °F

RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 82.1 °F

ROOM ATMOSPHERE
Relative Humidity 73%
Dry Bulb Temperature 85.8°F
Thermal Equilibrium Box Temperature 81.5 °F

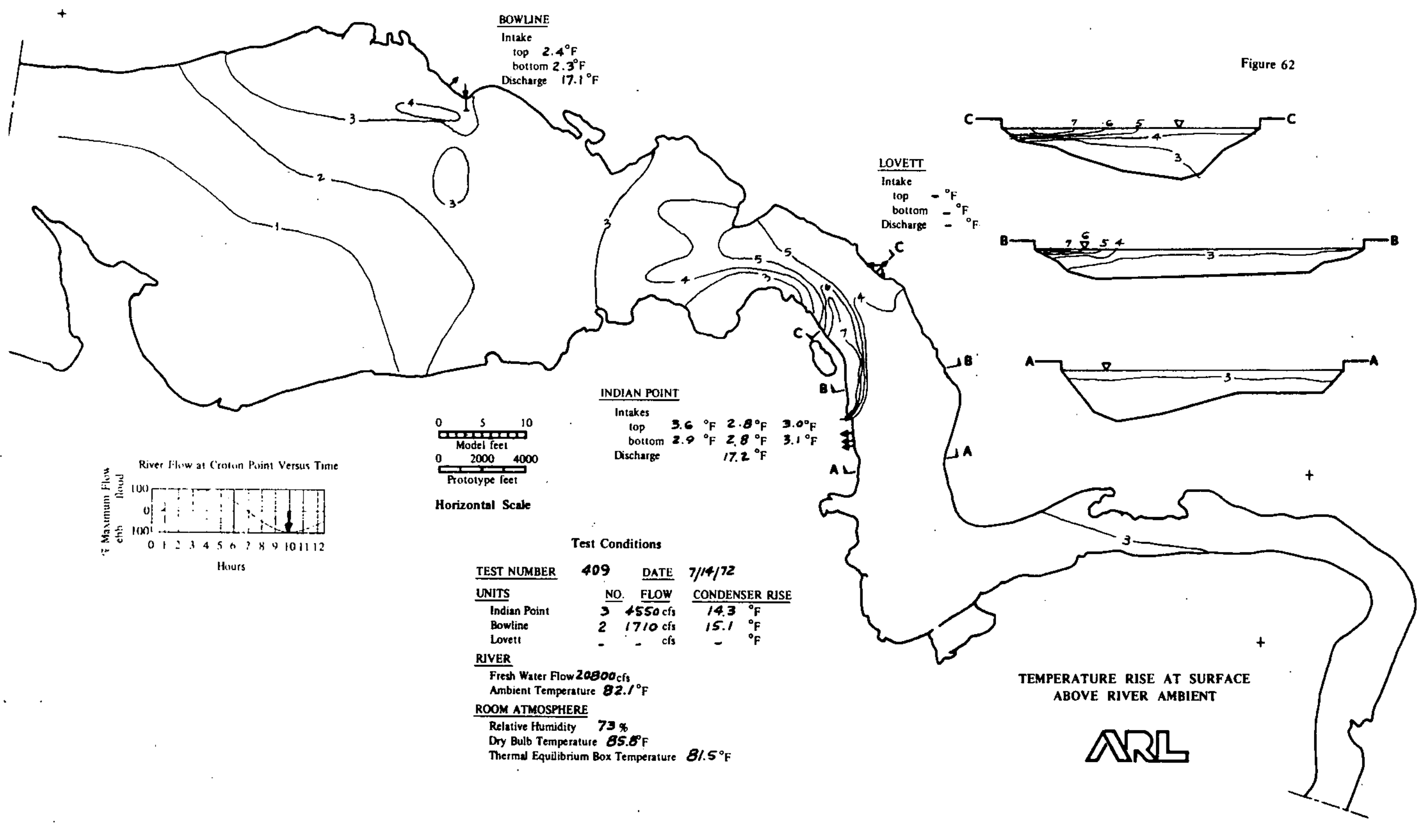


Figure 62

Test Conditions

TEST NUMBER 409 DATE 7/14/72

UNITS	NO.	FLOW	CONDENSER RISE
Indian Point	3	4550 cfs	14.3 °F
Bowline	2	1710 cfs	15.1 °F
Lovett	-	- cfs	- °F

RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 82.1°F

ROOM ATMOSPHERE
Relative Humidity 73%
Dry Bulb Temperature 85.8°F
Thermal Equilibrium Box Temperature 81.5°F

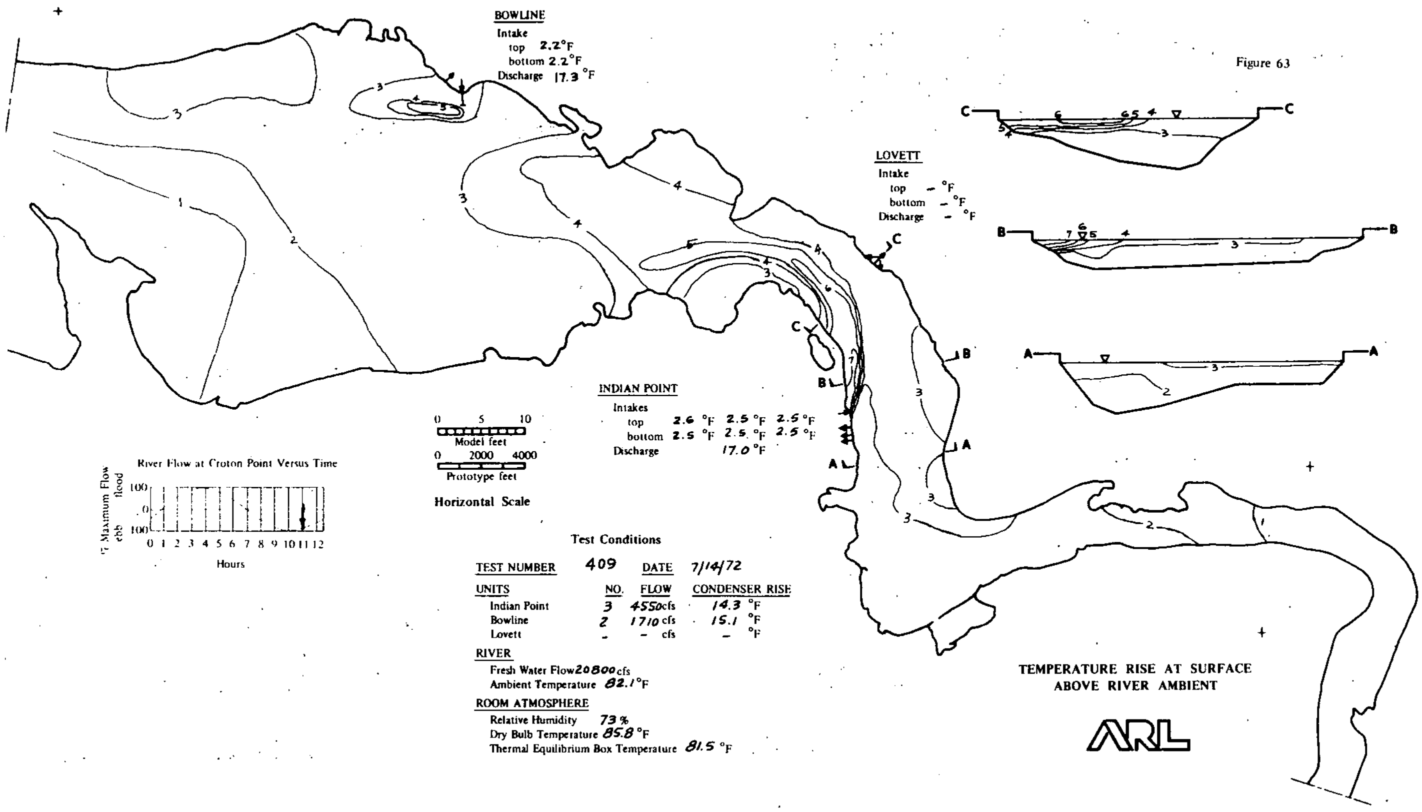


Figure 63

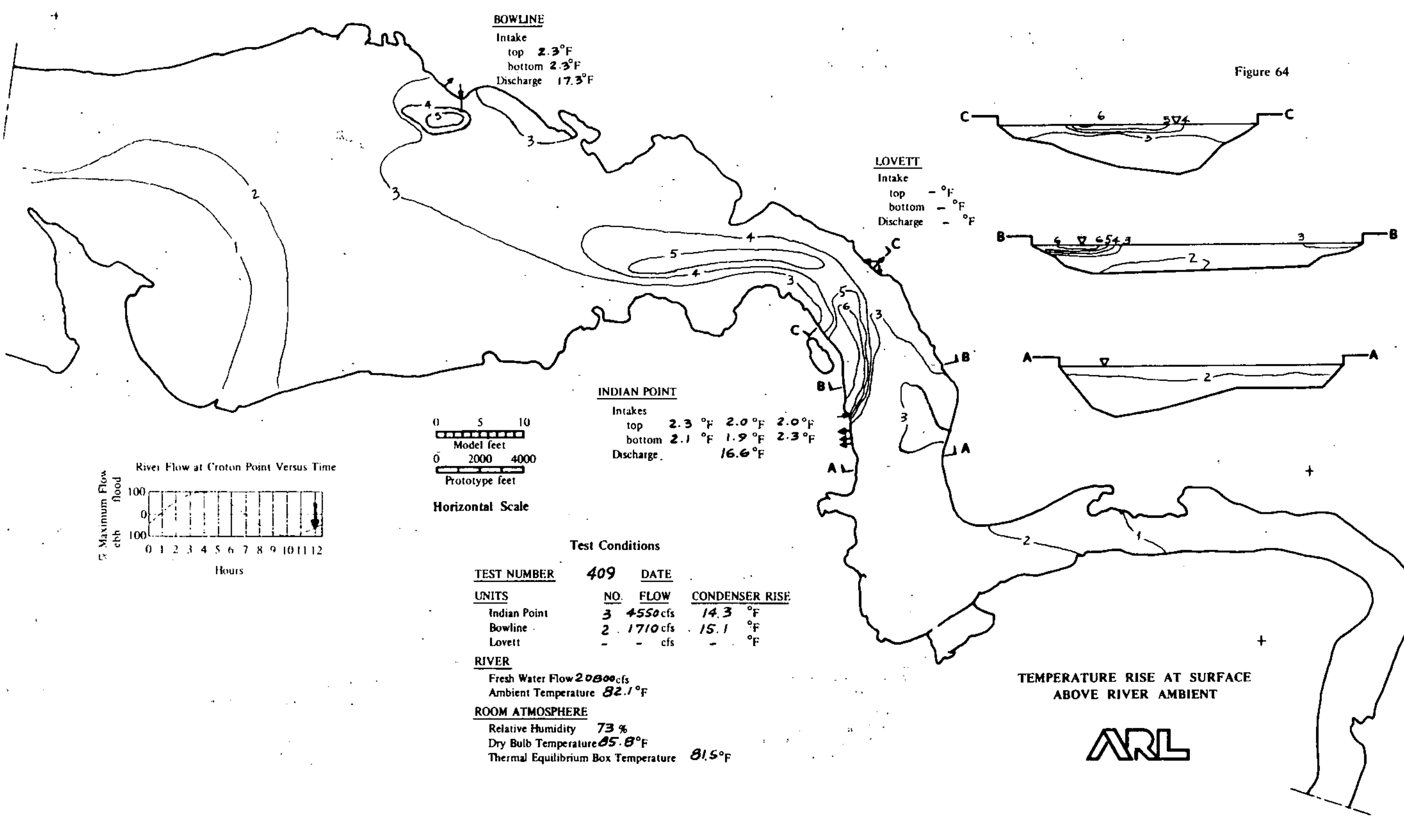
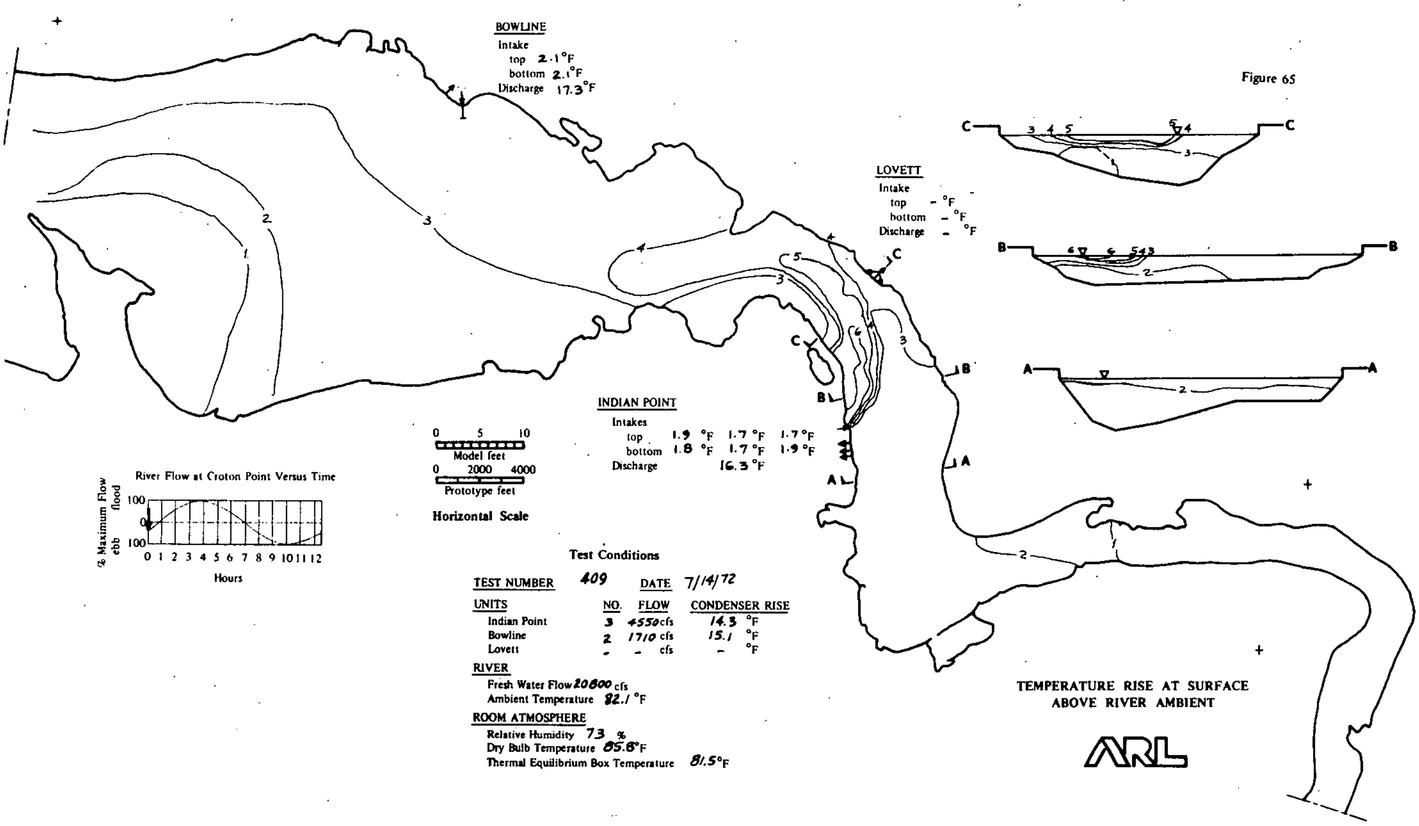


Figure 64

Figure 65


BOWLINE
Intake
top 2.1°F
bottom 2.1°F
Discharge 17.3°F
LOVETT
Intake
top - °F
bottom - °F
Discharge - °F
INDIAN POINT
Intakes
top 1.9 °F 1.7 °F 1.7 °F
bottom 1.8 °F 1.7 °F 1.9 °F
Discharge 16.3 °F
0 5 10
Model feet
0 2000 4000
Prototype feet
Horizontal Scale
River Flow at Croton Point Versus Time
% Maximum Flow
flood
ebb
100
0
100
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours
Test Conditions
TEST NUMBER 409 DATE 7/14/72
UNITS NO. FLOW CONDENSER RISE
Indian Point 3 4550 cfs 14.3 °F
Bowline 2 1710 cfs 15.1 °F
Lovett - - cfs - °F
RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 82.1 °F
ROOM ATMOSPHERE
Relative Humidity 73 %
Dry Bulb Temperature 85.6°F
Thermal Equilibrium Box Temperature 81.5°F
TEMPERATURE RISE AT SURFACE
ABOVE RIVER AMBIENT
ARL

Time-Spacial Average Surface
Temperature Rise
With Lovett Operating

ARL

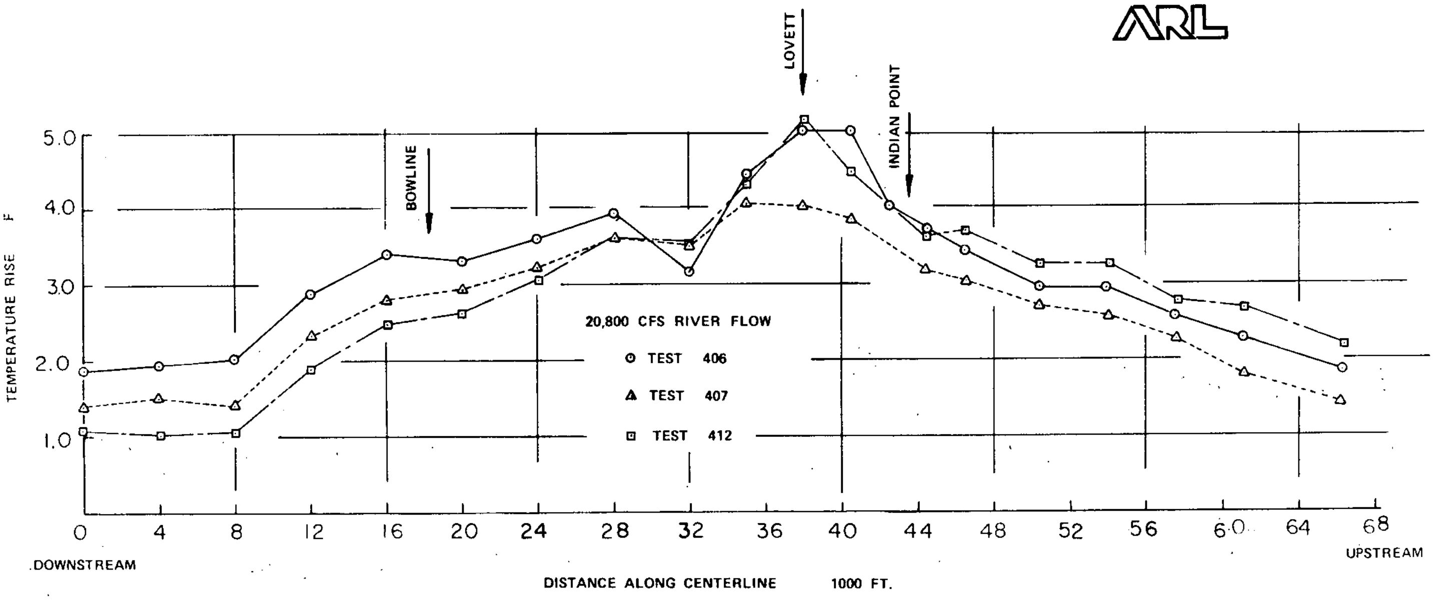
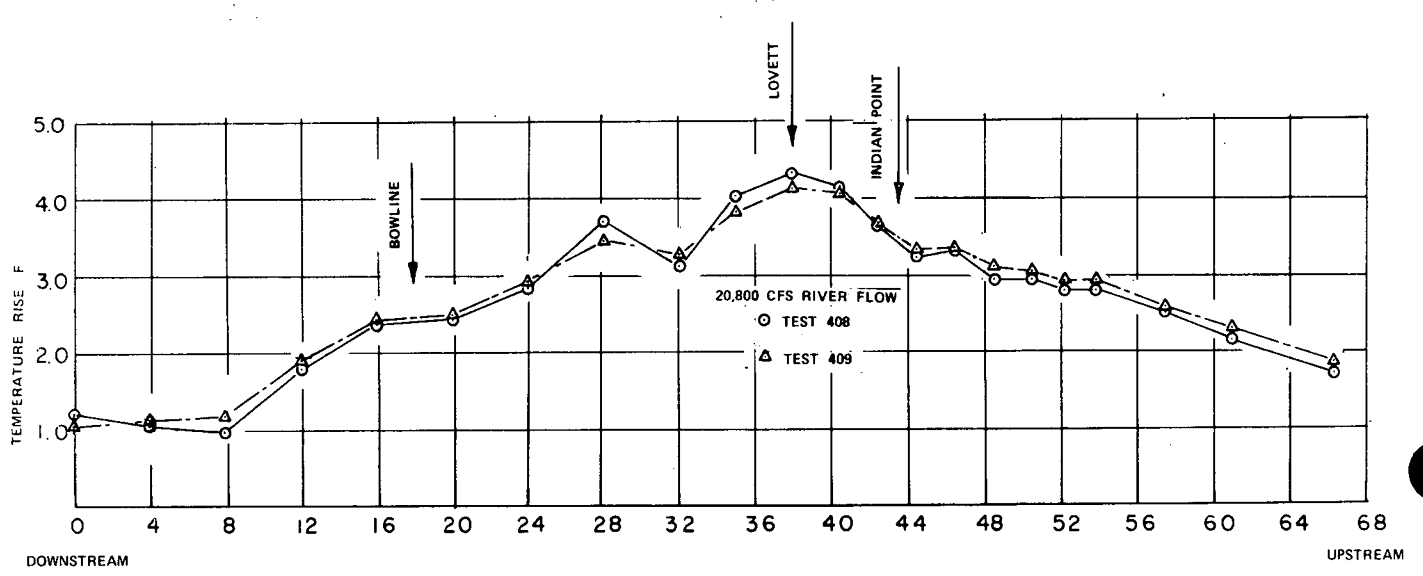


Figure 67

Time-Spacial Average Surface
Temperature Rise
Without Lovett Operating

ARL



Comparison of Time-Spacial
Average Surface Temperature Rise
With and Without Lovett Operating

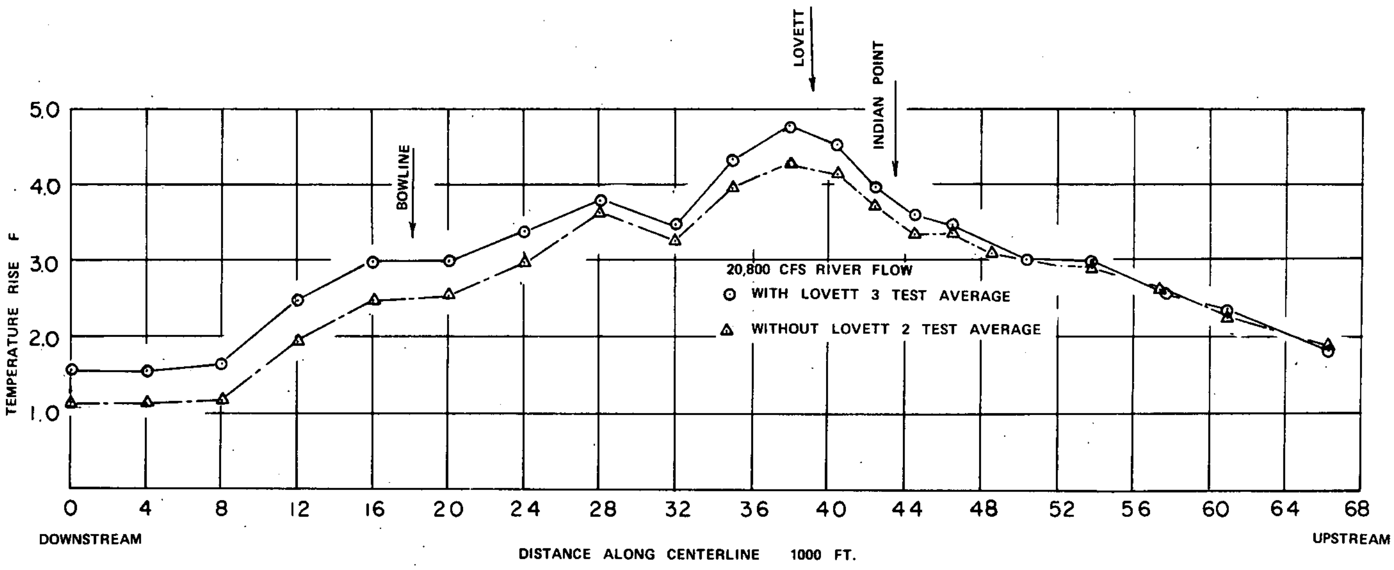
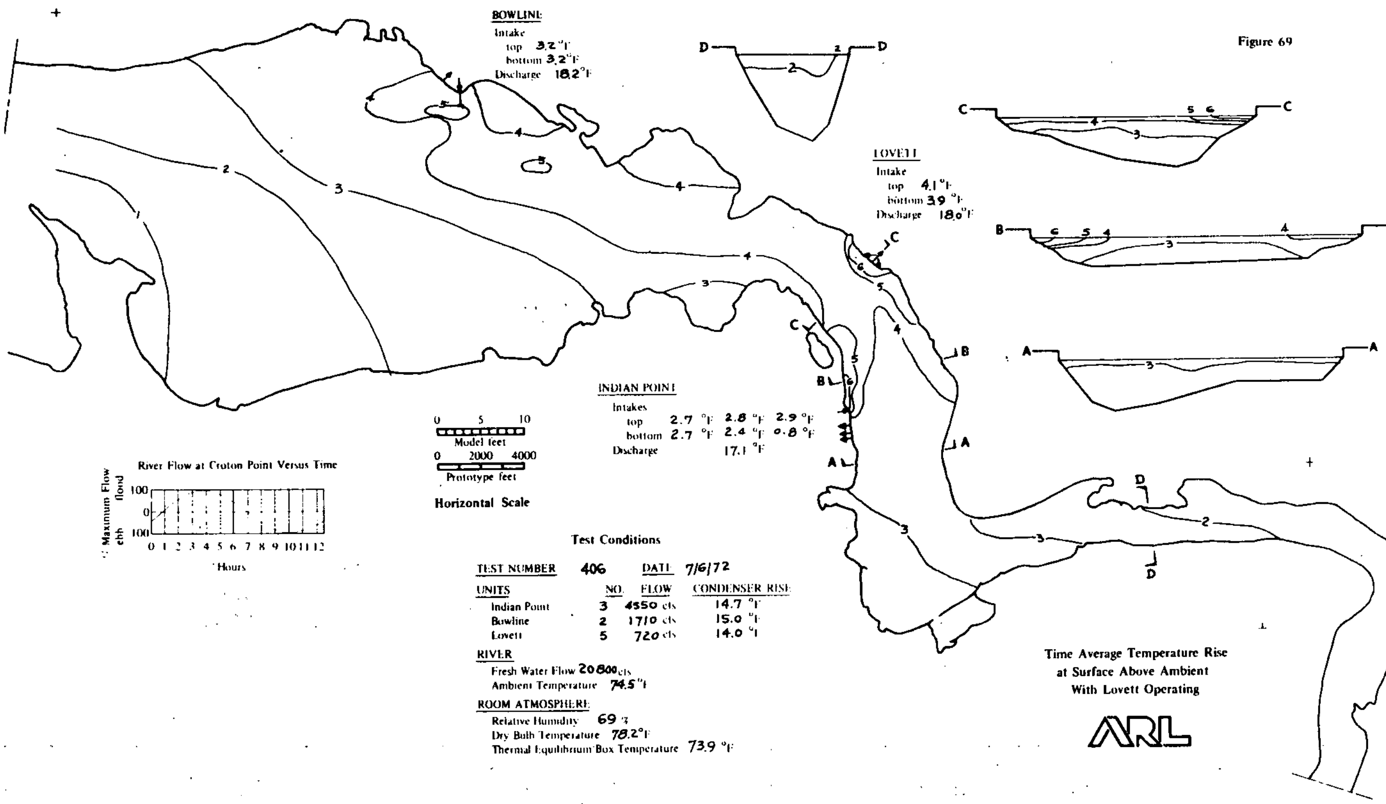


Figure 69



Test Conditions

TEST NUMBER 406 DATE 7/6/72

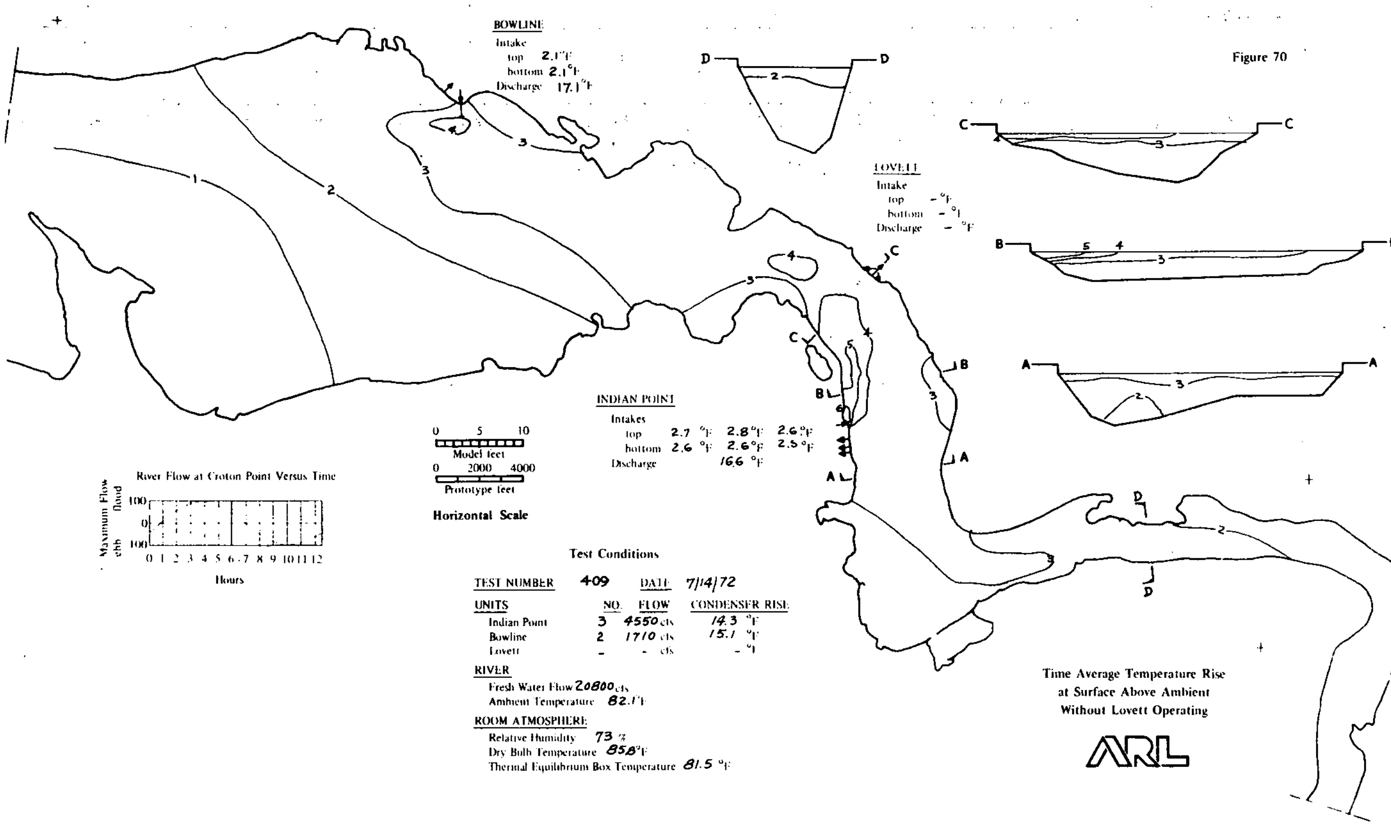
UNITS	NO.	FLOW	CONDENSER RISE
Indian Point	3	4550 cfs	14.7 °F
Bowline	2	1710 cfs	15.0 °F
Lovett	5	720 cfs	14.0 °F

RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 74.5 °F

ROOM ATMOSPHERE
Relative Humidity 69 %
Dry Bulb Temperature 78.2 °F
Thermal Equilibrium Box Temperature 73.9 °F

Time Average Temperature Rise at Surface Above Ambient With Lovett Operating

Figure 70



Test Conditions

TEST NUMBER 409 DATE 7/14/72

UNITS	NO.	FLOW	CONDENSER RISE
Indian Point	3	4550 cfs	14.3 °F
Bowline	2	1710 cfs	15.1 °F
Lovett	-	- cfs	- °F

RIVER
Fresh Water Flow 20800 cfs
Ambient Temperature 82.1 °F

ROOM ATMOSPHERE
Relative Humidity 73 %
Dry Bulb Temperature 85.8 °F
Thermal Equilibrium Box Temperature 81.5 °F

Time Average Temperature Rise at Surface Above Ambient Without Lovett Operating

Quirk, Lawler & Matusky Engineers

Environmental Science & Engineering Consultants

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WILLIAM J. STEIN, P.E.
JOHN P. BADALICH, P.E.

ROBERT A. NORRIS, DIR.
COMPUTER APPLICATIONS

October 30, 1972
File: 115-31

Mr. Herman C. Bremer
Emissions Control Engineer
Consolidated Edison Company of
New York, Inc.
Room 1500
4 Irving Place
New York, New York 10003

Dear Mr. Bremer:

In accordance with your authorization we are submitting our report on the evaluation of the effects of Indian Point Unit 1 through 3 thermal effluents on Hudson River temperature distribution.

The study utilizes several mathematical models previously developed by QL&M. Since comprehensive thermal measurements have not been made at Indian Point, available observations at other Hudson River thermal discharges were used to evaluate some of the system parameters.

The results of the study must be considered as preliminary and, therefore, a detailed thermal monitoring program and additional mathematical modelling effort at Indian Point are needed.

For your convenience, study conclusions are given on pages 23-24.

Very truly yours,

Karim A. Abood
Associate

KAA:wh

Consolidated Edison Company of New York, Inc.

EFFECT OF THREE UNIT OPERATION AT INDIAN POINT ON HUDSON RIVER TEMPERATURE DISTRIBUTION

MEMORANDUM REPORT

QL&M Job. No. 115-31

October 1972

Quirk, Lawler & Matusky Engineers
Environmental Science & Engineering Consultants
415 Route 303, Tappan, New York 10983

TABLE OF CONTENTS

I. INTRODUCTION

The purpose of this memorandum report is to present the results and methodologies of QL&M's recent analyses of the effects of the Indian Point Generating Station on Hudson River water temperature distribution. Combined operation of Indian Point units 1 through 3, Lovett units 1 through 5 and Bowline units 1 & 2 were considered. Table 1 summarizes electrical outputs and heat loads as well as other basic parameters of all power plants included in the study.

Analyses were made for two different combinations of hydrological and meteorological conditions:

Case (1): Incipient salt flow condition (20,800 cfs) with a low heat transfer coefficient of 90 BTU/sf/day/°F

Case (2): Critical low freshwater flow (4,000 cfs) with a summer heat transfer rate (140 BTU/sf/day/°F)

Case 1 represents the most severe set of hydrological and meteorological conditions that can occur at Indian Point. A recent investigation of Hudson River density induced circulation undertaken by QL&M (3) indicated that absolute minimum river flow available for dilution at Indian Point is the freshwater flow quantity of 20,800 cfs. Furthermore, an inspection of Hudson River long term monthly average freshwater flow records indicates that the 20,800 cfs freshwater flow may occur during May when the prevailing meteorological conditions result in a low value for the heat transfer coefficient.

TABLE 1

PARAMETERS OF POWER PLANTS IN THE STUDY AREA

	Indian Point (3) 1	2	3	3 Units	5 Units Lovett	2 Units Bowline
I. Power Plants Operating Conditions						
1. Rated Capacity, MWe	265	873	965	2103	5035	1200
2. Heat Load, BBtu/hr *	1.915	6.350	6.950	15.215	2.38	5.17
3. Condenser Water Flow, 1,000 gpm	280	840	840	1960	323	768
4. Service Water Flow, 1,000 gpm	38	30	30	98	--	--
5. Total Circulating Water Flow, 1,000 gpm	318	870	870	2058	323	768
6. Cooling Water Temperature Rise, °F (through condenser)	12.0	14.6	16.0	14.8	14.8	13.8

*Billion BTU/Hr.

The fresh water flow of 20,800 cfs develops conditions in the river under which the salt intrusion just reaches Indian Point and the flow pattern becomes a one layer system*.

Case 2 represents a set of summer conditions characterized by low fresh water inflow into the Hudson River estuary with well developed density induced circulation and a corresponding system of two layer flow at Indian Point.* These summer climatological conditions result in a high rate of heat exchange between the water surface and the atmosphere which is expressed on a high value for the heat transfer coefficient.

This set of conditions results in less severe effects of the power plant on Hudson River temperature distributions, however, it may result in more significant impact on the river biology.

The presented analysis of the predicted combined thermal effects of the three power plants (Indian Point 1,2 & 3, Lovett and Bowline) utilizes five previously developed mathematical models: (1) four-segment model, (2) constant parameter - heat dissipation model, (3) two-layer system model, (4) submerged discharge model and (5) exponential decay model.

The use of these models to predict Hudson River temperature distribution at Indian Point are based upon a number of assumptions derived from available observations of thermal discharges located on the Hudson River and from hydraulic model studies. However, lack of significant heat quantities in existing Hudson River discharges and lack of comprehensive river hydrodynamic measurements make the selection of certain system parameters difficult.

*A detailed description of two layer and one layer flow systems in partially stratified estuaries, similar to the Hudson River, is given in References 3,8,10 & 11.

The Hudson River temperature distributions presented in this study as a prediction of combined effects of Indian Point units 1 through 3 and Lovett and Bowline power plants are therefore based on presently available data. Use of more refined models now under development by QL&M may be expected to measure more precisely these thermal effects.

II. DESCRIPTION OF PROCEDURE USED

The mathematical models, described in Chapter I, were used to predict Hudson River temperature distributions resulting from combined operation of the Indian Point, Lovett and Bowline power plants.

The predictions for the set of conditions listed under Case 1 (20,800 cfs and 90 BTU/sf/day/°F) were made using the two available models which were best applicable to a one layer system flow. These were the "four-segment model"* and "constant parameter - heat dissipation model" (1,9). The latter was used primarily to demonstrate that somewhat less severe thermal effects than those predicted by the four-segment model were a possibility.

The set of hydrological and meteorological conditions listed under Case 2 (4,000 cfs, 140 BTU/sf/day/°F) which results in a well developed density induced circulation at Indian Point necessitated the use of the "two-layer system model" (2,7).

The submerged discharge model (3,8,10) was employed to describe temperature patterns in the immediate vicinity of the Indian Point discharge. A determination of the maximum surface temperature rises (ΔTsm) were of the most interest to this region. The exponential decay model (1) predicted temperature distributions over the river cross-sectional area and surface width. Detailed descriptions of all models appear in References 1,2,3,7,8,9 & 10.

Predictions were made for both tidal average (TA) and critical tidal phase (CTP) conditions. The general procedure was the same for all cases and can be itemized as follows:

*A brief description of the four-segment model is presented in Appendix I.

Step 1: Using one of the three heat dissipation models (four-segment, constant parameter or two-layer system) calculate the area-average temperature rises ($\Delta\overline{T}$) at selected cross-sections along the river corresponding to the tidal average conditions.

Step 2: Multiply these temperatures by approximately extracted values of the stratification factors (TSF or F) to obtain corresponding values of surface-average temperature rises.

Step 3: Calculate the maximum surface temperature rise at the plane of discharge using the submerged discharge model. By applying empirically determined characteristics of the longitudinal decay of the maximum surface and sub-surface temperature rises, determine their values at the selected river cross-sections.

Step 4: Using the above results and the exponential decay model, determine the portions of river surface widths and cross-sectional areas corresponding to temperature rises in excess of 1°F, 2°F, 4°F, 6°F, 8°F, etc., at all selected sections and for tidal average conditions.

Step 5: Multiply the values obtained from Step 4 by the empirically derived ratios of the critical tidal phase to tidal average (CTP/TA) to obtain corresponding values for the critical tidal phase.

Step 6: Plot the surface isotherms by connecting the appropriate temperatures at each of the river sections.

Step 7: Plot graphs indicating cross-sectional temperature distributions at selected river sections.

The general procedure described above was slightly modified in those cases for which detailed descriptions follow. The system parameters used for the two different sets of hydrological and meteorological conditions are summarized in Table 2. Justification for selecting the tabulated values of the parameters appears in References 2,5,6,7 & 9.

Items A and B below describe the procedures used to predict thermal effects of the Indian Point station on Hudson River temperature distributions for the set of hydrological and climatological conditions listed under Case 1. Item A describes the use of the four-segment model and Item B illustrates the use of the constant-parameter model. The results from both methods are summarized and compared at the end of the latter item.

Item C presents procedures for the use of the two-layer system model to predict the Indian Point thermal effects for the conditions described in the introduction under Case 2.

A. Case 1. Predictions by Four-Segment Model

In this case, the tidal average temperature distributions with an incipient salt flow of 20,800 cfs at Indian Point and a heat transfer coefficient of 90 BYU/sf/day/°F were considered. Heat loads from Indian Point, Lovett

TABLE 2

PARAMETERS USED TO DETERMINE TEMPERATURE DISTRIBUTION IN HUDSON RIVER DUE TO THREE UNIT OPERATION AT INDIAN POINT

PARAMETERS	CASE 1*	CASE 2**
TIME PERIOD	November	Summer
MATHEMATICAL MODELS USED	4-segment model & constant parameter model	two-layer system model
FRESHWATER FLOW, Q_f (cfs)	20,800	4,000
NET NON-TIDAL FLOW, Q_n (cfs)	-	35,000
HEAT TRANSFER COEFFICIENT, $\overline{K}$ (BTU/°F/SF/DAY)	90	140
DISPERSION COEFFICIENT, E (sq. miles/day)	6	-
THERMAL STRATIFICATION COEFFICIENT, TSF ***	1.5	2.0 (F_o = 1.0)

*Case 1 - Freshwater flow of 20,800 cfs, heat transfer coefficent of 90 BTU/SF/DAY/°F

**Case 2 - Freshwater flow of 4000 cfs, heat transfer coefficient of 140 BTU/SF/DAY/°F

***F_o = upper layer thermal stratification factor (see Reference 2) and Bowline discharges were input into the four-segment model to compute the area average ($\Delta\overline{T}$) and surface-average ($\Delta\overline{T}s$) temperature rises for tidal average conditions along the longitudinal axis of the river. Table 3 summarizes the area-average temperature rises at four Hudson River cross-sections.

Next, sections at mile points*(MP) 41,42,43 and 45 above the Battery were selected. Heat loads from Indian Point and Lovett are introduced at MP 43 and 42, respectively. At MP 43, the maximum surface temperature rise (ΔTsm) was computed by use of the submerged discharge model. Since it has been established empirically that the temperature decay at a given point in the river is most closely simulated both at the surface by the exponential decay model, and over the cross-sections, the distances and cross-sectional areas of each temperature rise isotherm from the shore can be determined (Reference 1).

At MP 42, the temperature rise was affected by both the Indian Point and Lovett discharges. Since the temperature rise caused by Indian Point may affect the full width of the river, it will further increase the temperature rise caused by the Lovett discharge near the west shore.

Figure 1 demonstrates the method of imposing the temperature rise from the east shore on the temperature rise behavior near the west shore. The lower shaded area in Figure 1 represents the area over which temperature rises overlap. Based on the assumption that total surface average temperature rise from the two sources does not change, a new temperature rise curve for the Lovett discharge was plotted, the upper shaded area being equal to the lower shaded area.

*River channel miles above the Hudson River mouth at the Battery.

TABLE 3

TIDAL AVERAGE AND AREA-AVERAGE TEMPERATURE RISES AT VARIOUS MILEPOINTS AFFECTED BY PLANT DISCHARGES*
(Four-Segment Model Predictions)

TEMP. RISE AFFECTED BY:	MP 41	MP 42 Lovett (Discharge)	MP 43 I.P. (Discharge)	MP 45
	(Temperature rise in °F)			
Indian Point Units 1 - 3	2.78	2.84	2.91	1.42
Lovett Units 1 - 5	0.39	0.41	0.28	0.13
Bowline Units * 1 - 2	0.30	0.21	0.15	0.07
TOTAL EFFECT:	3.47	3.46	3.32	1.62

Note: Multiply the above values by a factor of 1.5 to obtain surface average temperature rise.

*conservative estimates using the Four-Segment Model.

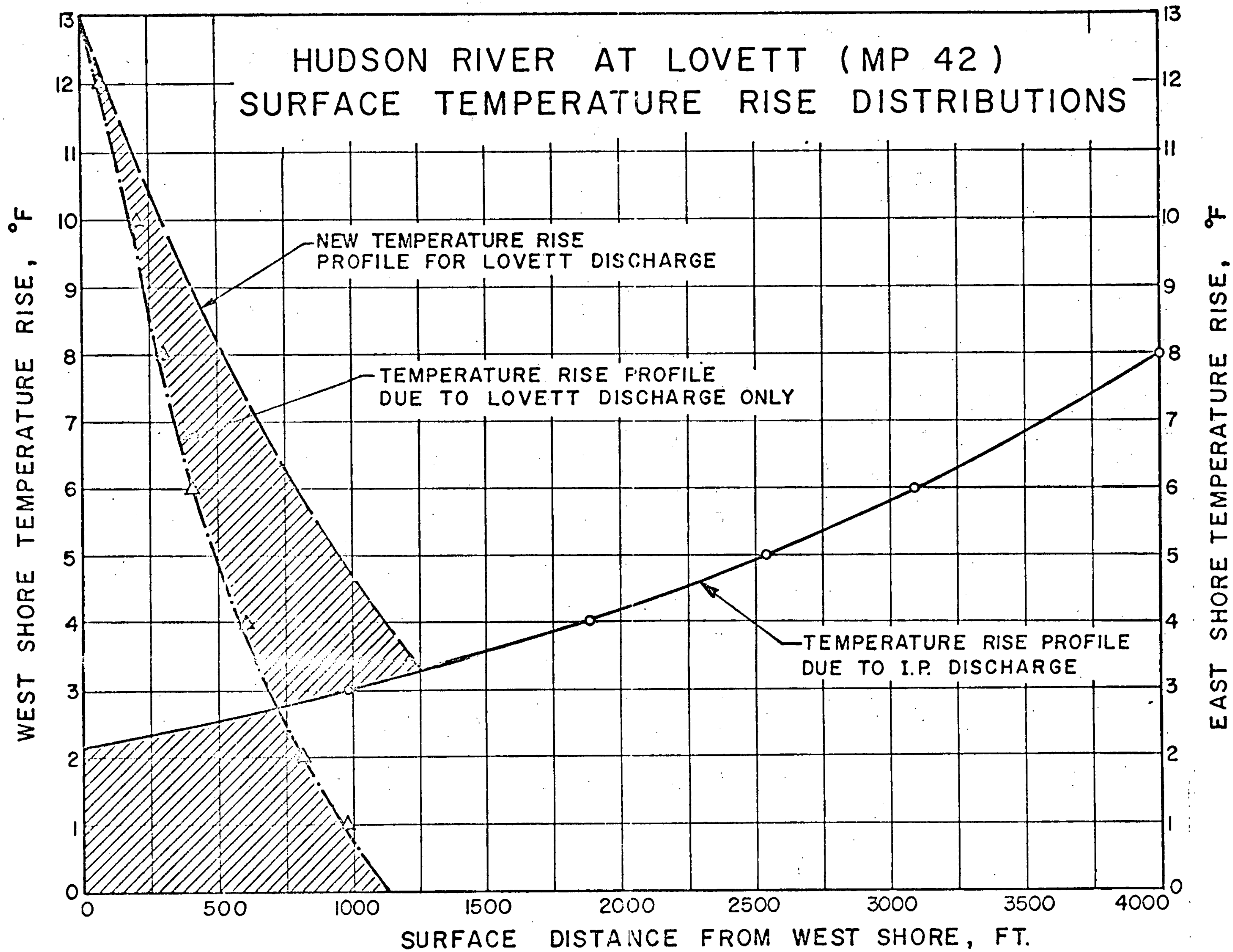
HUDSON RIVER AT LOVETT (MP 42)
SURFACE TEMPERATURE RISE DISTRIBUTIONS
NEW TEMPERATURE RISE PROFILE FOR LOVETT DISCHARGE
TEMPERATURE RISE PROFILE DUE TO LOVETT DISCHARGE ONLY
TEMPERATURE RISE PROFILE DUE TO I.P. DISCHARGE
WEST SHORE TEMPERATURE RISE, °F
EAST SHORE TEMPERATURE RISE, °F
SURFACE DISTANCE FROM WEST SHORE, FT.
0
500
1000
1500
2000
2500
3000
3500
4000
0
1
2
3
4
5
6
7
8
9
10
11
12
13

FIGURE 1.

Once the surface distances of each temperature rise are determined as above, the cross-sectional temperature rise distributions can be determined from the exponential decay model. The same procedure was adopted for construction of temperature distributions at MP, 41.

At MP 45, temperature rises effected by Lovett and Bowline discharges are small as compared with that of the Indian Point discharge. Furthermore, by the time the heated discharge reaches MP 45, there has been sufficient mixing to combine the effects from the three discharges into one.

Finally, the surface isotherms were constructed by connecting each temperature rise at the four sections by smooth lines. The tidal average isothermal map for Case 1 is presented in the attached Exhibit on Figure E1. The corresponding cross-sectional temperature distributions at MP 41, 42, 43 and 45 are depicted on Figures E2 through E5.

Temperature distributions resulting from the combined operation of the three power plants during the critical tidal phase were also evaluated. In order to determine the longitudinal extent of temperature isotherms, field measurements at the Lovett plant and Danskammer power plant at MP 66 were utilized. The ratios of the longitudinal extent of 4°F temperature rise at the critical tidal phase (CTP) to that of tidal average condition (TA) for Lovett and Danskammer were reported by QLM in References 4 and 5. Averages of the two ratios (0.654) were used to determine those points at which the 4°F isotherm ends.

The CTP/TA ratios of the lateral extent of each temperature rise were also established at the plane of discharge for Lovett and Danskammer. The averages of these ratios (1.3 and 1.16 for the 4°F and 6°F isotherms respectively) were used to compute the lateral extent of the temperature rises at the Indian Point discharge.

The surface temperature rises due to the Lovett discharge were plotted using field measurements reported by QLM in Reference and were then adjusted by the same procedures shown in Figure 1 for tidal average conditions.

Once the surface isotherms at the four sections are established, the surface-average temperature rises corresponding to CTP can be computed. Assuming that the TSF remains at 1.5 for CTP, the area-average temperature rise can also be estimated at the four cross-sections. Using the exponential decay model, the cross-sectional temperature distributions were then constructed at the four river sections (MP 41,42,43 & 45).

The surface isothermal map as well as cross-sectional temperature distributions corresponding to the critical tidal phase conditions are shown on Figures E6 through E10 in the Exhibit.

B. Case 1 Predictions by Constant Parameter Heat Dissipation Model

The following paragraphs present a description of an attempt to obtain a more liberal prediction of the Indian Point plant thermal effects for severe non-summer conditions (Case 1) than those obtained in the previous procedure.

The constant parameter, convection-dispersion model, was previously described in Reference 1. This model includes longitudinal decay and plane of discharge factors. The factors were introduced, and their values derived in 1969 in the process of coordinating area-average temperature rises observed in 1966 and 1967 as a result of Indian Point Unit 1 operation. The introduction of the adjustment factors accounts for uncertainties in the determination of the heat transfer coefficient (K), dispersion coefficient (E) and density induced circulation as well as for differences resulting from an assumption of an infinite, constant parameter receiver.

This model yields a much faster area-average temperature decay in the longitudinal direction that the four-segment model. Once the area-average temperature rises ($\Delta\overline{T}$) along the longitudinal axis of the river were determined from the model, the surface-average temperature rises ($\Delta\overline{T}s$) were computed using a thermal stratification factor of 1.5. Next, hydraulic model measurements were employed to determine the maximum surface temperature rises (ΔTsm) along the longitudinal axis of the river. The surface widths of each of the isotherms were then computed using the exponential decay model and the local $\Delta\overline{T}s$ and ΔTsm at MP 43,42,41 & 45. The cross-sectional isotherms were constructed by applying $\Delta\overline{T}$ and ΔTm to the exponential decay model. The method demonstrated in Figure 1 was used at MP 42 & 41 to impose the temperature rise from the east shore on the temperature rise behavior near the west shore, both at the surface and over the cross-sectional area.

The surface isothermal map and cross-sectional temperature distributions for the critical tidal phase conditions were constructed using the tidal average results and the CTP/TA ratios as described in the Item A. Graphical interpretation of results is presented on Figures E11 through E15 in the Exhibit.

Table 4 summarizes and compares results of predictions obtained by using the four-segment and constant parameter models. Results obtained for the critical tidal phase conditions only are compared.

Table 4 indicates that the predicted maximum thermal effects (portion of cross-sectional area and surface width subjected to temperature rises in excess of 4°F and maximum surface temperature rises) at the plane of discharge at Indian Point are the same, no matter which of the two models was used. However, the surface width bounded by the 4°F temperature rise at the Lovett section (MP 42) is predicted by the four segment model to be 90 percent of the total width and only 43 percent by the constant parameter model. This difference is attributable to the greater longitudinal decay of the area-average as well as surface-average temperature rises predicted by the constant parameter model, as mentioned earlier in this chapter.

C. Case 2. Predictions by Two-Layer System Model

The conditions assumed in this case are a critical low freshwater flow of 4000 cfs and summer heat transfer rate of 140 BTU/sf/day/°F. At this low freshwater flow, density-induced circulation is present in the study area and consequently, the two-layer system model was used (Reference 2). The same techniques described and used in the two previous examples were employed to construct surface temperature isotherms for the tidal average conditions. For evaluation of cross-sectional temperature distributions, the upper layer average temperature rises ($\Delta\overline{T}u$) were used instead of the area-average temperature rises ($\Delta\overline{T}$) used previously.

TABLE 4

SUMMARY AND COMPARISON OF TEMPERATURE EFFECTS AT INDIAN POINT PREDICTED BY FOUR-SEGMENT AND CONSTANT PARAMETER MODELS*
-CRITICAL TIDAL PHASE-

TEMPERATURE EFFECT	FOUR-SEGMENT MODEL	CONSTANT PARAMETER MODEL
EFFECTS AT THE INDIAN POINT PLANE OF DISCHARGE:		
% Cross-sectional Area Bounded by 4°F	40	40
% Surface Width Bounded by 4°F	67	67
Max. Surface Temperature Rise, °F	9-10	9-10
EFFECTS AT THE LOVETT SECTION (MP 42):		
% Surface Width Bounded by 4°F	90	42.5

*Prediction made for hydrological and meteorological conditions listed under Case 1, i.e., 20,800 cfs and 90 BTU/SF/DAY/°F

In order to determine the surface isotherms for the critical tidal phase conditions, the ratios of the longitudinal and lateral extents of the 4°F rises of CEP versus TA at Lovett and Danskammer were used in a manner similar to that described in Item A.

For cross-sectional temperature distributions, during the critical tidal phase, the upper layer stratification factor (F_o) is assumed to be 1.0, i.e., the upper layer area-average temperature rises ($\Delta\overline{T}o$) is assumed to be equal to the surface-average temperature rises ($\Delta\overline{T}s$) in the study area. The cross-sectional temperature isotherms were then constructed at the four sections using $\Delta\overline{T}o$ and maximum temperature rise ($\Delta\overline{T}m$).

The surface isothermal maps and cross-sectional temperature distributions for the Case 2 hydrological and meteorological conditions are shown in the exhibit Figures E16 through E25.

III. PRESENTATION AND DISCUSSION OF THE RESULTS

The unavailability of the more advanced models necessitated the use of certain assumptions and extrapolations in order to construct the temperature isotherms for the critical tidal phase and at locations other than the plane of the Indian Point discharge.

Data collected only at the Lovett and Danskammer plants were utilized to obtain some of the factors used in this study. For example, the CTP/TA values for surface width bounded by 4°F was determined by averaging the values obtained from observations at Lovett and Danskammer. Corresponding measurements at Indian Point were unavailable. The validity of these values can be verified once the anticipated extensive thermal monitoring program at Indian Point is completed.

Graphical interpretations of the surface and cross-sectional temperature distributions evaluated for both Case 1 and Case 2 are presented in the attached exhibits. Both cases are represented by several sets of figures each of which consists of five figures. The first in each set is the surface isothermal map. This is followed by four figures depicting the cross-sectional temperature distributions at mile points 43,42,41 and 45, respectively. Table 5 indicates the organization of the figures in the exhibits with the corresponding conditions.

TABLE 5

ORGANIZATION OF THE SURFACE AND CROSS-SECTIONAL MAPS PRESENTED IN THE EXHIBITS

SET NO.	FIGURE NO.	ITEM	HYDROLOGICAL AND METEOROLOGICAL CONDITIONS	MATHEMATICAL MODEL USED	TIDAL CONDITIONS
I	E1	Surface isotherms	CASE 1: 20,800 cfs 90 BTU/SF/day/°F	FOUR-SEGMENT MODEL	TIDAL AVERAGE
	E2	Cross-sectional Temp. Distribution at MP 43			
	E3	Ditto at MP 42			
	E4	Ditto at MP 41			
	E5	Ditto at MP 45			
II	E6	Surface isotherms			CRITICAL TIDAL PHASE
	E7	Cross-sectional Temp. Distribution at MP 43			
	E8	Ditto at MP 42			
	E9	Ditto at MP 41			
	E10	Ditto at MP 45			
III	E11	Surface isotherms		CONSTANT PARAMETER MODEL	CRITICAL* TIDAL PHASE
	E12	Cross-sectional Temp. Distribution at MP 43			
	E13	Ditto at MP 42			
	E14	Ditto at MP 41			
	E15	Ditto at MP 45			
IV	E16	Surface isotherms	CASE 2: 4,000 cfs 140 BTU/SF/day/°F	TWO-LAYER SYSTEM MODEL	TIDAL AVERAGE
	E17	Cross-sectional Temp. Distribution at MP 43			
	E18	Ditto at MP 42			
	E19	Ditto at MP 41			
	E20	Ditto at MP 45			
V	E21	Surface isotherms			CRITICAL TIDAL PHASE
	E22	Cross-sectional Temp. Distribution at MP 43			
	E23	Ditto at MP 42			
	E24	Ditto at MP 41			
	E25	Ditto at MP 45			

*Corresponding tidal average maps are not presented

A summary of thermal effects of combined operation of Indian Point units 1 through 3, Lovett units 1 through 5 and Bowline units 1 & 2 is presented in Table 6. The tabulated values represent (a) portion of surface width, (b) percentage of cross-sectional area subject to temperature rises in excess of 4°F and (c) the maximum surface temperature rises at the Indian Point plane of discharge. Percentages of surface width bounded by the temperature rise of 4°F at mile point 42 (Lovett) are also shown.

The results indicate that although the cross-sectional area bounded by 4°F complies with the NYSDEC thermal discharge criterion in all cases, the compliance of the surface width bounded by 4°F at the plane of the Indian Point discharge is only marginal. The critical effects (2/3 of surface width bounded by 4°F) were obtained by assuming the most severe set of hydrological and meteorological conditions (Case 1) combined with critical tidal phase conditions.

The calculated values of the percentage of surface width subjected to the temperature rises in excess of 4°F at Lovett (MP 42) indicate that although a conservative estimate by the four segment model clearly exceeds the criterion, a more liberal estimate by the constant parameter model does not contravene the criterion. This further demonstrates the need for verification of the results reported in this study.

The thermal effects of the Indian Point power plant, operating during somewhat less severe summer conditions (Case 2), remain well within the limits of the NYSDEC thermal discharge criteria at both the Indian Point plane of discharge and at mile point 42 (Lovett).

TABLE 6

SUMMARY OF TEMPERATURE EFFECTS AT INDIAN POINT PLANE OF DISCHARGE FOR STUDY CASES

Temperature Effect	CASE 1*			CASE 2**	
	Four-Segment Model		Constant Parameter Model	Two-Layer System Model	
	Tidal Average	Critical Tidal Phase	Critical Tidal Phase	Tidal Average	Critical Tidal Phase
% of Cross-sectional area bounded by 4°F	29	40	40	19	26
Portion of Surface Width bounded by 4°F	1/2	2/3	2/3	1/3	4/10
Max. Surface Temp. Rise, °F	8-9	9-10	9-10	8-9	9-10
% of Surface Width bounded by 4°F at Lovett (MP42)	81	90	43	38	63

*Case 1: Freshwater flow = 20,800 cfs, heat transfer coefficient = 90 BTU/SF/day/°F
**Case 2: Freshwater flow = 4,000 cfs, heat transfer coefficient = 140 BTU/SF/day/°F

The maximum surface temperature rise at Indian Point was determined to be 8 to 9°F for tidal average conditions and 9 to 10°F for critical tidal phase. Based on a maximum ambient temperature of 79°F in summer, the maximum surface temperature would be 89°F, which would not exceed the NYSDEC criterion of 90°F for maximum surface temperature.

IV. CONCLUSIONS

The presented mathematical model study of Indian Point Units 1 through 3 effects on Hudson River temperature distributions is based upon a number of assumptions. These assumptions have been derived from available observations and hydraulic model studies. However, lack of significant heat quantities in existing Hudson River discharges and in comprehensive hydrodynamic measurements make the selection of certain system parameters extremely difficult.

The assumptions are based on the present knowledge of art and most of them are related to overall dilution of the thermal effluent by ambient water in the vicinity of Indian Point and to performance of the existing submerged discharge outfall. In particular, the study assumed:

a. existence of at least 20,800 cfs dilution flow in the vicinity of Indian Point.

b. the present outfall design and its capability to attain an initial dilution ratio of 2 to 1, effecting a thermal stratification factor on the order of 1.5 to 2.0.

c. intratidal behavior of far-field temperature distributions similar to those resulting from existing Hudson River discharges.

The following conclusions can be made based on the presented analysis:

1. The surface width subjected to the temperature rises in excess of 4°F at the Indian Point plane of discharge, using the present outfall design, may be marginal to, but

not contravene, the NYSDEC criterion. This conclusion is made for conditions of maximum severity.

2. The conservative estimate for surface width bounded by the 4°F isotherm at Lovett (MP 42) may exceed the criterion under conditions of maximum thermal severity, whereas the liberal estimate indicates compliance with the criterion.

3. In all cases, the criterion for cross-sectional area subjected to the temperature rises in excess of 4°F may not be exceeded at any section if present design of the Indian Point outfall structure is used.

4. The maximum surface temperature during critical summer conditions (river ambient temperature of 79°F) may not contravene the criterion of 90°F.

The effects of the Indian Point power plant on Hudson River surface temperature distributions could be lowered by changing the present design of outfall structure to a submerged diffuser with maximum possible submergence of the discharge ports. However, this will require a detailed study supported by measurements of temperature distributions for conditions of the existing outfall structure.

References

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APPENDIX I

FOUR SEGMENT MODEL

The mechanisms considered in this model include convection, dispersion, and heat transfer across the water surface by convection, evaporation and radiation. These mechanisms have been incorporated in an ordinary differential equation describing the decay of the tidal-smoothed, area-averaged temperature rise along the longitudinal axis of an estuary subject to heated water discharges under steady state conditions. This equation is given below:

$$E \frac{d^2\Delta\overline{T}}{dx^2} - \frac{Q}{A}\frac{d\Delta\overline{T}}{dx} - \frac{\overline{K}\ B\ TSF}{\rho\ Cp\ A}\Delta\overline{T} = 0 \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

The general solution of this second order, linear ordinary differential equation is:

$$\Delta\overline{T}(x) = Ce^{jx} + De^{kx} \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

in which

$$\left.\begin{matrix} j \\ k \end{matrix}\right\} = \frac{Q}{2AE}\left[1 \pm \sqrt{1 + \frac{4K\ B\ TSF\ E\ A}{\rho\ Cp\ Q^2}}\right] \ldots\ldots\ldots\ldots\ldots(3)$$

C & D = constants of integration

Heat loads are applied to either one or both of the two interior segments of the four segment model. Equation 1 does not contain a term for the heat load, H, and is not applicable across the plane of discharge. For this reason, six equations of the form of Equation 2 are necessary to describe temperature behaviour along the full length of the four segment model. The resulting twelve integration constants are evaluated by the assignment of twelve boundary conditions and subsequent solution of twelve simultaneous equations.

The area-averaged, tidal smoothed, temperature rise is representative of the overall river effect. Theoretical development of this parameter required a model that includes overall energy transport and dissipation mechanisms. Application of Equation 1 to 4 consecutive river segments does just that.

Computer output has been directed at determining whether the thermal discharge criteria can be met for a known station generating capacity. Therefore, rather than stop the solution at the point at which area-averaged behaviour is obtained, empirically developed mathematical relationships have been employed to relate near-field behaviour to the overall temperature rises gleaned from Equation 2. This permits evaluation in terms of the NYSDEC thermal discharge criteria.

The specific forms of Equation 2 for each of the six river lengths and previously developed exponential decay equations, which convert overall results to near-field behaviour, have been programmed. The following input parameters are averaged over each segment. Segment lengths ranging between one and five miles have been used: water density (ρ), heat capacity (Cp), fresh water flow (Q_f), dispersion coefficient (E), cross-sectional area (A), surface width (B), heat transfer coefficient ($\overline{K}$), heat load (H), thermal stratification factor (TSF) and ratio of critical tidal phase to tidal average behaviour (n).

Computer inputs include area average temperature rise ($\Delta\overline{T}_X$), surface average temperature rise ($\Delta\overline{T}_{SX}$), % width & area ($\%B_{TA}$, $\%B_{CTP}$, $\%A_{TA}$, $\%A_{CTP}$) bounded by a given isotherm (ΔT or ΔT_S)

APPENDIX I Cont'd

The subscripts TA and CTP refer to tidal average and critical tidal phase conditions, respectively.

This program may be used to determine the effect of a single heat load as well as for two heat loads located in adjacent segments.

The above described program was used to determine temperature rises resulting from rated capacity operation of the Indian Point-Lovett complex as well as from the proposed Bowline generating station.

EXHIBIT

LIST OF CONTENTS

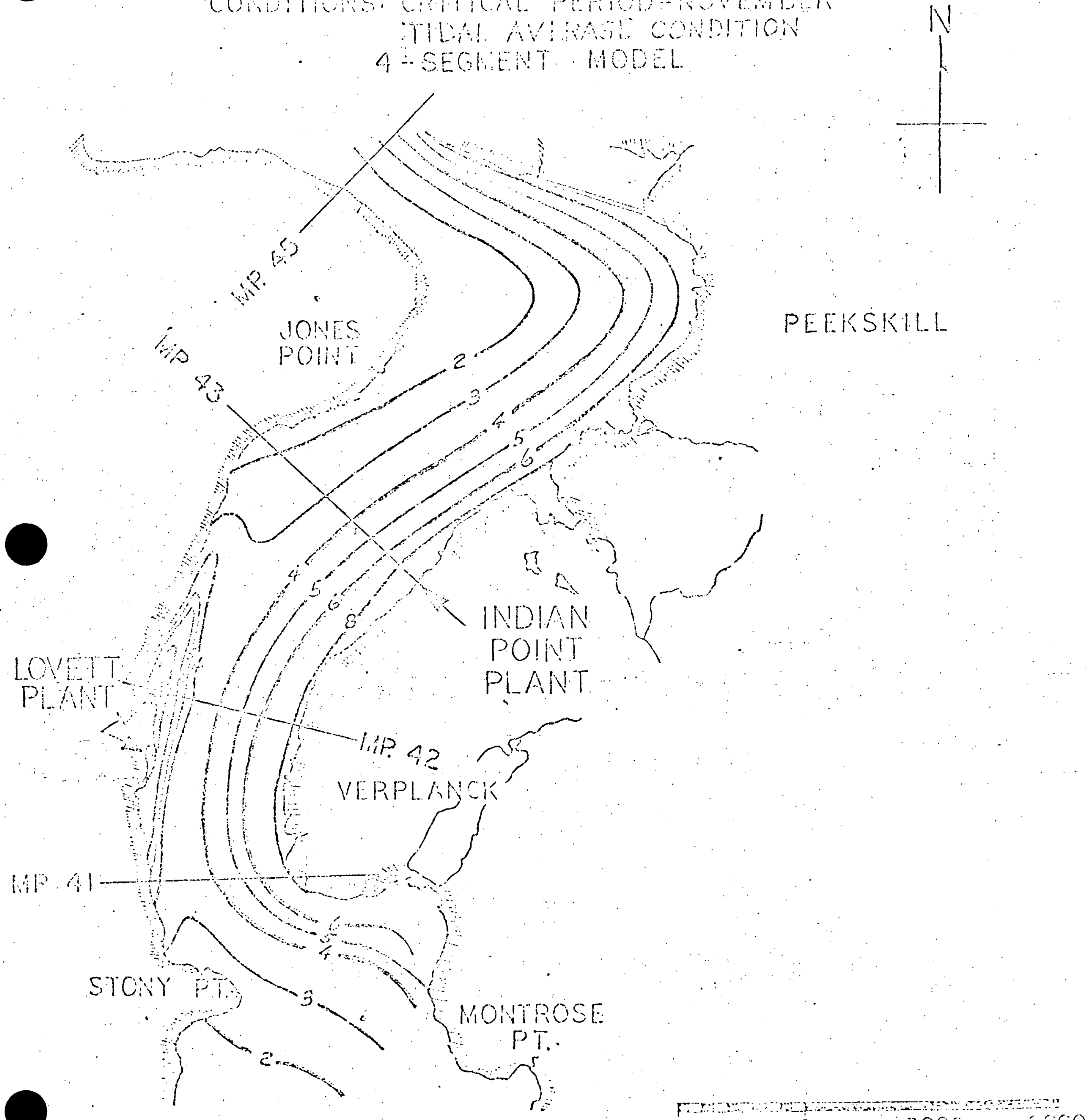
*Corresponding tidal average maps are not presented

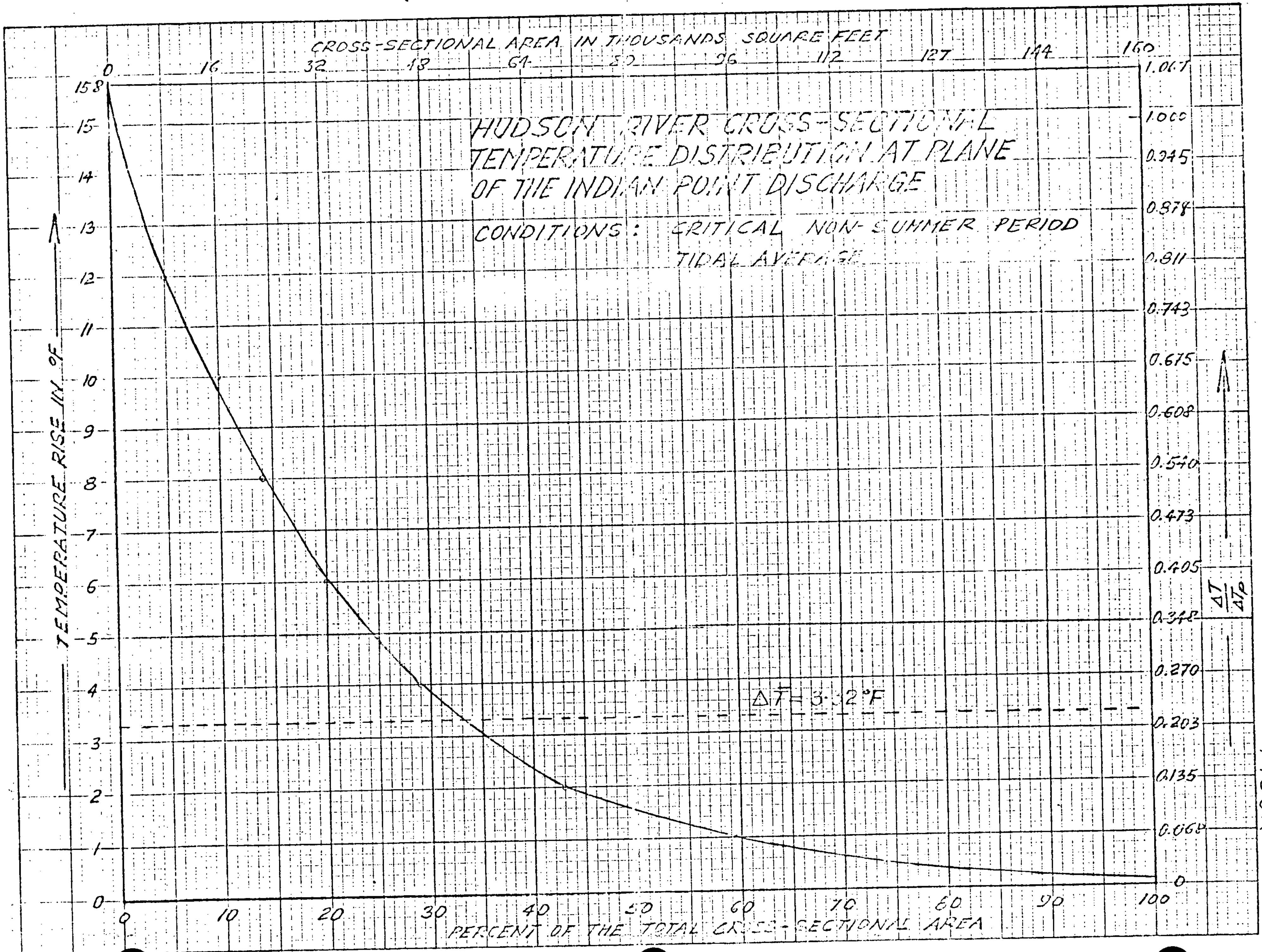
SET I (Case 1)

FIGURE E1

HUDSON RIVER SURFACE TEMPERATURE DISTRIBUTION AT INDIAN POINT

CONDITIONS: CRITICAL PERIOD-NOVEMBER
TIDAL AVERAGE CONDITION
4-SEGMENT MODEL





CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AT PLANE OF THE INDIAN POINT DISCHARGE
CONDITIONS: CRITICAL NON-SUMMER PERIOD
TIDAL AVERAGE
ΔT = 3.32°F
TEMPERATURE RISE IN °F
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA
ΔT/ΔTp

FIGURE E 2

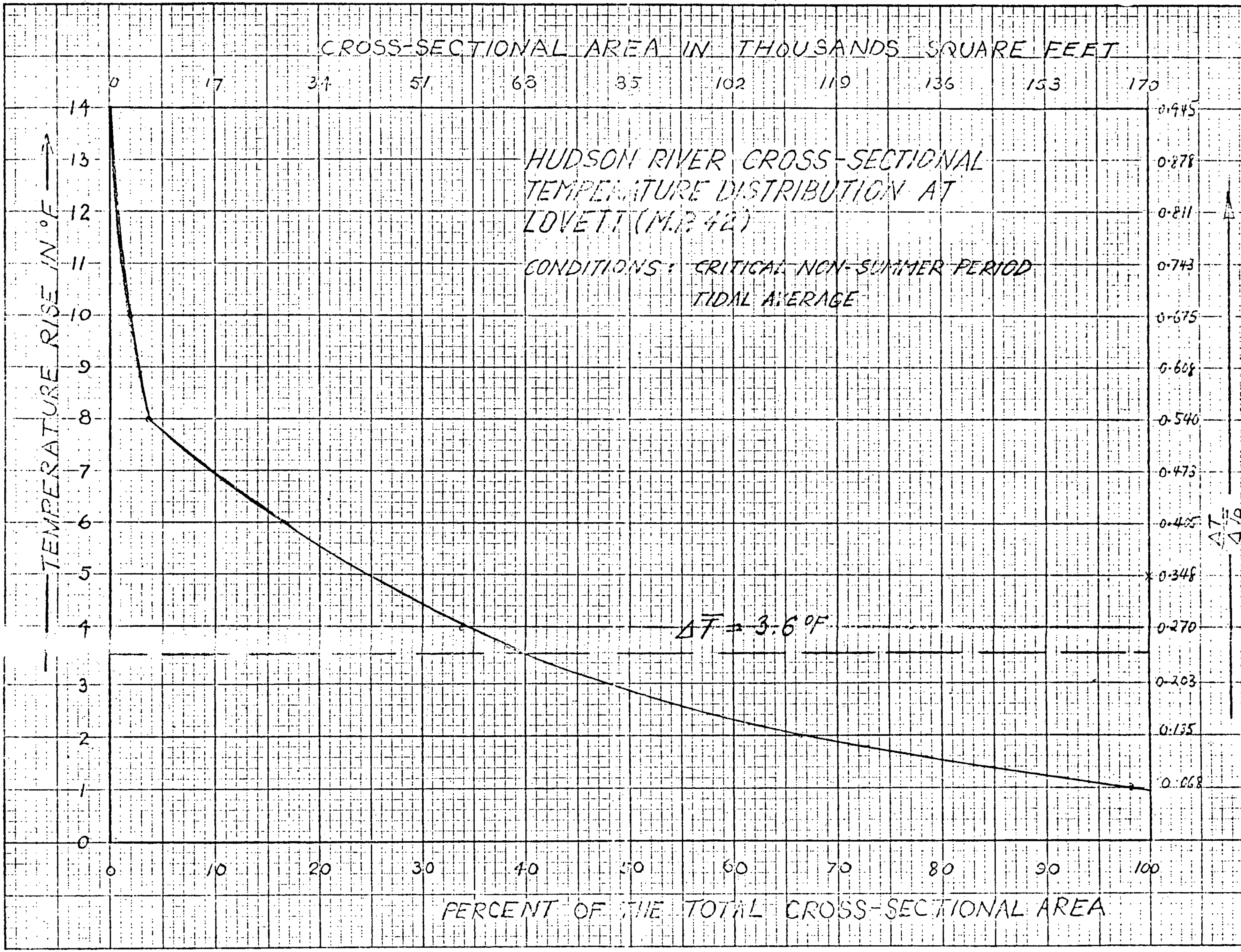
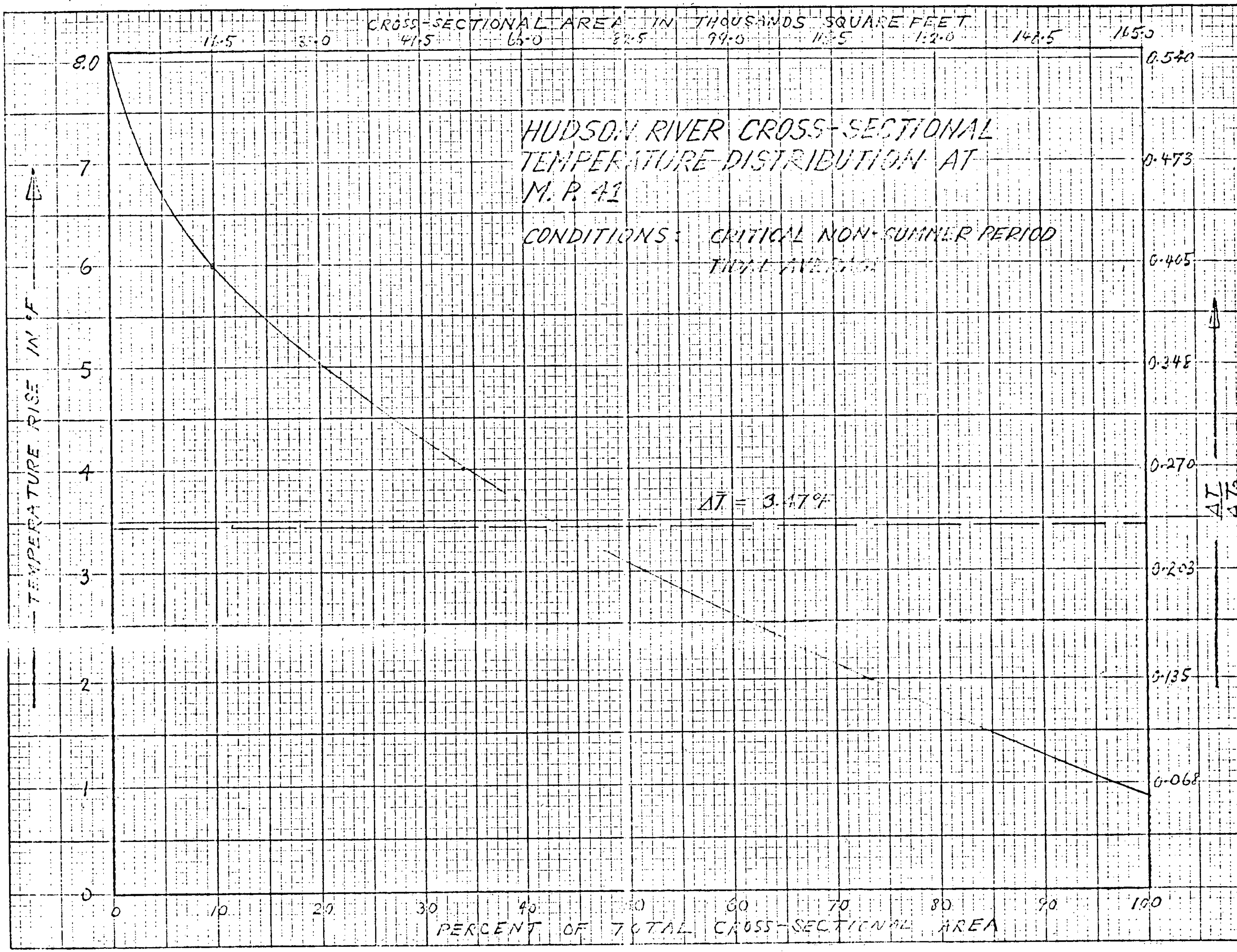
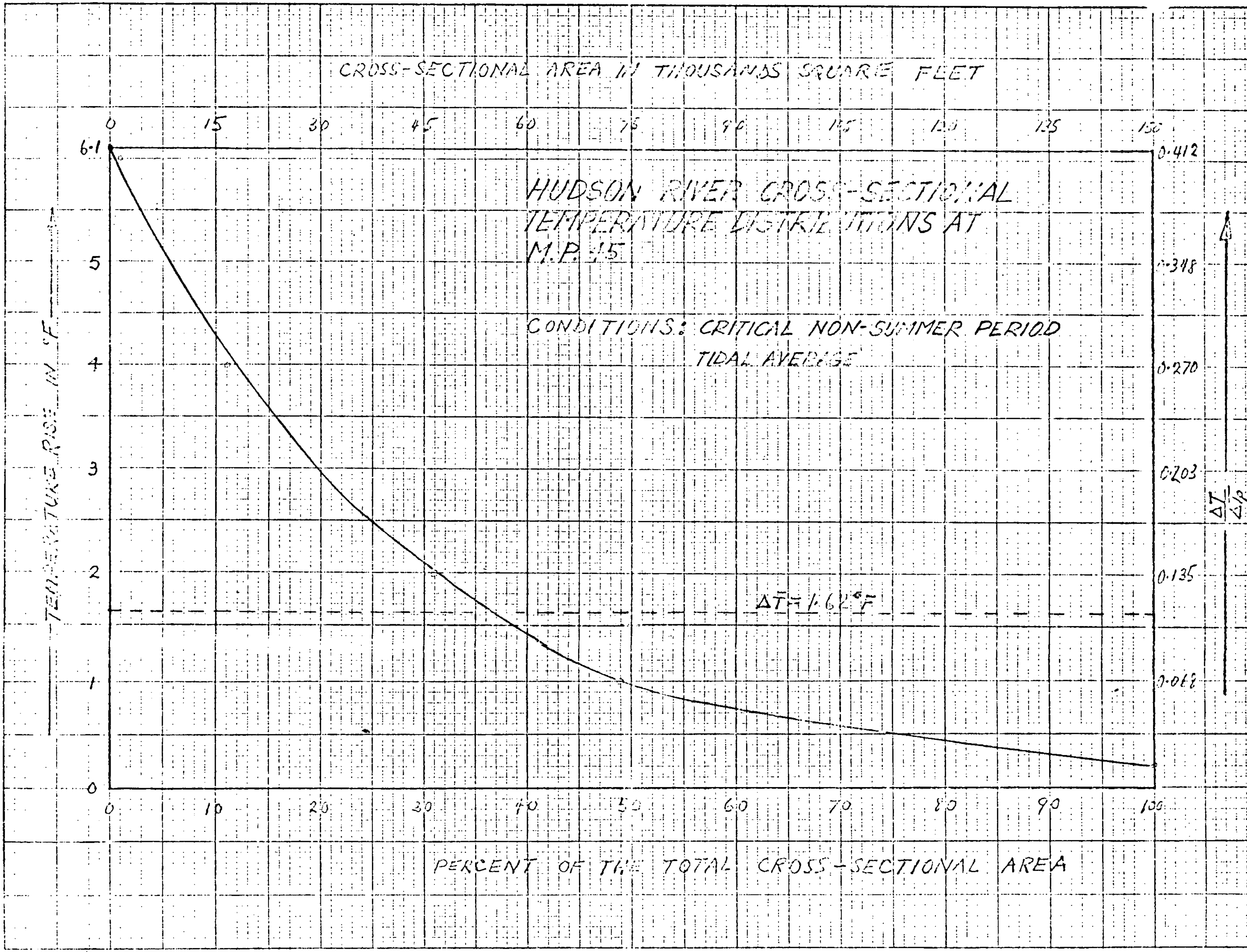

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0 17 34 51 68 85 102 119 136 153 170
HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AT LOVETT (M.P. 42)
CONDITIONS: CRITICAL NON-SUMMER PERIOD
TIDAL AVERAGE
TEMPERATURE RISE IN °F
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0.945 0.878 0.811 0.743 0.675 0.608 0.540 0.473 0.405 0.348 0.270 0.203 0.135 0.068
ΔT/ΔP
ΔT̄ = 3.6 °F
0 10 20 30 40 50 60 70 80 90 100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

FIGURE E3



HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT
M. P. 41
CONDITIONS: CRITICAL NON-SUMMER PERIOD
CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
41.5
65.0
99.0
148.5
165.0
TEMPERATURE RISE IN °F
8.0
7
6
5
4
3
2
1
0
0.540
0.473
0.405
0.348
0.270
0.203
0.135
0.068
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TOTAL CROSS-SECTIONAL AREA

FIGURE E4



CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0 15 30 45 60 75 90 105 120 135 150
HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTIONS AT M.P. 15
CONDITIONS: CRITICAL NON-SUMMER PERIOD
TIDAL AVERAGE
ΔT = 1.62°F
TEMPERATURE RISE IN °F
6.1
5
4
3
2
1
0
0.412
0.348
0.270
0.203
0.135
0.068
ΔT/ΔP
0 10 20 30 40 50 60 70 80 90 100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

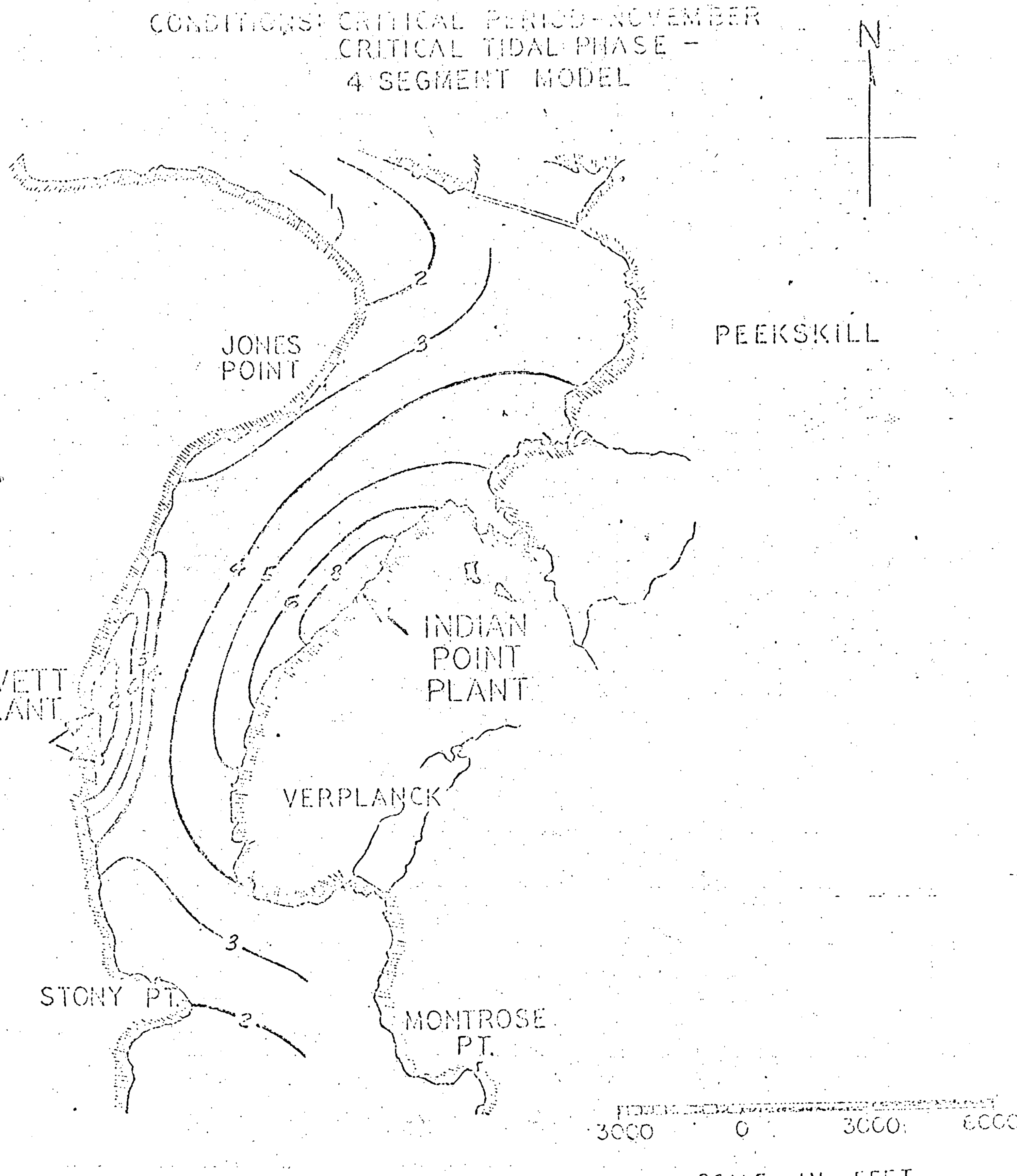
FIGURE E5

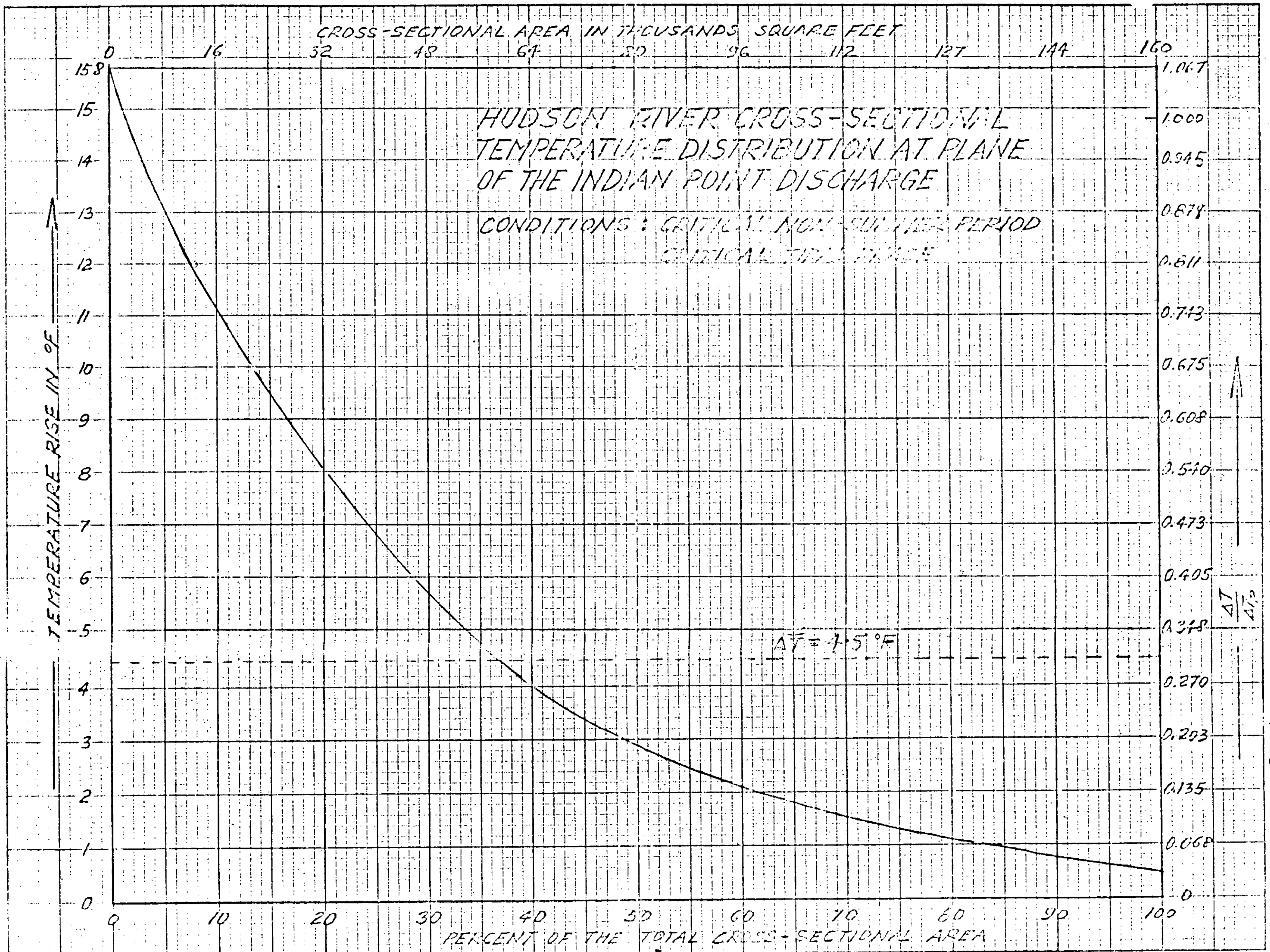
SET II (Case 1)

FIGURE E6

HUDSON RIVER SURFACE TEMPERATURE DISTRIBUTION AT INDIAN POINT

CONDITIONS: CRITICAL PERIOD - NOVEMBER
CRITICAL TIDAL PHASE -
4 SEGMENT MODEL





CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0 16 32 48 64 80 96 112 127 144 160
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT PLANE
OF THE INDIAN POINT DISCHARGE
CONDITIONS : CRITICAL NON-SUMMER PERIOD
TEMPERATURE RISE IN °F
158 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1.067 1.000 0.945 0.878 0.811 0.743 0.675 0.608 0.540 0.473 0.405 0.348 0.270 0.203 0.135 0.068 0
ΔT = 4.5 °F
0 10 20 30 40 50 60 70 80 90 100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

FIGURE E 1

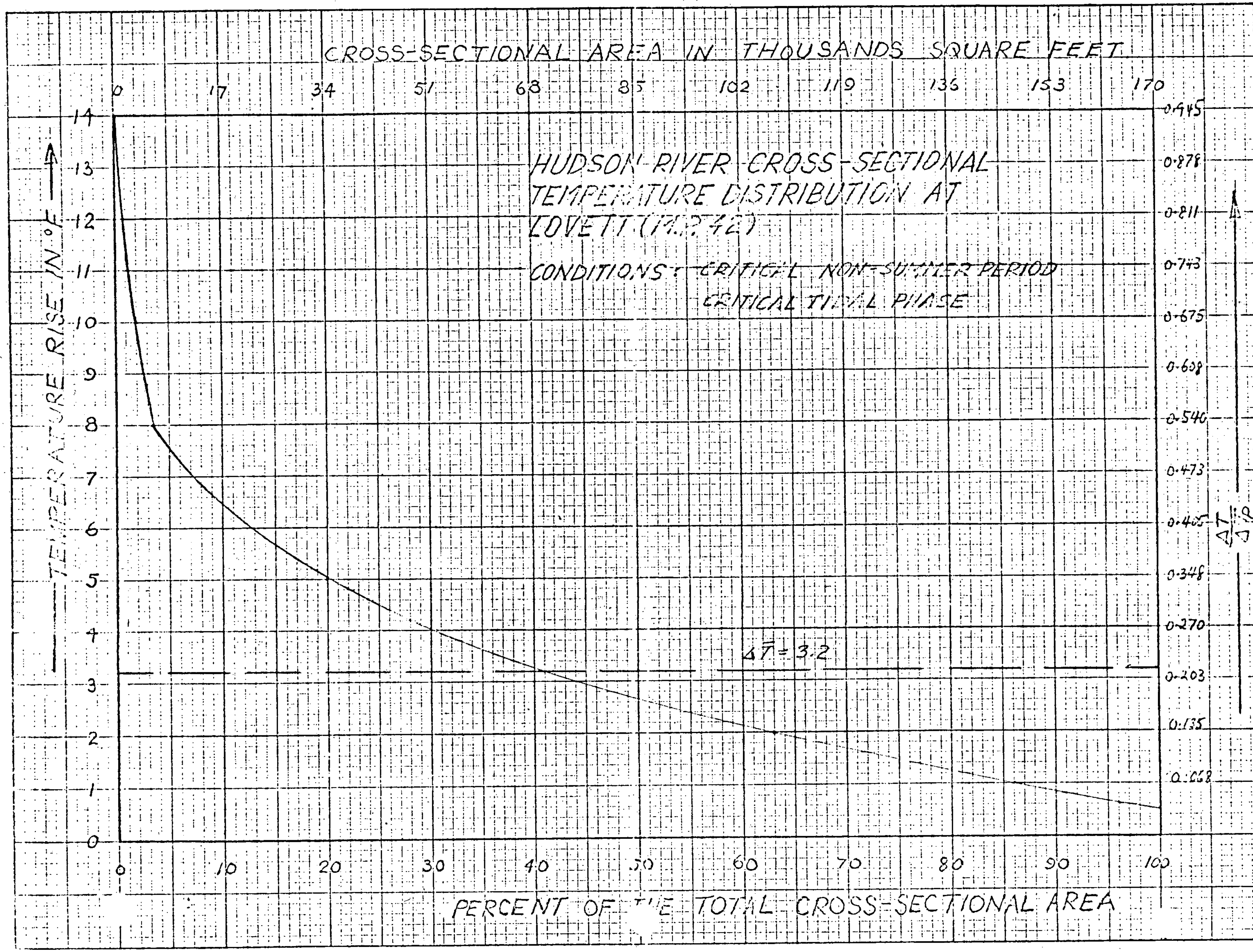
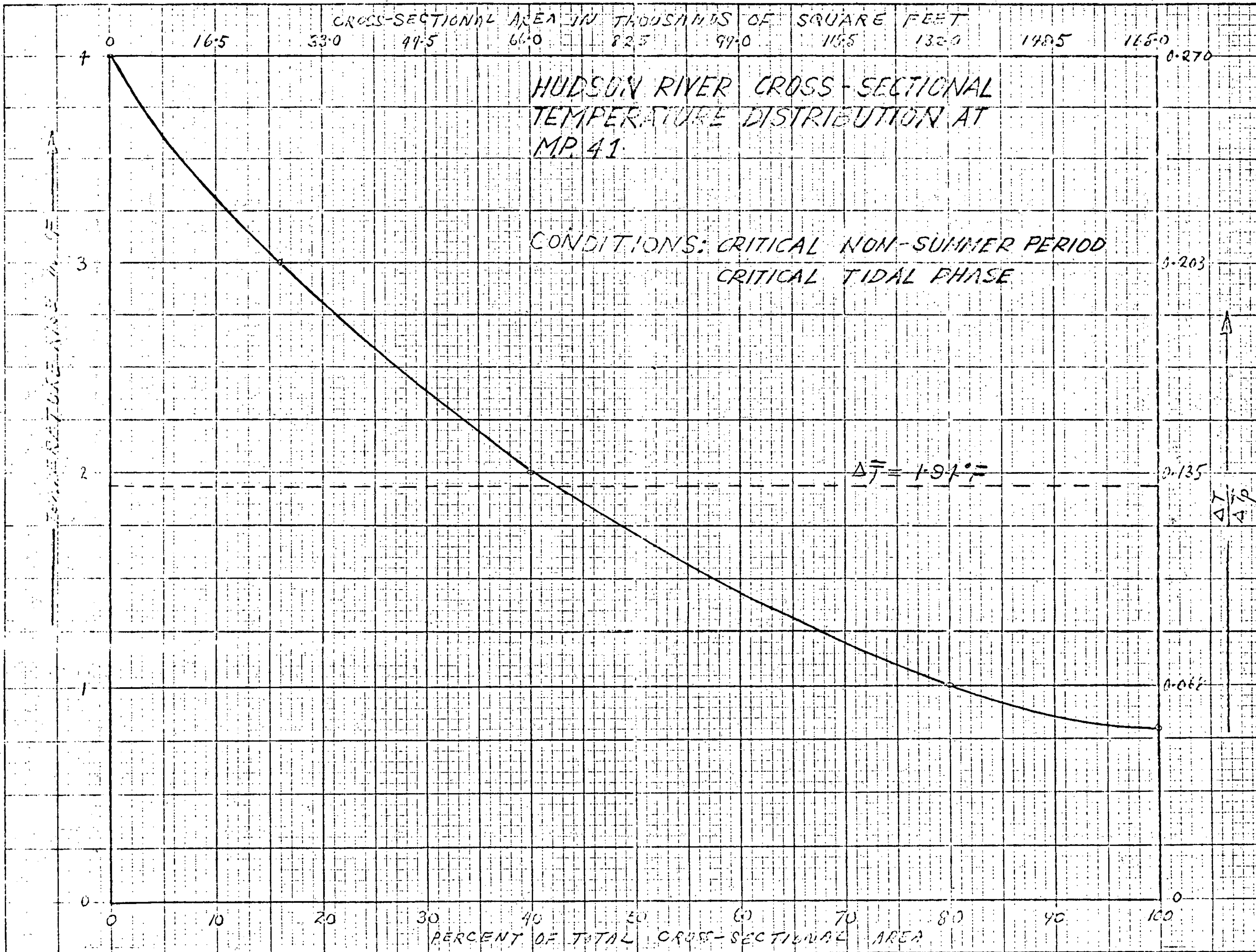

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0 17 34 51 68 85 102 119 136 153 170
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT
LOVETT (M.P. 42)
CONDITIONS: CRITICAL NON-SUMMER PERIOD
CRITICAL TIDAL PHASE
TEMPERATURE RISE IN °F
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0.945 0.878 0.811 0.743 0.675 0.608 0.540 0.473 0.405 0.348 0.270 0.203 0.135 0.068
ΔT/ΔP
ΔT = 3.2
0 10 20 30 40 50 60 70 80 90 100
PERCENT OF
TOTAL CROSS-SECTIONAL AREA

FIGURE E


CROSS-SECTIONAL AREA IN THOUSANDS OF SQUARE FEET
0
16·5
33·0
49·5
66·0
82·5
99·0
115·5
132·0
148·5
165·0
HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AT M.P. 41
CONDITIONS: CRITICAL NON-SUMMER PERIOD
CRITICAL TIDAL PHASE
ΔT̄ = 1·91°F
TEMPERATURE RISE IN °F
4
3
2
1
0
0·270
0·203
0·135
0
ΔT/ΔTp
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TOTAL CROSS-SECTIONAL AREA
FIGURE E9

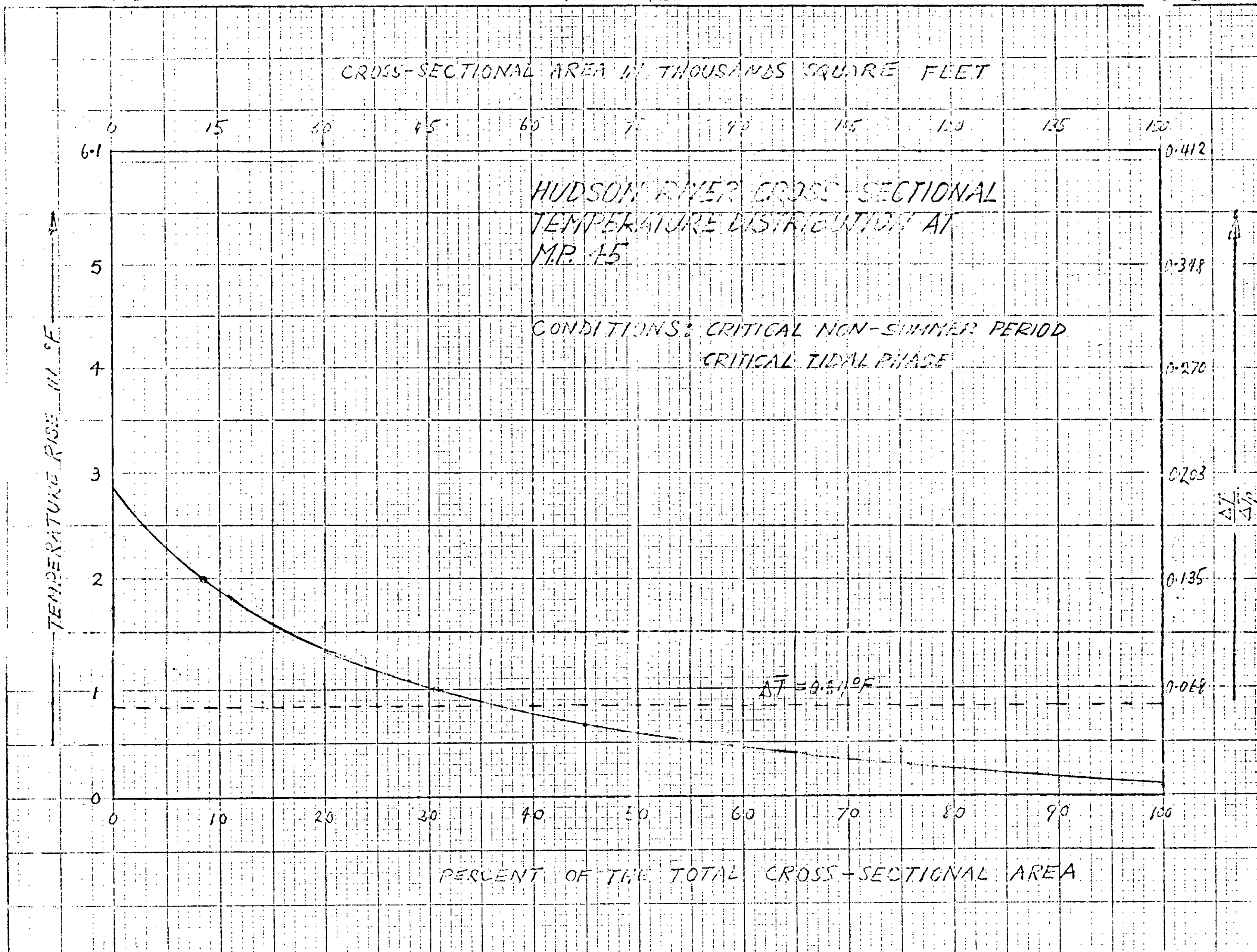
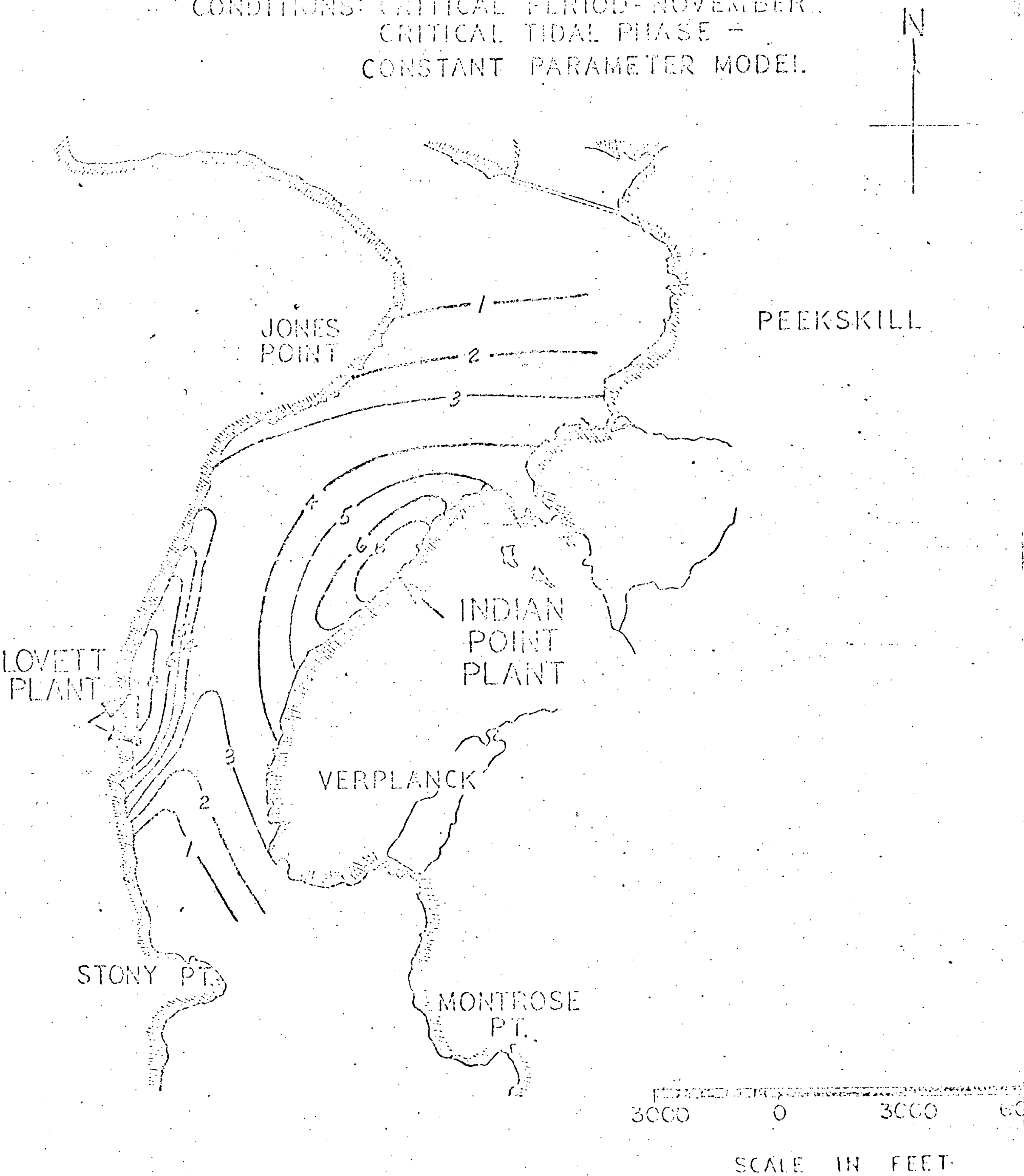

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
HUDSON RIVER CROSS SECTIONAL TEMPERATURE DISTRIBUTION AT M.P. 45
CONDITIONS: CRITICAL NON-SUMMER PERIOD
CRITICAL TIDAL PHASE
TEMPERATURE RISE IN °F
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

FIGURE E10

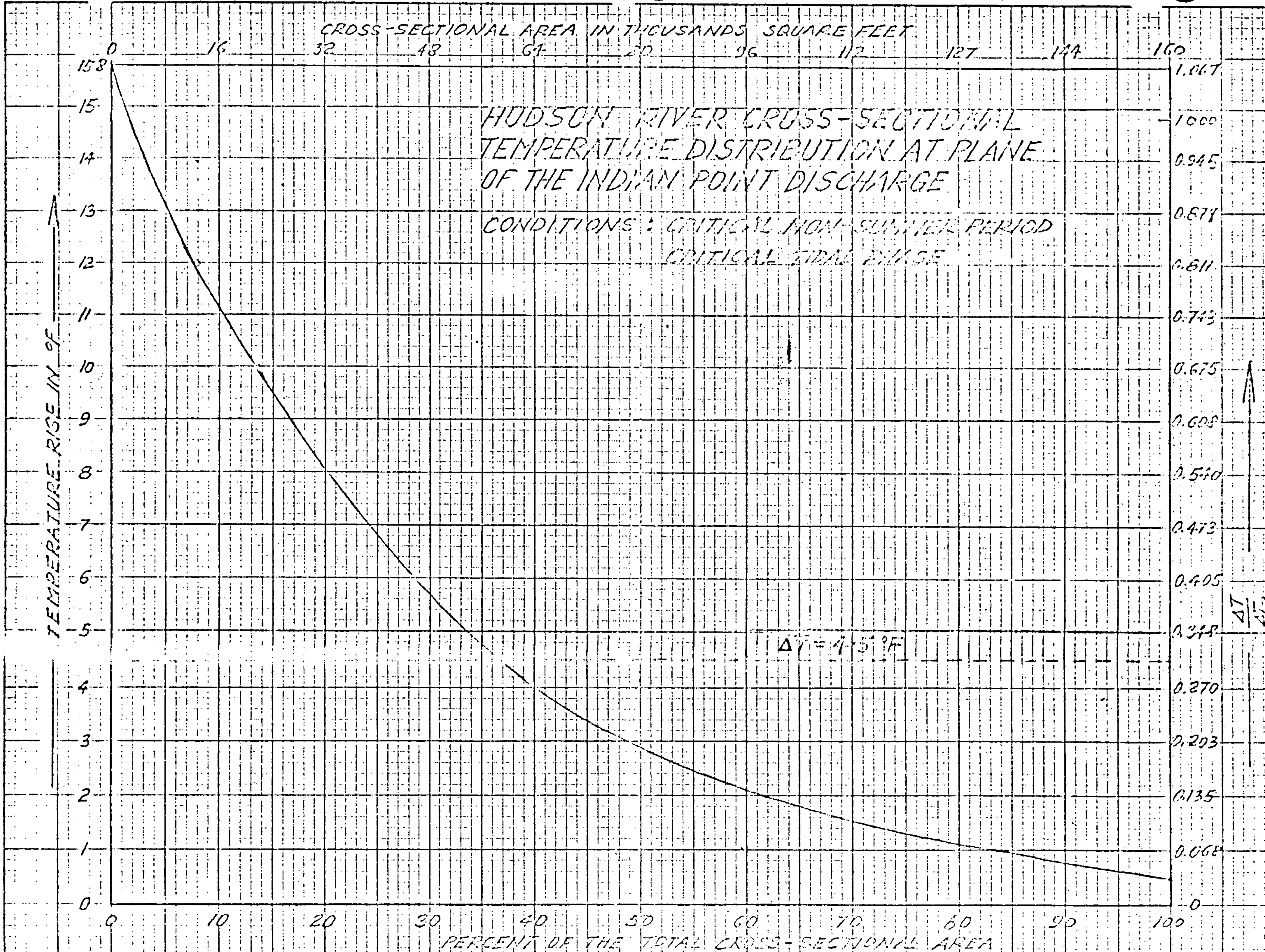
SET III (Case 1)

HUDSON RIVER SURFACE TEMPERATURE DISTRIBUTION AT INDIAN POINT

CONDITIONS: CRITICAL PERIOD - NOVEMBER
CRITICAL TIDAL PHASE -
CONSTANT PARAMETER MODEL



KEUFFEL & ESSER CO. 7 1/2 X 10 INCHES MADE IN U.S.A.



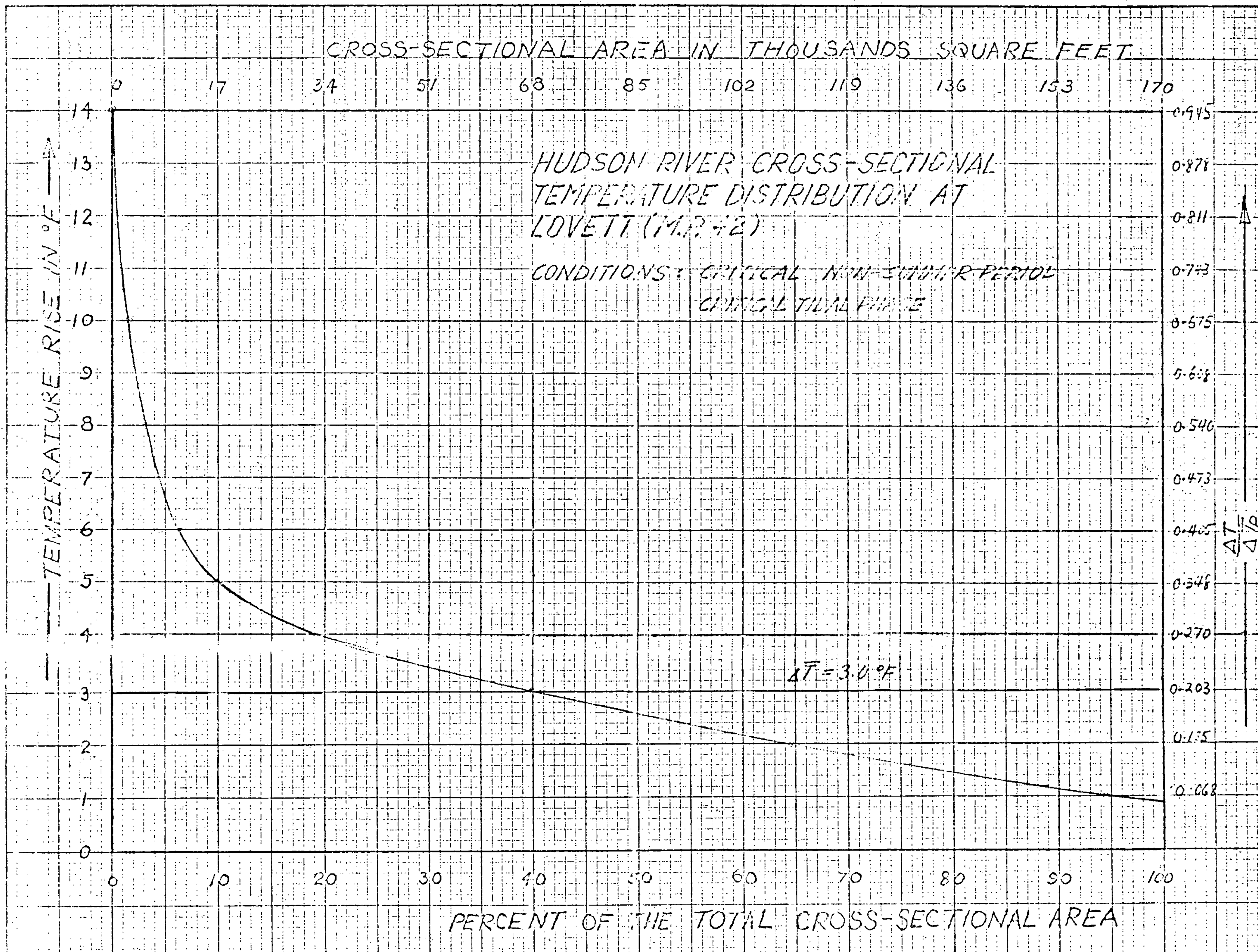

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0 17 34 51 68 85 102 119 136 153 170
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT
LOVETT
CONDITIONS:
TEMPERATURE RISE IN °F
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
$\Delta \overline{T} = 3.0$ °F
0 10 20 30 40 50 60 70 80 90 100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA
0.945 0.878 0.811 0.743 0.675 0.608 0.540 0.473 0.405 0.348 0.270 0.203 0.135 0.068
$\Delta T / \Delta P$

FIGURE E 13

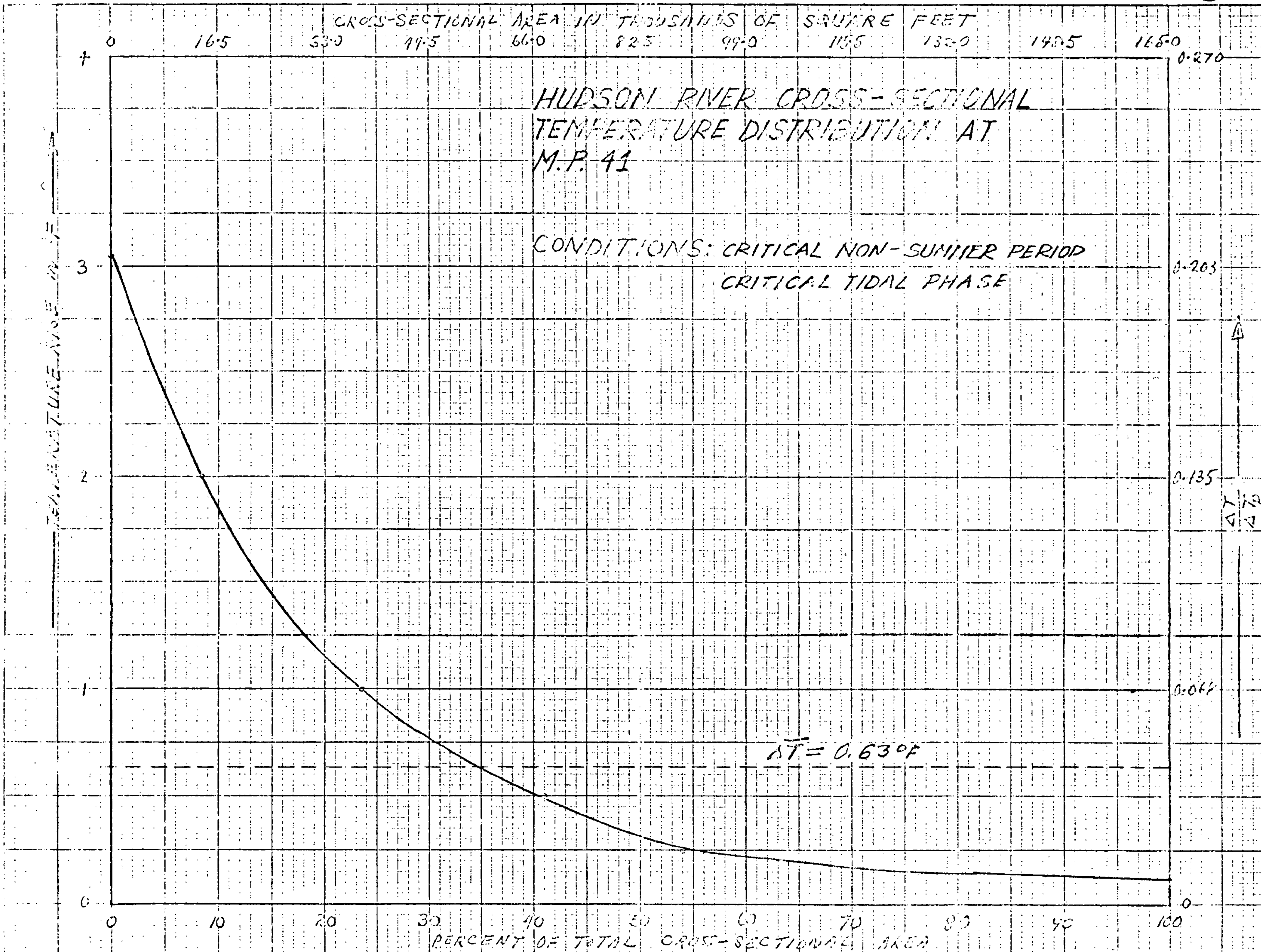
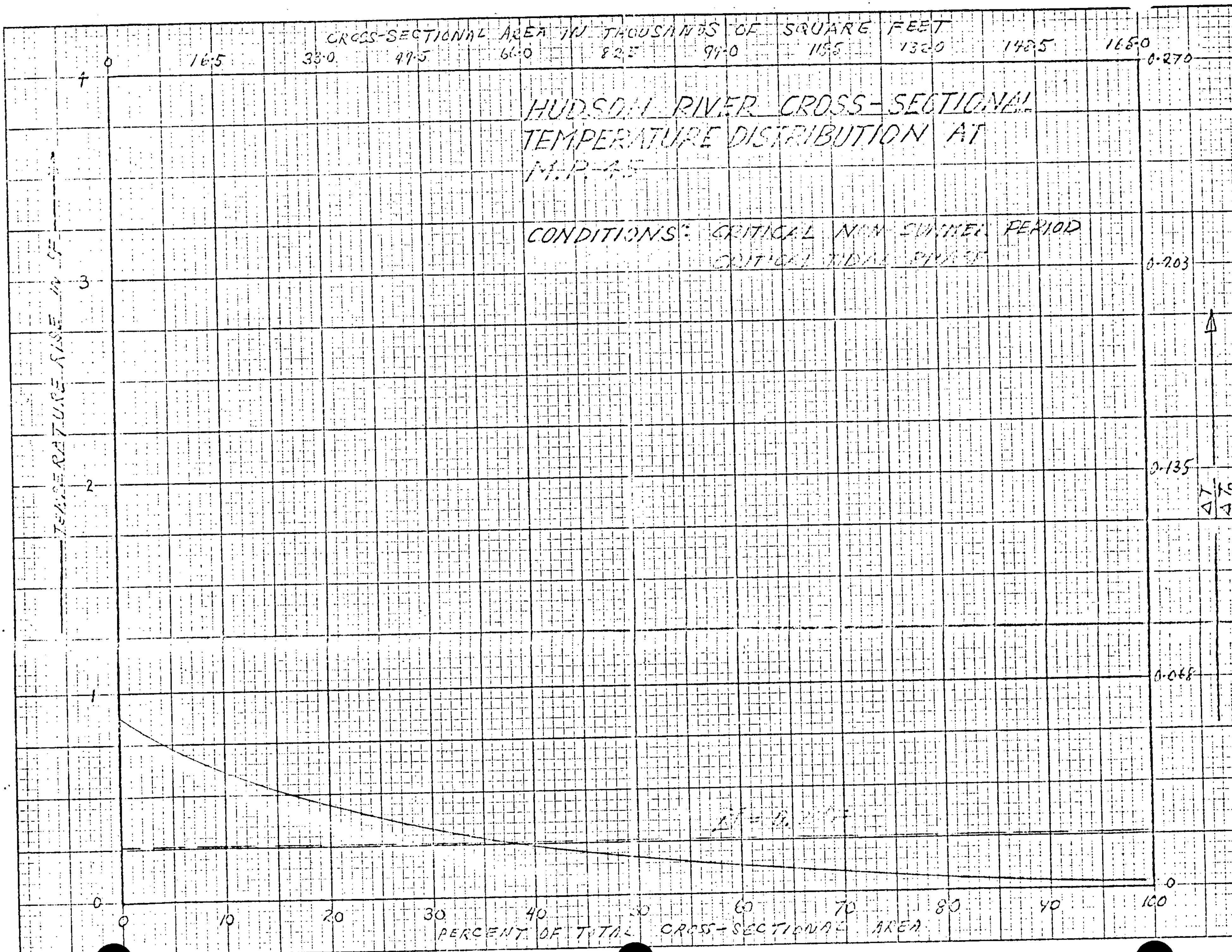

CROSS-SECTIONAL AREA IN THOUSANDS OF SQUARE FEET
0
16.5
33.0
49.5
66.0
82.5
99.0
115.5
132.0
148.5
165.0
HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AT M.P. 41
CONDITIONS: CRITICAL NON-SUMMER PERIOD
CRITICAL TIDAL PHASE
TEMPERATURE RISE IN °F
4
3
2
1
0
0.270
0.203
0.135
0.0??
0
ΔT = 0.63°F
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TOTAL CROSS-SECTIONAL AREA

FIGURE E 14



CROSS-SECTIONAL AREA IN THOUSANDS OF SQUARE FEET
0
16.5
33.0
49.5
66.0
82.5
99.0
115.5
132.0
148.5
165.0
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT
M.P. 45
CONDITIONS: CRITICAL NON-SUMMER PERIOD
TEMPERATURE RISE IN °F
4
3
2
1
0
0.270
0.203
0.135
0.068
0
ΔT / ΔP
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TOTAL CROSS-SECTIONAL AREA

FIGURE E15

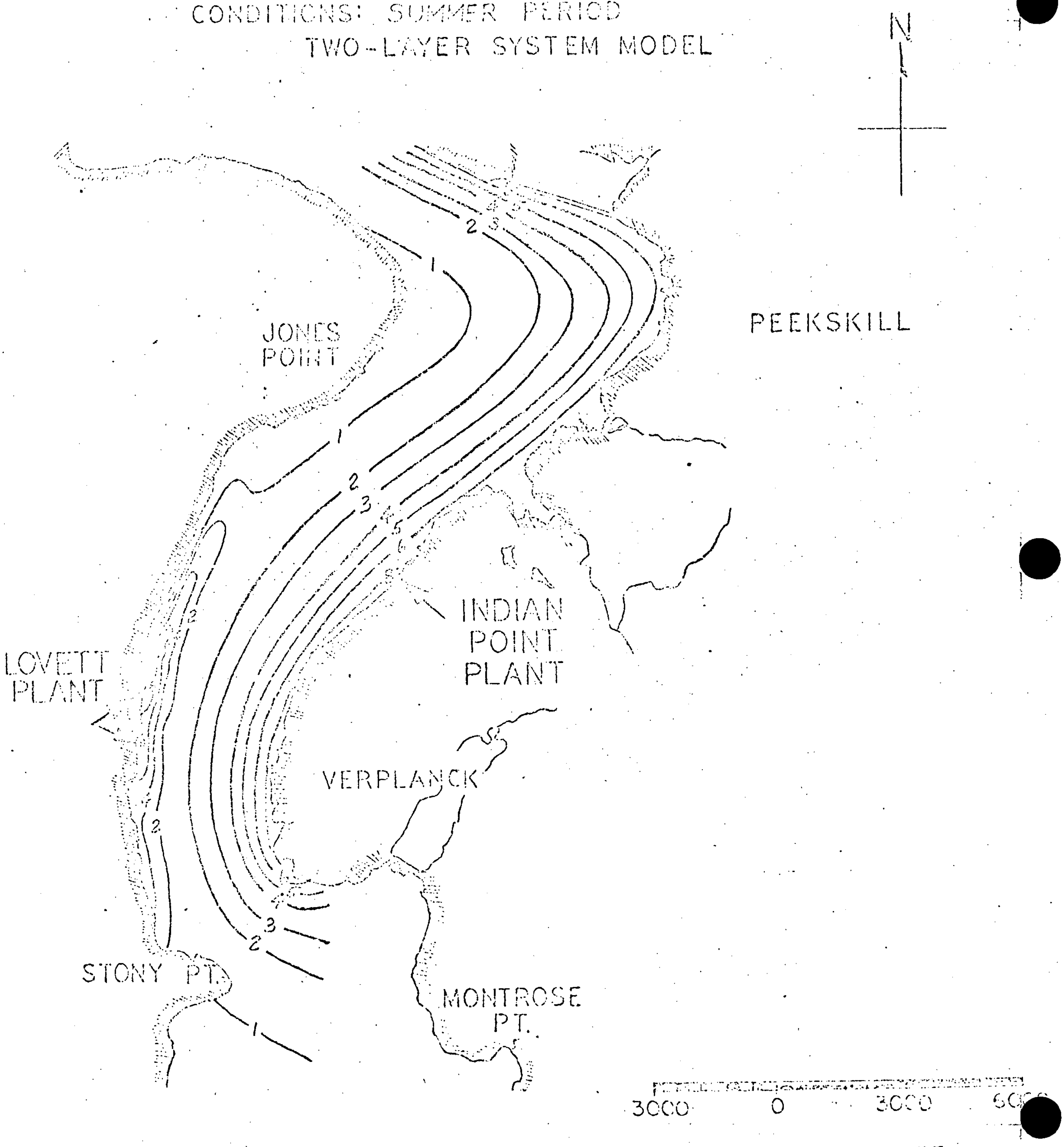
SET IV (Case 2)

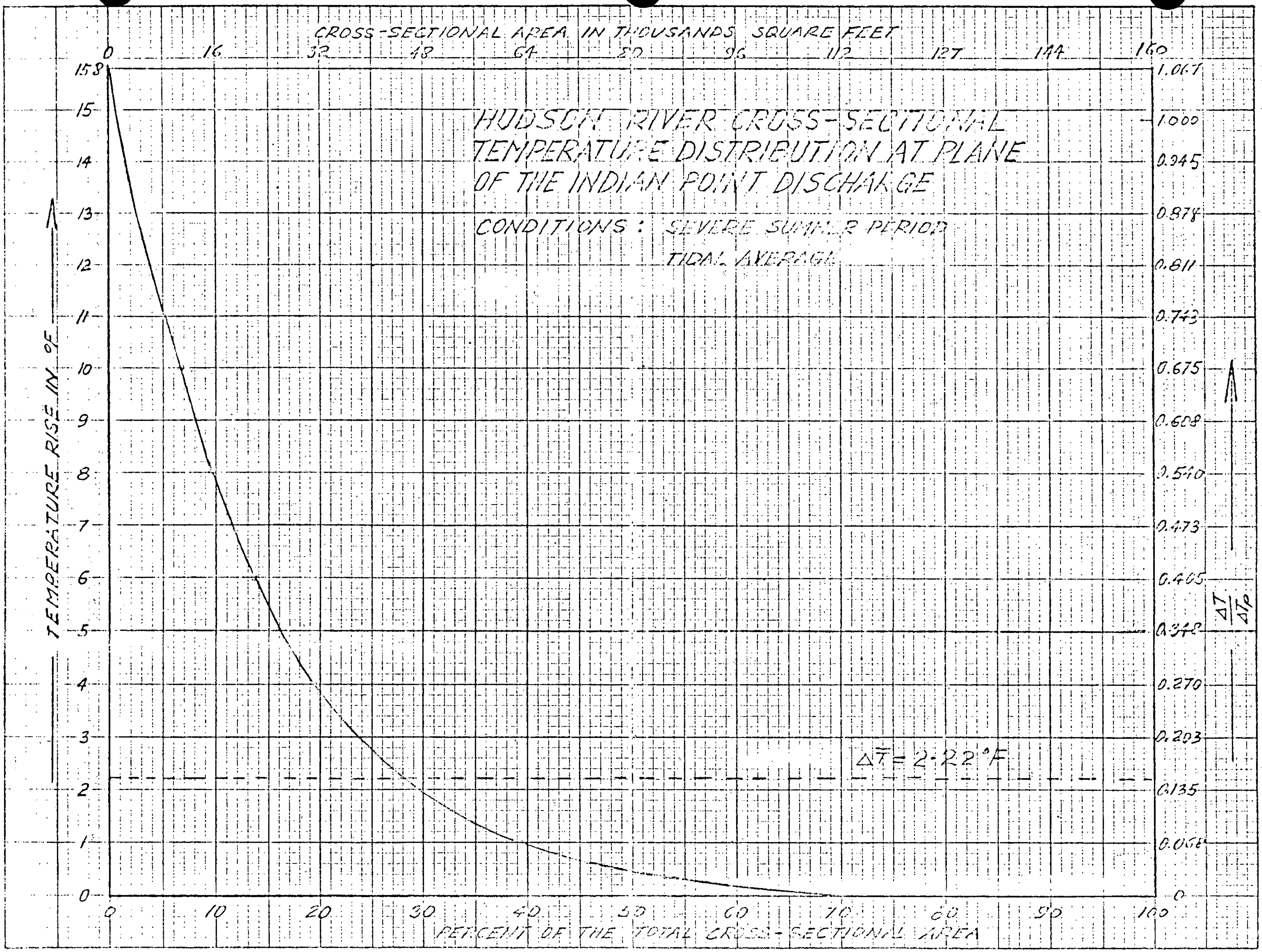
FIGURE E16

HUDSON RIVER SURFACE TEMPERATURE DISTRIBUTION AT INDIAN POINT

CONDITIONS: SUMMER PERIOD

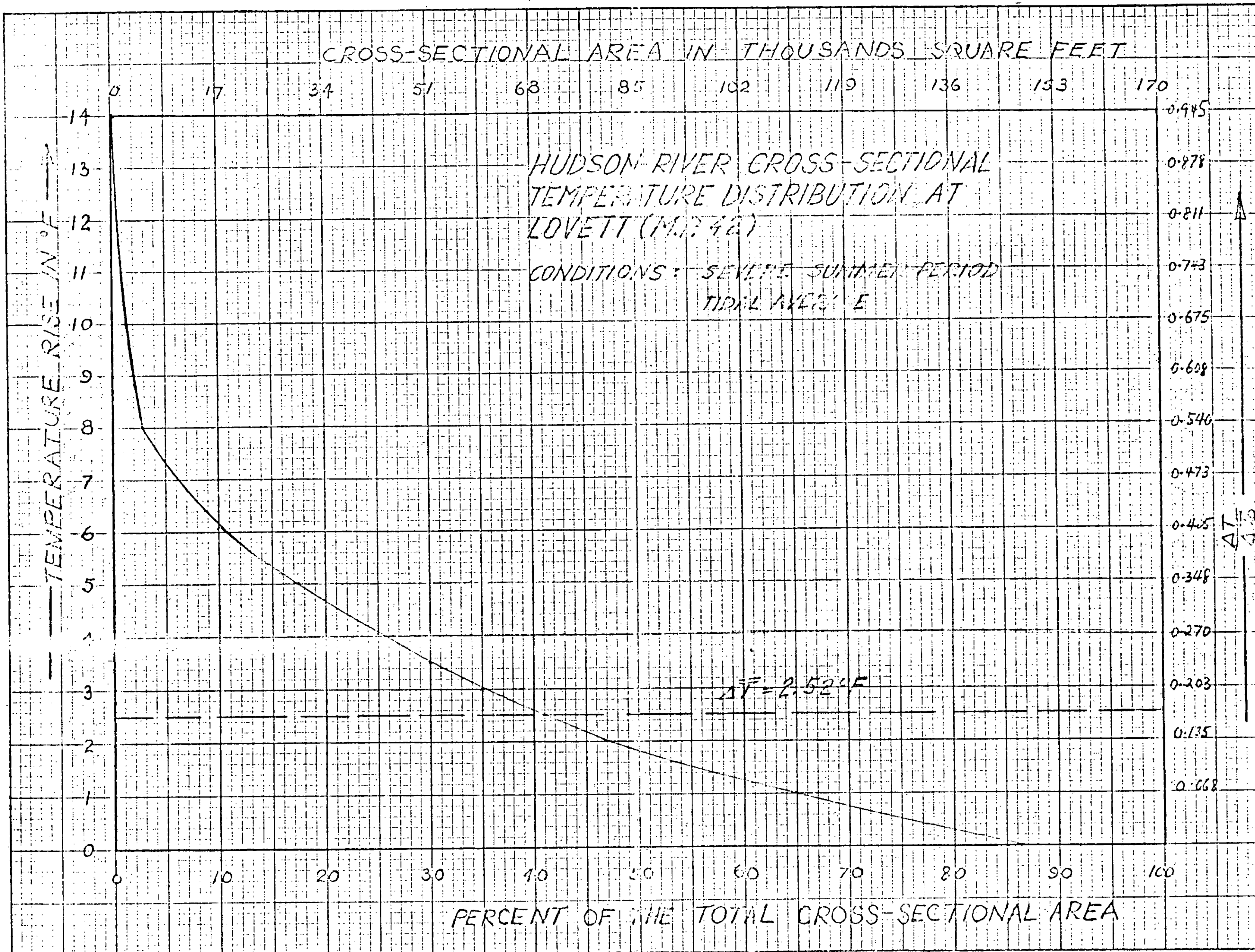
TWO-LAYER SYSTEM MODEL





CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AT PLANE OF THE INDIAN POINT DISCHARGE
CONDITIONS: SEVERE SUMMER PERIOD
TIDAL AVERAGE
TEMPERATURE RISE IN °F
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA
$\Delta \bar{T} = 2.22°F$
$\frac{\Delta T}{\Delta T_P}$

FIGURE E17



CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0 17 34 51 68 85 102 119 136 153 170
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT
LOVETT
CONDITIONS :
TEMPERATURE RISE IN °F
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
0.945 0.878 0.811 0.743 0.675 0.608 0.540 0.473 0.405 0.348 0.270 0.203 0.135 0.068
ΔT = 2.52°F
0 10 20 30 40 50 60 70 80 90 100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

FIGURE E 18

K+E 10 X 10 TO ½ INCH 46 1020
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

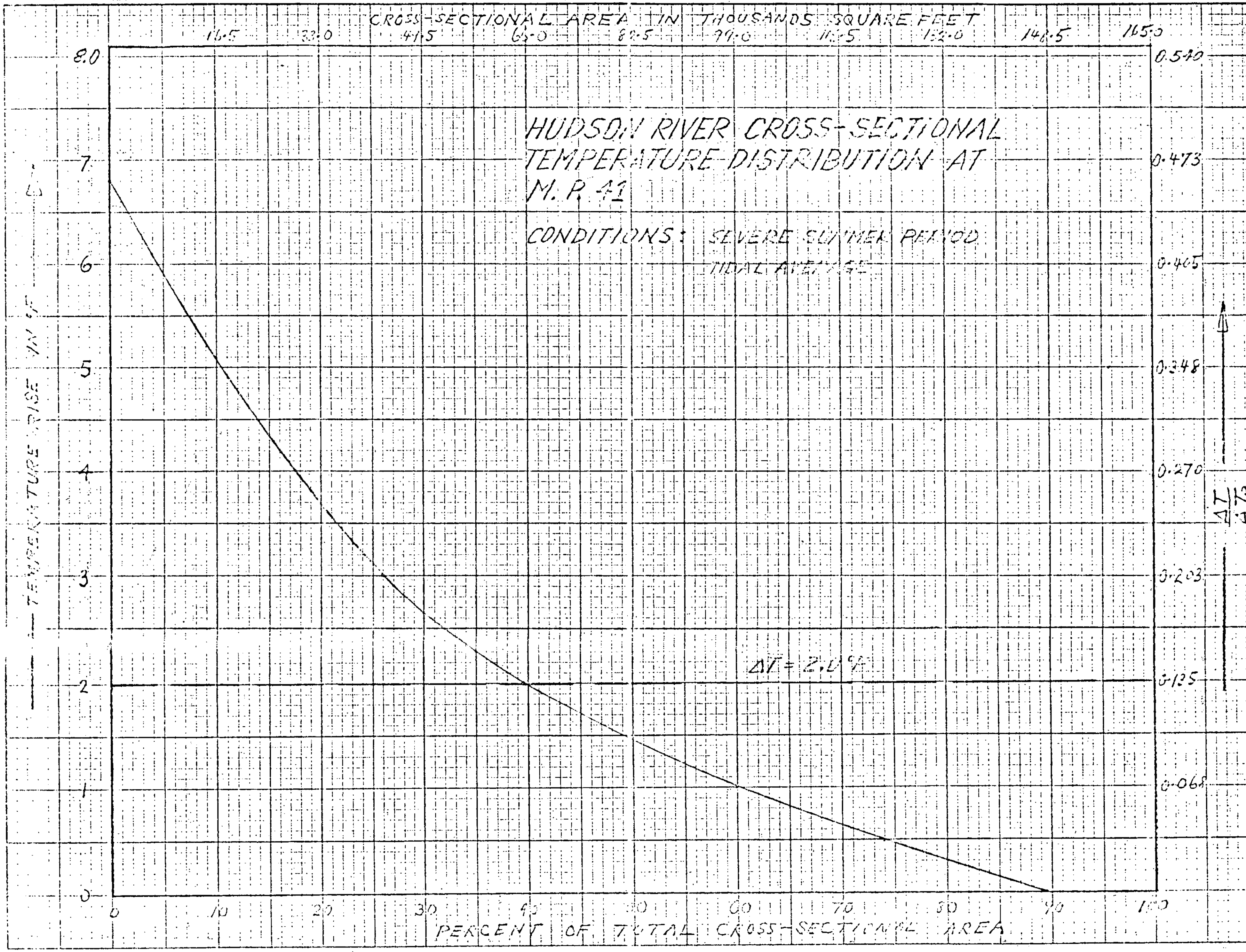


FIGURE E10

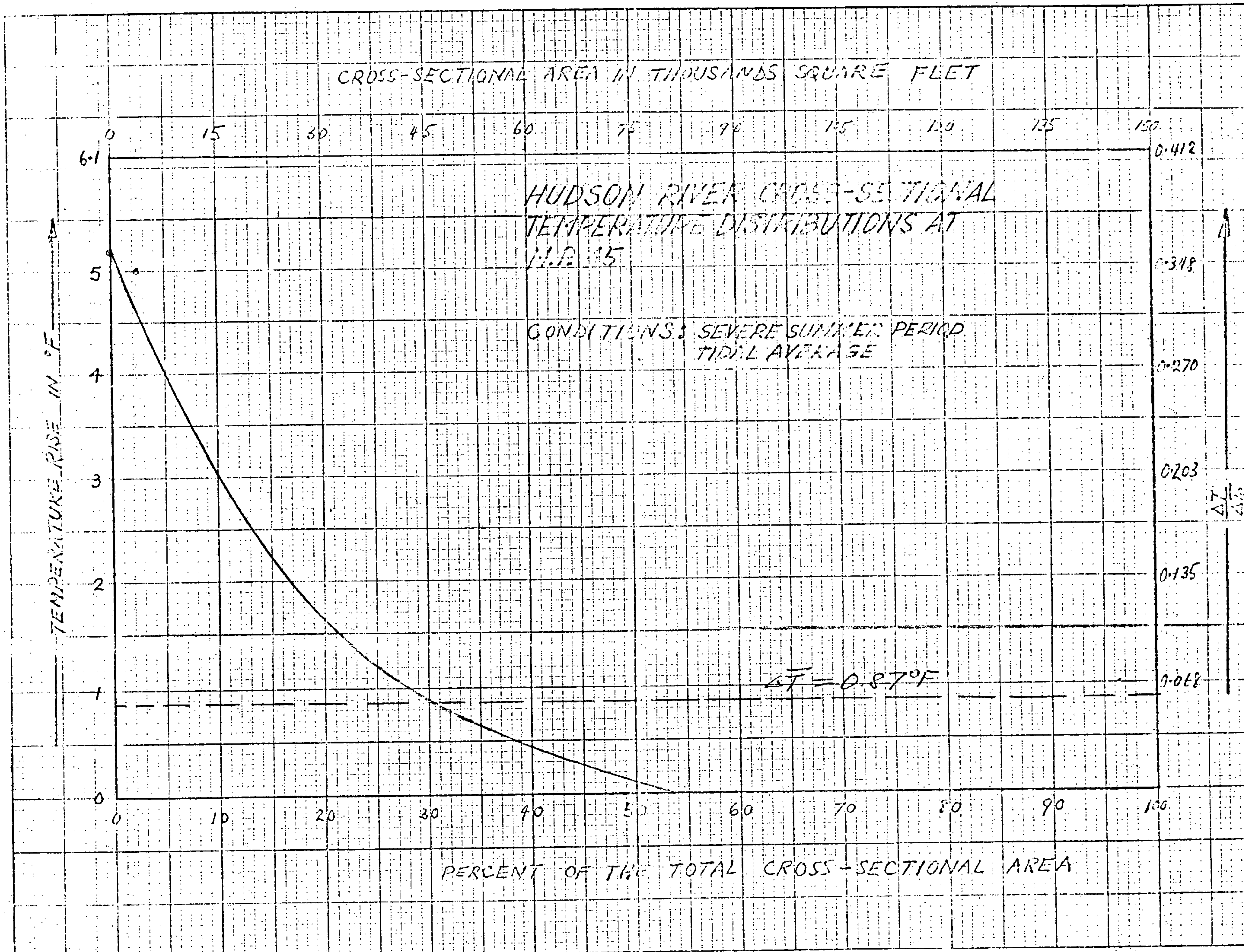

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTIONS AT
CONDITIONS: SEVERE SUMMER PERIOD
TIDAL AVERAGE
TEMPERATURE RISE IN °F
ΔT = 0.87°F
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA
0 15 30 45 60 75 90 105 120 135 150
6.1 5 4 3 2 1 0
0.412 0.348 0.270 0.203 0.135 0.068
0 10 20 30 40 50 60 70 80 90 100

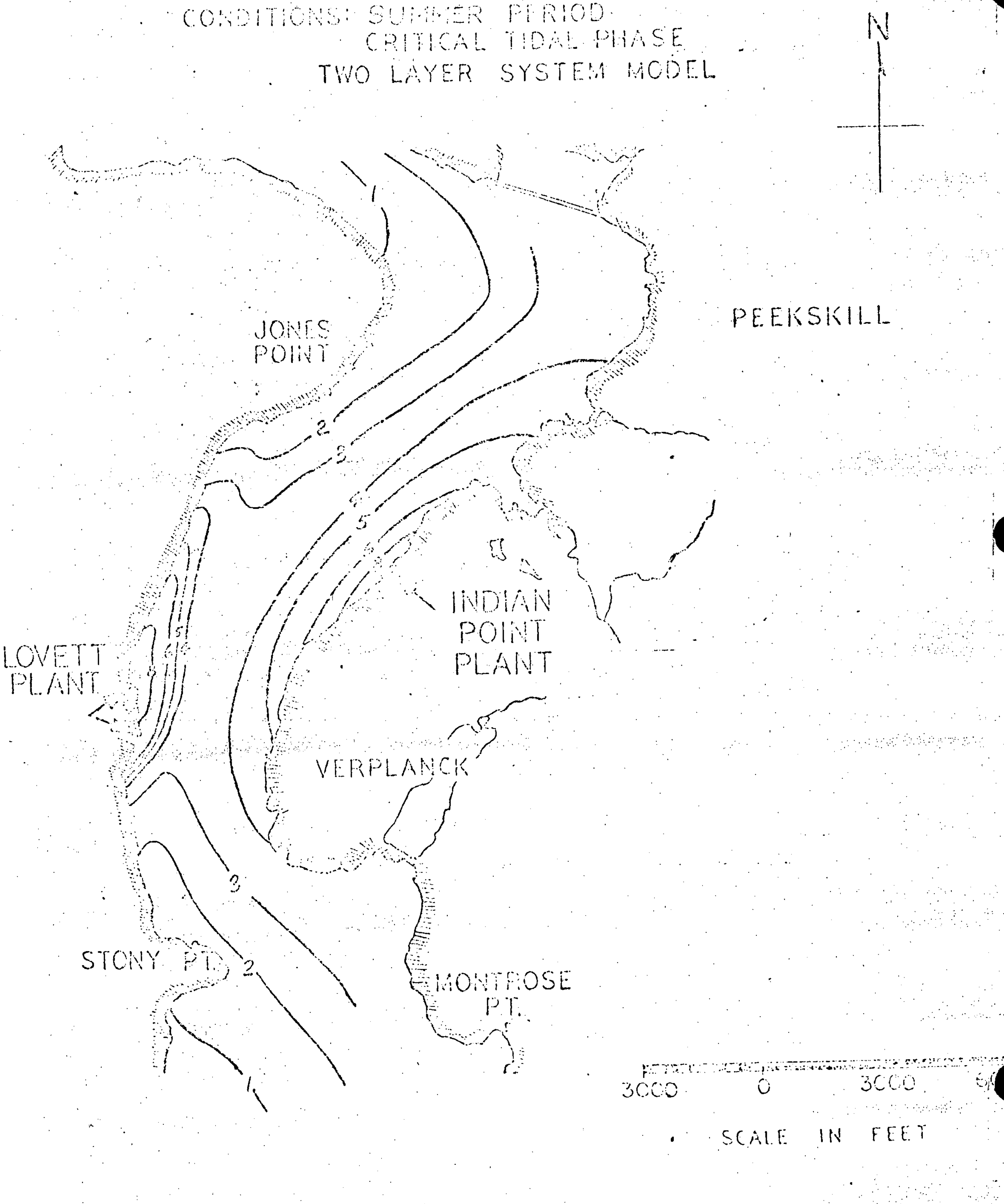
FIGURE E-20

SET V (Case 2)

FIGURE E21

HUDSON RIVER SURFACE TEMPERATURE DISTRIBUTION AT INDIAN POINT

CONDITIONS: SUMMER PERIOD
CRITICAL TIDAL PHASE
TWO LAYER SYSTEM MODEL



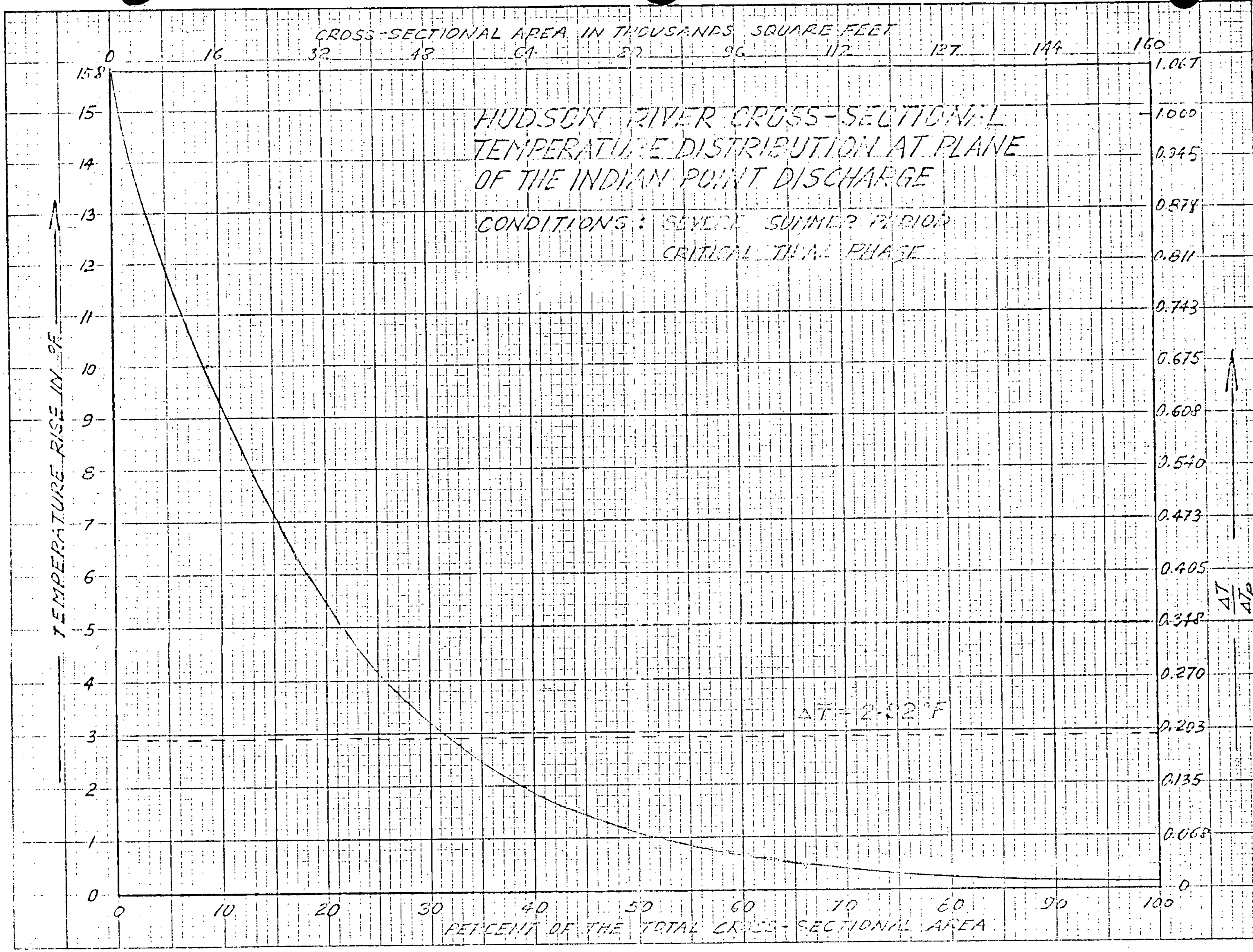

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0
16
32
48
64
80
96
112
127
144
160
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT PLANE
OF THE INDIAN POINT DISCHARGE
CONDITIONS:
CRITICAL
15.8
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
TEMPERATURE RISE IN °F
1.067
1.000
0.945
0.878
0.811
0.743
0.675
0.608
0.540
0.473
0.405
0.348
0.270
0.203
0.135
0.068
0
ΔT/ΔTp
ΔT = 2.92 °F
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

FIGURE E22

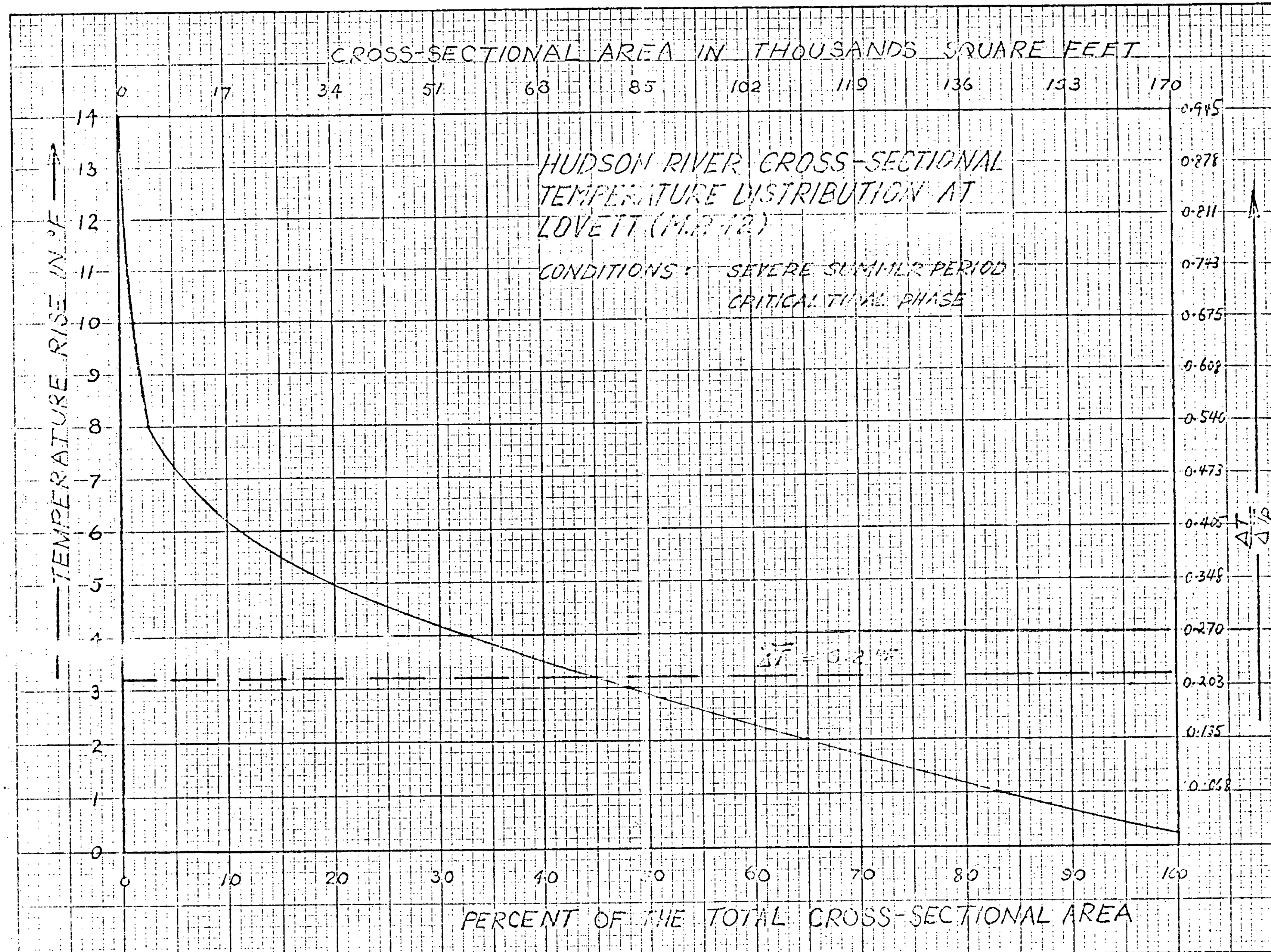

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0
17
34
51
68
85
102
119
136
153
170
HUDSON RIVER CROSS-SECTIONAL
TEMPERATURE DISTRIBUTION AT
LOVETT
CONDITIONS: SEVERE SUMMER PERIOD
CRITICAL TIDAL PHASE
TEMPERATURE RISE IN °F
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0.945
0.878
0.811
0.743
0.675
0.608
0.540
0.473
0.405
0.348
0.270
0.203
0.135
0.068
ΔT/ΔP
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

FIGURE E 23

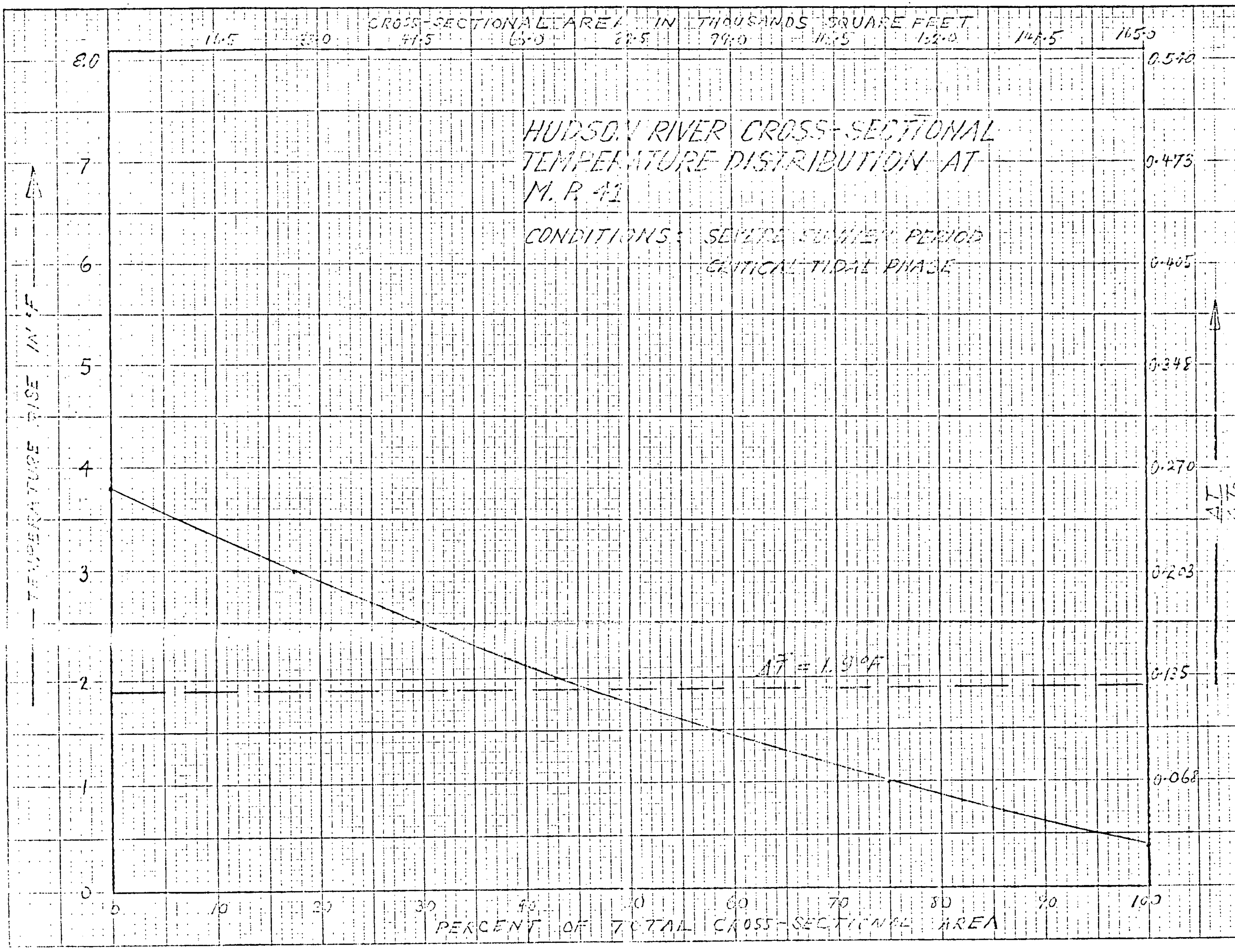

HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AT M. P. 41
CONDITIONS: SEVERE SUMMER PERIOD
CRITICAL TIDAL PHASE
CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
16.5
33.0
49.5
66.0
82.5
99.0
115.5
132.0
148.5
165.0
TEMPERATURE RISE IN °F
8.0
7
6
5
4
3
2
1
0
0.540
0.473
0.405
0.348
0.270
0.203
0.135
0.068
$\Delta\bar{T} = 1.9°F$
PERCENT OF TOTAL CROSS-SECTIONAL AREA
0
10
20
30
40
50
60
70
80
90
100

FIGURE E24

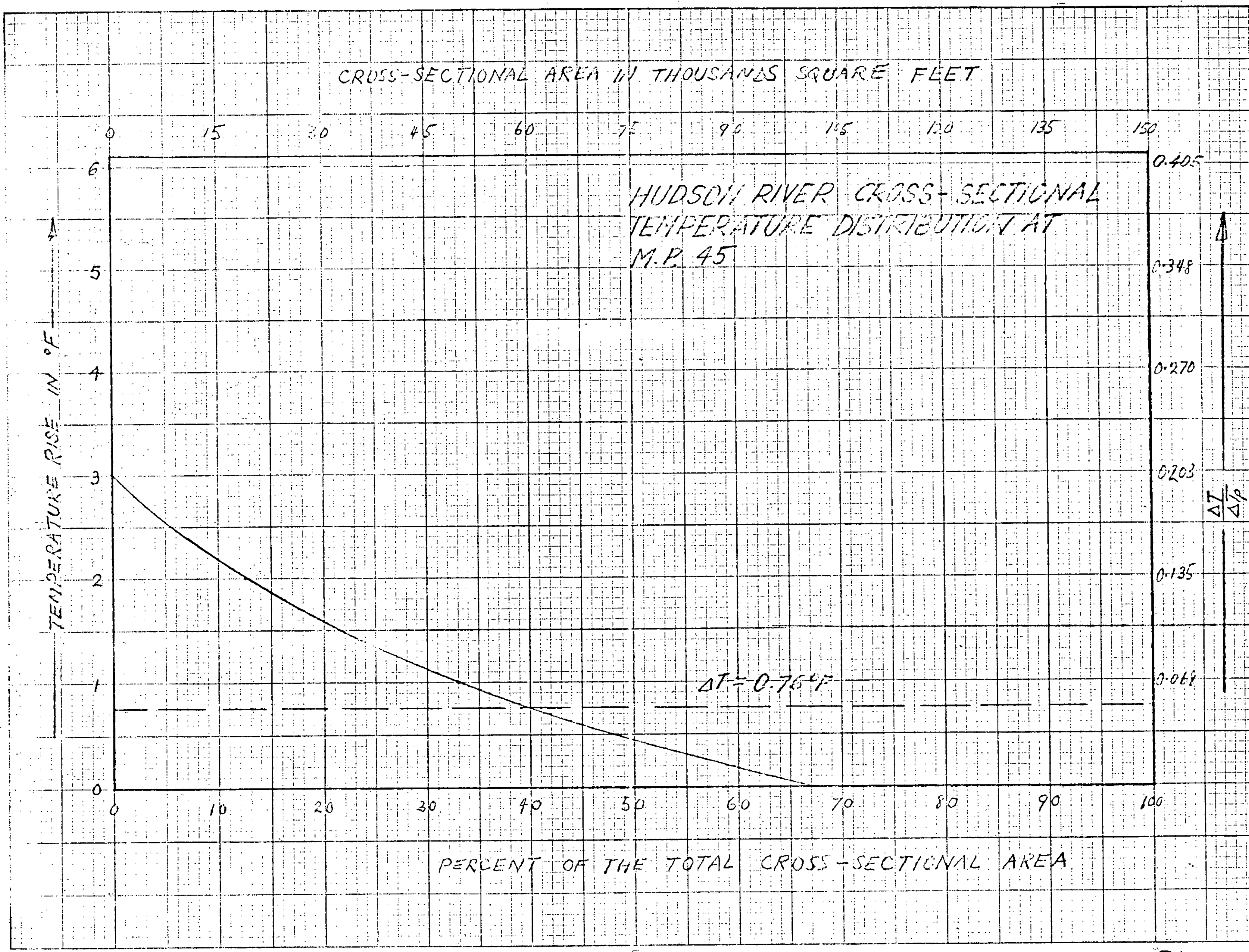

CROSS-SECTIONAL AREA IN THOUSANDS SQUARE FEET
0
15
30
45
60
75
90
105
120
135
150
HUDSON RIVER CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AT M.P. 45
TEMPERATURE RISE IN °F
6
5
4
3
2
1
0
0.405
0.348
0.270
0.203
0.135
0.068
$\frac{\Delta T}{\Delta T_P}$
$\Delta T = 0.76°F$
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF THE TOTAL CROSS-SECTIONAL AREA

FIGURE E.25

APPENDIX EE

(1) "Testimony of John P. Lawler on the Effect of Indian Point Units 1 and 2 Cooling Water Discharge on Hudson River Temperature Distribution," April 5, 1972

(2) "Supplemental Study of Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution", Quirk, Lawler and Matusky Engineers, May 1972.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

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

Testimony of
John P. Lawler,
Quirk, Lawler & Matusky Engineers,
on
The Effect of Indian Point Units 1 & 2
Cooling Water Discharge on
Hudson River Temperature Distribution

April 5, 1972

TABLE OF CONTENTS

SUMMARY OF

FINDINGS, CONCLUSIONS & RECOMMENDATIONS

1. This report summarizes work done by Quirk, Lawler & Matusky Engineers from 1967 to date on the expected effect of thermal discharges from the Indian Point nuclear units 1 and 2 and the Lovett fossil-fueled units 1 through 5 on the temperature distribution in the Hudson River. Previous studies showed that the effect of the Danskammer station will have been dissipated to the atmosphere well before it reaches Indian Point.

   The objective of this evaluation is to predict the thermal effect and to determine compliance with the NYSDEC thermal discharge criteria. These criteria require that temperature rises of 4°F shall not be exceeded over more than two-thirds of the river surface width nor over more than one half the cross-section and a maximum surface temperature of 90°F at any point.

   The presence of the Lovett Plant about one mile downstream of Indian Point has required detailed investigation of this reach and the interaction between the two plants.

2. Maximum cooling water flow including service water for Indian Point 1 & 2 will be 1,188,000 gpm. Should both units be operated at their maximum capacity, the waste heat which is discharged to the river will amount to 200 BBTU/day. This waste heat will increase the cooling water temperature by 14.8°F. Design values corresponding to the individual Indian Point units are summarized below:

	Indian Point Unit 1	Indian Point Unit 2
Rated Capacity, MWE	265	873
Cooling Water Flow, gpm	280,000	840,000
Service Water, gpm	38,000	30,000
Unit Temperature Rise at Rated Capacity, °F	14	15.1
Heat Load at Rated Capacity, BBTU/day	47	153

3. The combined effluent will be discharged through seven of the twelve slots of the submerged discharge outfall for three units. The final three unit outfall design will consist of twelve 4' x 15' slots, spaced on 20 ft. centers, submerged 12 feet below the water's surface, and discharging at 10 fps normal to the River's longitudinal axis. This design was selected after extensive testing in an undistorted hydraulic model of the outfall site at the Alden Research Laboratory. Ten of these slots are equipped with fully adjustable gates to insure an initial jet velocity of 10 fps for any combination of units in operation.

   The original depth of submergence was 18 ft. This was changed to 12 feet to improve mixing of the effluent with the ambient water by entrainment of river water from the lower layer and to minimize river bottom scour action. Recent hydraulic model tests showed that the revised outfall design produced lower overall temperatures.

   Extensive hydraulic model and analytical studies of the outfall indicated that the revised design would produce a maximum surface temperature rise of 8°F under rated capacity operation conditions. In addition, studies of thermal recycling showed combined recirculation effects of 1°F.

4. The maximum naturally occurring river water ambient temperature in the vicinity of Indian Point is 79°F. This value is considered to be the highest ambient water temperature that can be experienced by the intake at any time. Review of available Hudson River temperature measurements over more than a ten year period shows that the highest ambient temperatures normally occur in August. During this summer period, the maximum surface temperature rise of 8°F and the recirculation effects of 1°F will result in a maximum surface temperature of 88°F. This indicates that the 90°F maximum surface temperature NYS criterion at any point can be met always.

5. Several mathematical models describing the hydrodynamic characteristics of interest to this study and the response of the Hudson River to thermal discharges have been developed. These models employ measurable or known characteristics of the Hudson River and prevailing meteorological conditions to describe the distribution of temperature resulting from continuous thermal discharges. These models are applicable to freshwater flow conditions as well as to salinity intrusion flow conditions and incorporate the influence of convection by river flow, dispersion by tidal turbulence and density induced circulating currents associated with ocean-derived salt intrusion and heat transfer across the water surface by convection, evaporation and radiation.

These mechanisms were incorporated in an early model developed to describe the decay of the tidal-smoothed, area-averaged temperature rise along the longitudinal axis of an estuary subject to heated water discharges. This model, however, when used to predict temperature, is considered to be conservative; i.e., predicted temperature rises for known thermal loads are greater than field measurements of temperature rises in the vicinity of those loads.

More recent refinements to describe the observed phenomena have been developed. These modifications recognize the increase in thermal stratification as one moves away from the plane of discharge and the use of the known phenomenon of net non-tidal flow or density-induced circulation in the saline reaches of estuaries.

The increase in thermal stratification is supported by observations at several existing power plant sites on the Hudson River. Theoretically, this increase should be expected, because the surface should be the last zone to see elevated temperature rises before complete elimination of all residual excess heat.

Partially stratified estuaries, in which class the Hudson River falls, are subject to a net upstream movement of sea water in their lower layers and a downstream movement in their upper layers. This movement is induced by density differences which exist on account of the vertical and longitudinal salinity distribution. This effect is called the net non-tidal flow or density induced circulation.

The existence of the net non-tidal flow concept has been established by several authors. This study has utilized numerous Hudson River tidal current and salinity surveys to establish its existence in the Hudson River and to derive a quantitative relation of net non-tidal flow to salinity levels and freshwater runoff.

6. The mathematical models and field observations of the previous item indicate that the minimum river flow available for dilution at Indian Point is the freshwater flow value of 20,800 cfs for which the salt just reaches Indian Point. Freshwater values higher or lower than this value provide more dilution flows due to contribution of more river runoff or density-induced circulation, respectively. Inspection of the Hudson River long term monthly average freshwater flow records indicates that a monthly average flow of 20,800 cfs occurs during May.

7. This study has evaluated the Indian Point thermal effect corresponding to several possible combinations of hydrological

and meteorological conditions including:

a- severe drought flow occurring during periods of low heat transfer rates.

b- critical low freshwater flow, summer conditions.

c- non-summer conditions characterized by absence of ocean-derived salt at Indian Point and low heat transfer rates.

d- incipient salt flow condition of 20,800 cfs occurring during certain winter months characterized by a low heat transfer coefficient of 90 BTU/sq ft /day/°F.

Detailed evaluation of these conditions indicated that the last set (item d above) represents the most severe set of hydrology and meteorology that can occur at Indian Point. This set of conditions coupled with rated capacity operation of two nuclear units at Indian Point (1138 MWE) and five fossil-fuelled units at Lovett (503 MWE) has been designated as the condition of maximum severity in this study.

8. Maximum surface temperature and percentages of cross-sectional area and surface width expected to experience temperature rises equal to or greater than 4°F above naturally occurring maximum ambient temperature at Indian Point and corresponding to the conditon of maximum severity are given below:

	Prediction		
Parameter	Tidal Average	Critical Tidal Phase	NYSDEC Criterion
% area bounded by 4°F	16	22	50
% surface width bounded by 4°F	24	32	67
Maximum surface temperature, °F			90

These results indicate that in all cases, the predictions are less than the New York State thermal discharge criteria. These predictions reflect the combined effect of rated capacity operation of Indian Point Units 1 and 2 and Lovett Units 1 through 5. However, to generalize the results, the following tabulation relates the extent of compliance with the controlling criterion (surface width bounded by 4°F) with several unit 2 power levels and rated capacity operation of Indian Point unit 1 and Lovett units 1 through 5.

Indian Point Unit 2 power level % full capacity	Maximum % surface width bounded by 4°F	
	Critical tidal phase	% of NYS Criterion
0	12	18
50	21	31
90	30	45
100	32	48

9. The above presented predictions were estimated using the mathematical models presented in this study and are based upon several assumptions. These assumptions are either conservative or derived from extensive field observations and hydraulic model studies. These models have been used to evaluate several existing and planned thermal effluents and industrial discharges along the main stem of the Hudson River and other New York State waterbodies. These models reflect our most recent thinking on the response of the river to thermal loads. Considerable additional development and modification has occurred since the January 1968 Indian Point report was submitted.

   Use of these models has resulted in good agreement with numerous dissolved oxygen, BOD and salt field surveys in a number of waterbodies. However, temperature measurements at all existing Hudson River and a number of East River and Arthur Kill plants yield lower temperature rises than predicted by any of the various thermal models. One of the major difficulties in testing the two unit operation predictions with Indian Point field data prior to operation of Unit 2 is the lack of a significant quantity of heat and cooling water flow in the Unit 1 discharge. Temperature rises beyond the immediate vicinity of the discharge are very small, and tend to be masked by natural variations in the river and instrument precision.

10. In conclusion, confidence in these models has been established since they have been successful in predicting the observed concentration of water quality parameters and in producing conservative estimates of the distribution of temperature resulting from known heat loads. We believe, therefore, that the distribution of temperature for two unit operation, computed using the mathematical models as well as the hydraulic models for reference, will not contravene the New York State criteria.

I. Introduction

This document presents a summary of studies conducted by Quirk, Lawler & Matusky Engineers (QL&M) from 1967 to date on the effect of thermal discharges from the Indian Point Units 1 and 2 on the distribution of temperature in the Hudson River. These studies have been presented in a number of reports*, hearing testimony** and meetings with the AEC.

Results of these studies are delineated in this summary report and reference should be made to the documents themselves for complete details, supporting data and calculations.

This report is formatted as follows. A brief discussion of the analytical investigations of the hydrodynamic characteristics and the response of the Hudson River to thermal discharges is given in item II.

Item III utilizes the hydrodynamic mathematical models and available field data developed in the previous item to determine the Hudson River mixing characteristics and circulation patterns. Selection of the numerical values of other system parameters which control the transport of mass and energy are also given in item III.

Item IV employs the thermal models of item II and the numerical values of the system parameters of item III to predict the effect of existing power plants and Indian Point Unit 2 on the distribution of temperature in the Hudson River.

Applicability of the mathematical models employed in this study in light of available field and hydraulic model measurements is evaluated in items II, III, and IV.

II. Mathematical Models

Several thermal and isothermal mathematical models describing the hydrodynamic characteristics and the response of the Hudson River to thermal discharges have been developed.

The thermal models employ the hydrodynamic characteristics of the Hudson River (measured and/or obtained using the isothermal models) and prevailing meteorological conditions to describe local as well as overall temperature distribution resulting from a heated effluent.

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* A list of these reports and related publications is given in Appendix A of this summary report.

** During November - December 1971 and January 1972 Docket No. 50-247

\+ on September 3, 1971 and February 7, 1972

The isothermal models utilize known or measureable physical and hydraulic parameters and were used to obtain a quantitative estimate of density induced currents and flow available for dilution in the Hudson River.[8]

A brief description of these models is given below.

A. Submerged Discharge (Local) Model[4]

The 1968 and 1969 QL&M studies indicated that the criterion of a maximum surface temperature of 90°F at any point could not be met with a surface discharge. Hydraulic model studies conducted by Alden Research Laboratories showed that the 14°F effluent channel temperature rise can be reduced markedly, before reaching the river's surface, by discharging the cooling water through a submerged discharge. Model studies showed that rectangular ports located along the discharge canal would yield maximum surface temperatures substantially lower than the 90° criterion.

In October 1969, QL&M prepared for Con Edison a report on "Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution".[4] This study consisted of the development of a mathematical model which is based on a consideration of the fluid mechanics of submerged jets, a comparison of the theoretical model to observations of actual submerged jet behavior made in the Alden model and in the Hudson River, and a prediction of behavior of Indian Point under a different and more severe set of conditions than those studied in the hydraulic model.

The mathematical model consists of a set of twelve simultaneous equations. It incorporates the effect of plant intake temperature, density and salinity, plant outfall temperature, density, salinity and flow, outfall geometry, including port size, shape, edging, orientation, and submergence, and linear velocity (both runoff and tidal), tidal phase, and ambient temperature, density and salinity.

The assumptions made in the development of this model are that initial jet momentum, induced buoyancy, and entrained river flow and momentum are the controlling mechanisms and that drag force and river boundaries, such as bank, surface and bottom can be neglected.

The computed results agree in general with measurements made in the undistorted hydraulic model, and with measurements taken in the river in the vicinity of the submerged outfall of Orange & Rockland Utilities' Lovett Unit #4.[4,]

B. Overall Thermal Models[2,3]

1. Convection - Dispersion Models

Several mathematical models have been developed to predict the effect of power plant thermal discharges on receiving tidal waterways, such as the Hudson River. These models utilize the hydrodynamic characteristics of the waterway and meteorological conditions to describe distribution of temperature from a heated effluent. The mechanisms considered include convection, dispersion by tidal turbulence and density induced circulating currents, and heat transfer across the water surface by convection, evaporation and radiation.

These mechanisms were incorporated in an early model developed to describe the decay of the tidal-smoothed, area-averaged temperature rise along the longitudinal axis of an estuary subject to heated water discharges. To determine the distribution of temperature across a river cross-section, empirically developed mathematical relationships have been employed to relate near field behavior to the overall area-averaged temperature rise. These were "the exponential decay model" and the "reciprocal decay model".[3]

The "exponential decay model" represents temperature as an exponentially decreasing function of river cross-sectional area. The "reciprocal decay model" represents temperature as being approximately inversely proportional to river area, as one moves from the point of discharge out across the river's cross-section.

These models, however, when used to predict temperature, must be considered to be conservative, i.e., predicted temperature rises for known thermal loads are greater than field measurements of temperature rises in the vicinity of those loads.

This characteristic was first observed in utilization of an early segmented model to predict temperature distribution in the vicinity of Indian Point.[2]

This model consisted of equilibrium behavior of a transient, variable space parameter, one dimensional energy transport equation. For the sake of introducing the system parameters used in the segmented model, its infinite receiver, constant parameter, steady state analog is given in Table 1.

TABLE 1

Infinite Receiver, Constant Parameter,

Steady State, One Dimensional Energy Transport Model

$$\left.\begin{matrix}\Delta\overline{T}_{I} \\ \Delta\overline{T}_{II}\end{matrix}\right\} = \frac{H \exp\left[\frac{U}{2E}\left(1 \pm \sqrt{1 + \frac{4K'E}{U^2}}\right) X\right]}{\rho C_p Q \sqrt{1 + \frac{4K'E}{U^2}}}$$

in which:

$\Delta\overline{T}$ = area-averaged temperature rise, °F

I - designates behavior above discharge
II - designates behavior below discharge

H = thermal discharge, BTU/day

ρ = water density, #/ft^3

C_p = heat capacity, BTU/# °F

Q = river freshwater flow, ft^3/day

A = cross-sectional area of the estuary, ft^2

U = freshwater velocity, Q/A, miles/day

E = longitudinal dispersion coefficient, mile^2/day

X = distance from plane of discharge (positive direction downstream), miles

K' = temperature decay coefficient. $\frac{\overline{K}\cdot B\cdot TSF}{\rho\cdot C_p\cdot A}$, day^{-1}

$\overline{K}$ = heat transfer coefficient, BTU/ft^2 day °F
B = surface width, ft
TSF = thermal stratification factor, $\Delta\overline{T}_s/\Delta\overline{T}$
$\Delta\overline{T}_s$ = surface average temperature rise, °F

Substantial additional effort since that time has been directed toward developing a model which will accurately describe the rapid observed rate of temperature decay. A summary of this progress follows.

Use of the segmented model to predict seasonally varying temperature rises at Indian Point is shown in Figure 1. These data are taken from Reference 2. Since the heated discharge is located at Indian Point, the given area averaged values, which represent behavior across the plane of discharge, are the maximum temperature rises expected due to this discharge. Temperature rise decreases in both upstream and downstream directions as one moves away from the plane of discharge.

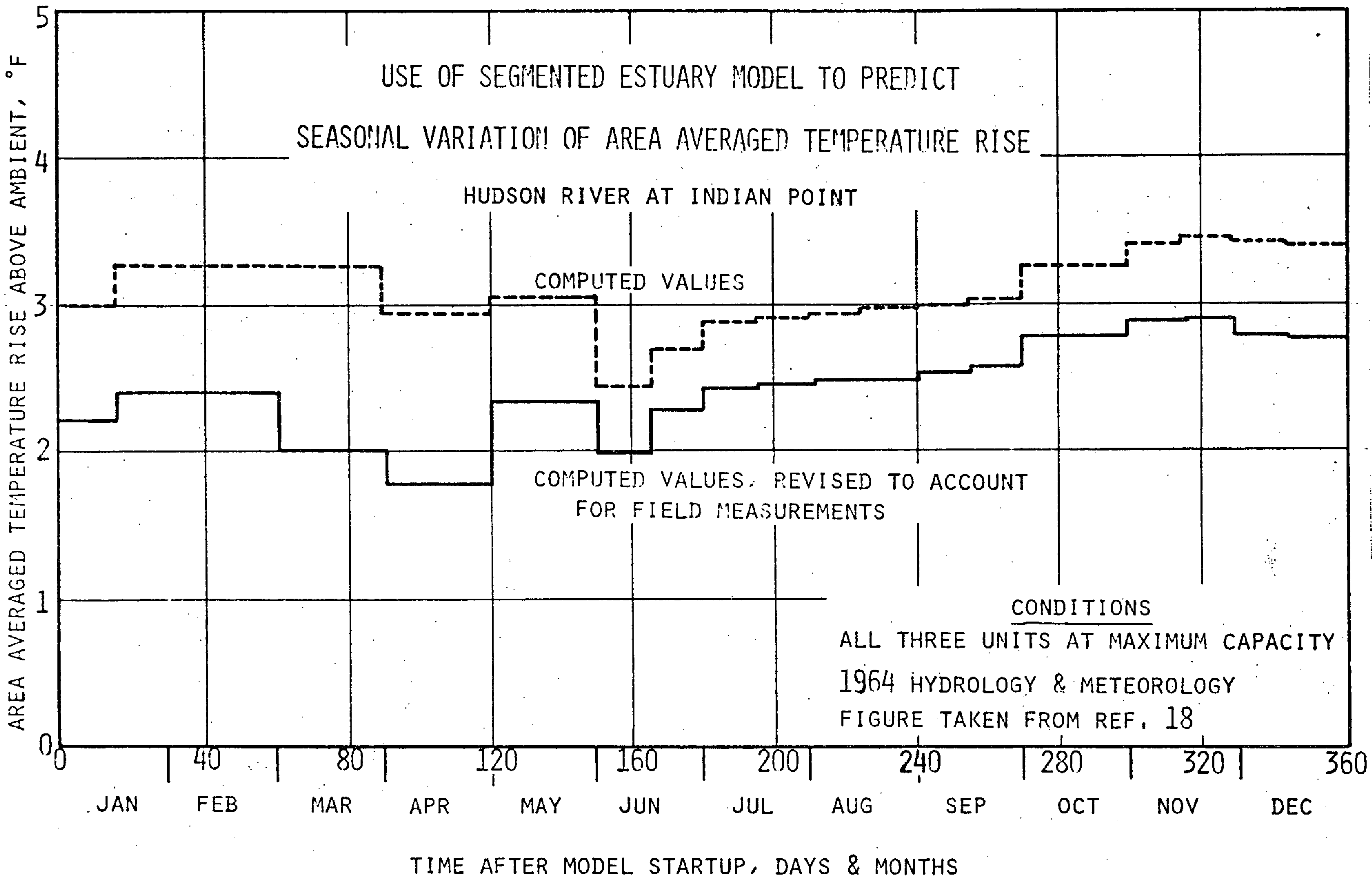
The lower curve in Figure 1 represents the expected area-averaged performance for three unit "stretched" operation at Indian Point, based on observed performance for the existing single unit.

Actually, the difference between the measured and predicted temperature rises at the plane of discharge only begin to suggest the inadequacy of the one-dimensional segmented model for use in predicting thermal effects. The rate at which elevated temperatures are observed to decay to ambient temperature conditions is much faster than that suggested by the segmented model.

These conclusions were drawn by comparing model results for one unit operation to river temperature measurements made in the vicinity of the Indian Point Unit No. 1 discharge by Northeastern Biologists, Incorporated (NBI), in July 1966 and April 1967.

Table 2 presents this comparison. For July 1966, the predicted temperature rise was 25% higher than the actual temperature rise at the plane of discharge and 69% higher than the actual temperature rise at a cross-section 800 feet downstream of the plane of discharge. Correspondingly, for April 1967, the predicted temperature rises were 85% and 100% higher than the measured temperature rises.

These area-averaged values are extemely small and the validity of the comparison could be questioned, i.e., one might consider temperature rises of 0.1 to 0.2°F to be negligible and conclude comparison of such results to be unacceptable.



USE OF SEGMENTED ESTUARY MODEL TO PREDICT
SEASONAL VARIATION OF AREA AVERAGED TEMPERATURE RISE
HUDSON RIVER AT INDIAN POINT
COMPUTED VALUES
COMPUTED VALUES, REVISED TO ACCOUNT FOR FIELD MEASUREMENTS
CONDITIONS
ALL THREE UNITS AT MAXIMUM CAPACITY
1964 HYDROLOGY & METEOROLOGY
FIGURE TAKEN FROM REF. 18
AREA AVERAGED TEMPERATURE RISE ABOVE AMBIENT, °F
0
1
2
3
4
5
0
40
80
120
160
200
240
280
320
360
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
TIME AFTER MODEL STARTUP, DAYS & MONTHS

FIGURE 1

TABLE 2

Comparison of Predicted and Measured Area-Average Temperature Rises

Hudson River Near Indian Point

Location	Area-Average Temperature Rise[1]					
	July 1966			April 1970		
	Measured °F	Predicted °F	Predicted / Measured	Measured °F	Predicted °F	Predicted / Measured
Across Plane of Discharge	0.2[1]	0.25[1]	1.25	0.093[1]	0.172[1]	1.85
Across Plane 800 ft. below Discharge	0.145[2]	0.245[3]	1.69	0.0825[1]	0.17[3]	2.06

1 Data taken from Reference 2, Table 1 and pages 9, 11 and 21

2 Obtained from field data by same procedures outlined in Reference 2 to obtain plane of discharge averages

3 Computed using unrevised one-dimensional mathematical models

4 Table 4, Reference 3

This objection is answered by pointing out that these area-averages represent the weighted effect of significant temperature rises near the east shore of each cross-section considered, and zero temperature rises over most of the remainder of the cross-section. The very small area-averages are merely the result of measurable temperature rises over less than 10% of the cross-section, reduced by the ratio of the affected area to the total area of some 160,000 sq. ft.

The methods used to compute the measured area-average temperature rise are given in detail in Reference 2. Additional discussion of the validity of the comparison described above is given in Reference 3.

Further evidence of the phenomenon of very rapid rate of elevated temperature loss has been subsequently observed in the Hudson River at the Danskammer Point Station and at the Lovett Station, as well as in the East River in the vicinity of several generating stations.

A number of modeling approaches have been employed to try to explain observed estuarine elevated temperature decay behavior. The first of these represents a semi-empirical approach, in which the single plane source, steady state, infinite receiver analog of the segmented model, Table 1, was employed, with correction factors, to force the predicted results of the segmented model to agree with field measurements. This approach is employed in Reference 3 to revise earlier[2] predictions made on the influence of the Indian Point plant on Hudson River temperature distribution.

This approach is useful in that results are forced to agree with field observations, but is limited because it does not explain the reason for rapid decay behavior. Secondly, although the receiver is assumed to be of infinite length, the results are only valid in the general vicinity of the discharge, since continuation of the decay at the same rapid rate does not permit either atmospheric dissipation or known dilution mechanisms to account for the loss of all the heat.

More recent attempts to describe the observed phenomena include the use of a variable stratifaction factor in the non-saline intruded reach of the estuary and the use of the known phenomenon of net non-tidal flow or density induced circulation in the saline reaches of the river.[5,8]

Due to the importance of the density induced circulation concept in estuarine thermal discharges, a brief description of this concept, its existence in the Indian Point area and validity of its use in thermal discharges is given below.

2. <u>Density Induced Circulation Models</u>

The tidal flow in the Hudson River is relatively large, as indicated by a maximum tidal flow of 667,500 cfs at the Battery by comparison to the freshwater flow, which ranges between 4,000 to 50,000 cfs with an average of some 15,000 cfs. Due to this tidal motion, turbulent eddies generated by a portion of the total tidal energy mix the lighter freshwater downwards and the heavier saltwater upwards.

As a result of this action, the density and water volume of the upland runoff which flows downstream through the estuary to the ocean increases and the density of the seawater which intrudes upstream through the ocean entrance decreases.

To compensate for the increase in the volume of the seaward flowing layer, more ocean-derived water invades the estuary and flows beneath the lighter freshwater. Thus, a circulation pattern in which the water moves downstream in the upper layer and upstream in the lower layer is developed.

The upper layer and lower layer flows associated with this net circulation pattern may be many times that of the upland runoff which is the actual difference between the upper and lower layer flows. Values ranging from ten to forty have been observed in several estuaries.[8]

The kinetic energy required to power this circulation is provided by the increase in the potential energy of the water. This increase is caused by vertical mixing resulting from the tide power-induced turbulence. Analysis of numerous tidal velocity and tidal amplitude observations in the Hudson River suggests a definite linear relationship between the tidal power and upper layer flow.

It is clear from the above discussion that only the saline portion of estuaries experiences significant density induced circulation patterns. In other words, this effect is weakest where salt is not present, which is the case at Indian Point when the freshwater flow exceeds about 20,000 cfs.

Results of Reference 8 indicate that this flow value represents non-summer conditions and corresponds to river ambient temperatures ranging between 35°F and 50°F, i.e., they do not occur during periods of maximum ambient temperature.

During summer months, when river ambient temperatures reach a maximum of 79°F, the freshwater flow in the Hudson ranges between 6,000 cfs and 12,000 cfs. For these flow conditions, the Indian Point reach is within the saline portion of the Hudson River.

Study results, given in Reference 8 and summarized in item III, show that the upper layer flows corresponding to these freshwater flows range between 21,500 cfs and 35,000 cfs at Indian Point and between 30,500 cfs and 38,000 cfs at Bowline. Further discussion of these results is given in item III.

The net circulation pattern described above is related to the net velocity distribution which, by and large, is a result of dynamic interactions between the tidal current and density distributions. The presence of the river upland runoff and the density difference between fresh and sea water control these distributions.

Therefore, density induced circulation patterns may be measured through evaluation of long term current and/or salinity (density) observations, at various depths throughout cross-sections, within the salt intruded reach, and over a full tidal cycle.

Several mathematical models expressing the above described principles and relating density induced circulation to salinity and velocity distributions have been developed. Published techniques[8] developed by several investigators and recently established methods arrived at in the course of this study are used in this report to convert all available Hudson River current observations (nine surveys) and salinity measurements (twenty sets of data) to density induced flow rates. These surveys are listed in Tables 3 and 4.

These methods are given in Chapter IV and used in Reference 8 to determine the upper layer flow in the Hudson River. In estimating these flows, every effort was made to make all the necessary assumptions as conservative as possible and the methods developed were closely verified using published data.

TABLE 3

INVENTORY OF HUDSON RIVER VELOCITY DATA

Year	Conducted or Reported by	Survey Duration	River Section Covered (miles above Battery)	Reference Number*
1919	Winston	Aug. 25-Nov. 4	0 to 14	42
1922	Denson	July 16-Aug. 30	1 to 16	42
1929	Finnegan	Aug. 29-Sept. 14	15 to 153	42
1932	Rittenburg	June 29-Aug. 31	5 to 15	42
1932	Corps of Engineers	July 22-Aug. 18	0.5	42
1952	Stewart	May 24-June 23	15 and 55	43
1957	Corps of Engineers	April 23-26	0 to 11	46
1958-59	Marmer	Oct. 7-16 April, June	35 and 50 35 and 50	44 44
1965	USGS	August 11	75	47

* As listed in the bibliography of Reference 8

TABLE 4

INVENTORY OF HUDSON RIVER SALINITY SURVEYS

Survey	Year
USC&GS density observations	1929
NYS Conservation Department	1936
USGS Surveys	1949 and 1951
Corps of Engineers	1957
NYC DH & NYS	1959
Indian Point Measurements	1958 - 1966
Danskammer Point Measurements	1958 - 1966
USGS Surveys	1962 and 1963
ISC Bay Measurements	1964
QL&M Kyma Survey	1964
FWPCA Survey	1965
NYCDWS Chelsae Measurements	1965
Michigan State University Survey	1966
QL&M Copter Survey	1966
QL&M Salinometer Survey	1966
NYSDH Copter Survey	1967
NYSDH Boat Survey	1967
USGS Intrusion Front Surveys	1968 and 1969
NYU Indian Point Measurements	1968 and 1969
QL&M Lovett, Danskammer and Bowline Surveys	1969 and 1970

Considerable attention has been paid to the validity of the use of upper layer flows in thermal discharge problems. Rigorous exposition of the basic principles considered in thermal discharge studies showed that the Bowline effluent, for example, will rise to the surface, remain in the upper layer, resist intermingling with the lower layer and be carried with the upper layer flow. The analysis showed that the effluent will increase the stability of the system by a factor of 2.25. Subsequent analysis showed similar results at Indian Point.

In addition to the above-described Convection-Dispersion models, models[8] applicable to saline regions have been used. These models incorporate the variation in the upper layer flow, channel geometry and continuous heat dissipation to the atmosphere with and without the contribution of longitudinal dispersion.

As indicated earlier, the effect of density induced circulation is weakest at the upstream end, or front, of the ocean-derived salt intrusion profile. Previous studies have established the overwhelming dominance of the freshwater flow as a control of the salinity front location. Therefore, the absolute minimum flow available for dilution at any location along an estuary is the freshwater value for which the salt front (location of 100 ppm isosal) just reaches that location. This value has been coined the incipient salt flow (ISF) and is equivalent to a freshwater flow value producing a mean salinity concentration of less than 100 ppm at the location of interest.

As will be shown later, an incipient salt flow of 20,800 cfs at Indian Point has been used in this study. Freshwater flow values higher or lower than this value provide more dilution flows due to contribution of more river inflow or density induced circulation respectively. Inspection of the Hudson River long term monthly average freshwater flow records indicates that the 20,800 cfs value occurs during May.

C. Study Conditions

In summary, the discussion in item B indicates that a detailed delineation of the effect of Indian Point units 1 and 2 on the Hudson River should include the following hydrological and meteorological conditions:

1. Indian Point within the Salt-Intruded Reach

Two critical conditions were studied. The condition of maximum severity was defined in Reference 3 as similar to that set of hydrology and meteorology which occurred in late 1964. A sustained six month drought flow of 4,000 cfs and a low heat transfer coefficient of 90 BTU/SF/day/°F, which occurred at that time, were shown, in the January 1968 report, to cause maximum temperature rises.

The critical summer condition consisted of the same flow, but used the August heat transfer coefficient of 135 BTU/SF/day/°F and ambient temperature of 79°F. Although this condition yields lower River temperature rises, it was studied because summer conditions are reported by many to constitute the critical biological condition.

Since these conditions are associated with low freshwater flow conditions, i.e., presence of density induced circulation, and two layer system, the Convection-Dispersion models as well as the density induced upper layer flow model can be used for prediction purposes.

2. Indian Point outside the Salt-Intruded Reach

This set of conditions may occur during non-summer months when the Hudson River freshwater flow is in excess of the Indian Point incipient salt flow. The condition of maximum severity, in this case, may consist of the absolute minimum dilution flow as defined by the incipient salt flow and a low heat transfer coefficient. This condition could occur during certain spring months, particularly during May when the Lower Hudson River flow is about 20,800 cfs and the heat transfer coefficient is about 130 BTU/SF/day/°F.

Due to absence of significant density induced circulation during these conditions, only the Convection-Dispersion models may be used for prediction purposes.

III. Selection of System Parameters

Prediction of the distribution of temperature in an estuary requires a knowledge of the mass and energy transport parameters presented in the previous section. A brief description of these parameters and selection of appropriate numerical values for the study area and seasons are discussed below. No detailed analyses of the data will be attempted here, as these can be found readily in previous QL&M reports and publications.[1-10]

A. River Geometry

The channel's geometry in the study area shown in Figure 2, as defined by cross-sectional area (A), surface width (B) and mean depth (D = A/B) is depicted in Figure 3. The variation is significant and somewhat erratic and may not be accurately described by simple mathematical models.

The Indian Point values are tabulated below:

Cross-sectional area, $ft.^2$	160,000
Surface width, ft.	4,000
Mean depth, ft.	40

B. Mass & Energy Transport Parameters

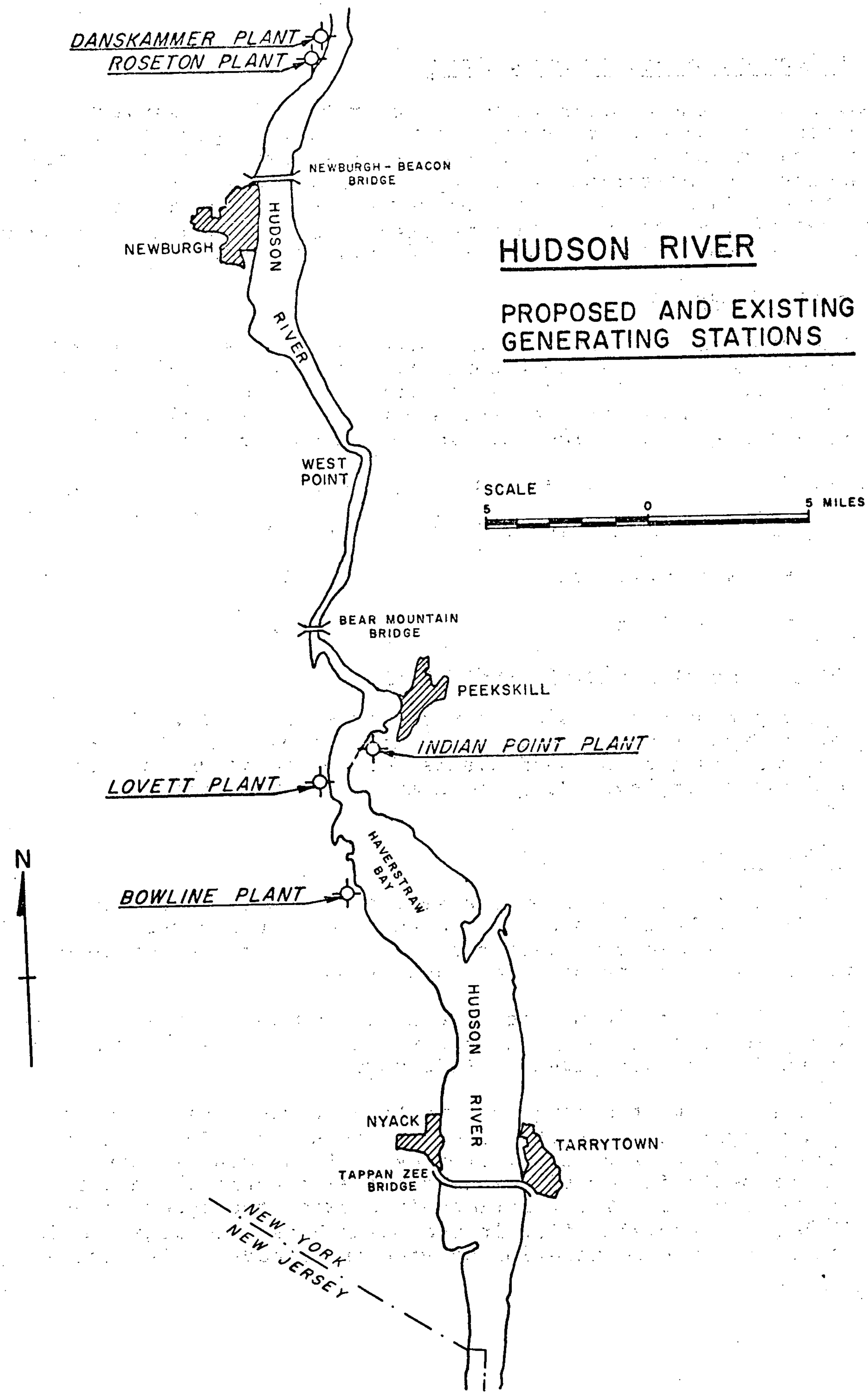
These parameters consist of river freshwater flow (Q_f), upper layer flow (Q_u), total dilution flow (Q_d), longitudinal dispersion coefficients for the total cross-section (E) and upper layer (E_u) and heat transfer coefficient ($\overline{K}$).

C. River Flows (Q_f, Q_u, Q_d)

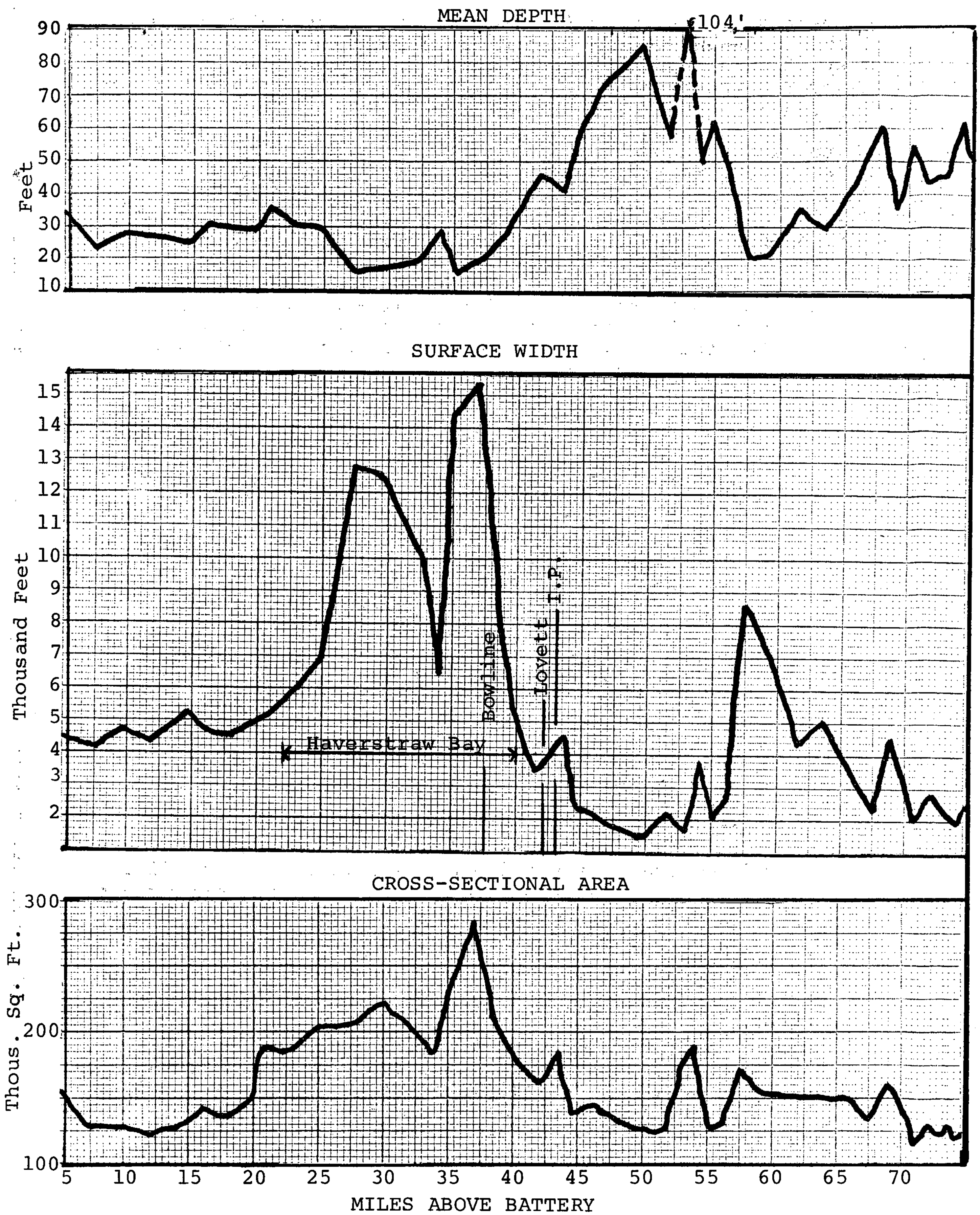
As indicated in the previous section, several river flow conditions have been studied depending upon presence of density induced circulation in the study area and different methods of estimating upper layer flows.

A brief discussion of the numerical flow values used in this study is given below. All other details of these parameters, omitted here, are given in Reference 8.

Figure 4 shows the long term monthly average freshwater and upper layer flows in the Lower Hudson River. These upper layer flows have been computed using long term salinity measurements in accordance with the salt approach described in Reference 8. The relationship between the upper layer flow and freshwater flow in the Lower Hudson is depicted in Figure 5. The correlation between the steady state length


HUDSON RIVER
PROPOSED AND EXISTING GENERATING STATIONS
DANSKAMMER PLANT
ROSETON PLANT
NEWBURGH - BEACON BRIDGE
NEWBURGH
HUDSON
RIVER
WEST POINT
SCALE
5
0
5 MILES
BEAR MOUNTAIN BRIDGE
PEEKSKILL
INDIAN POINT PLANT
LOVETT PLANT
HAVERSTRAW BAY
BOWLINE PLANT
N
HUDSON
RIVER
NYACK
TARRYTOWN
TAPPAN ZEE BRIDGE
NEW YORK
NEW JERSEY

HUDSON RIVER GEOMETRY



of mean salinity intrusion and mean salinity and freshwater flow in the Lower Hudson River is given in Figures 6 and 7 respectively. Figure 8 summarizes the Hudson River upper layer flows computed using salinity as well as tidal current observations.

These five figures (4 through 8) generalize the influence of all relevant parameters on salinity distribution (s vs. x) at Indian Point. These include freshwater flow (Q_f), upper layer flow (Q_u), incipient salt flow (Q_i) and intrusion length (L). The following conclusions may be deduced from these figures:

1. Indian Point is within the salt-intruded reach during the period from June through February. For this period, the following Indian Point flow values are applicable:

   - Freshwater flow ranges from about 6,000 to 15,000 cfs. (Figure 4)

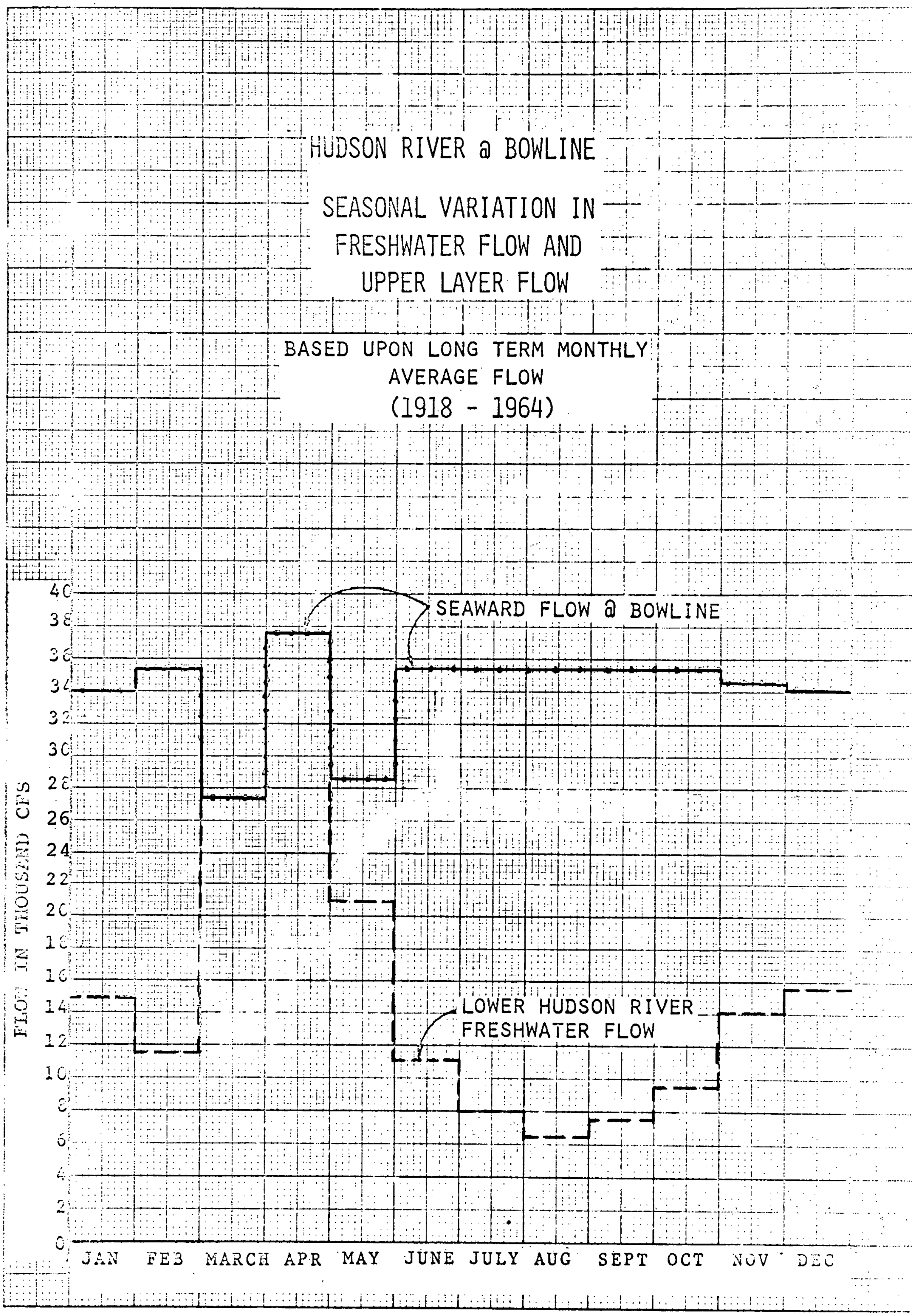
   - On the basis of salinity observations, the upper layer flow ranges from about 20,800 cfs to 35,400 cfs. (Figure 5)

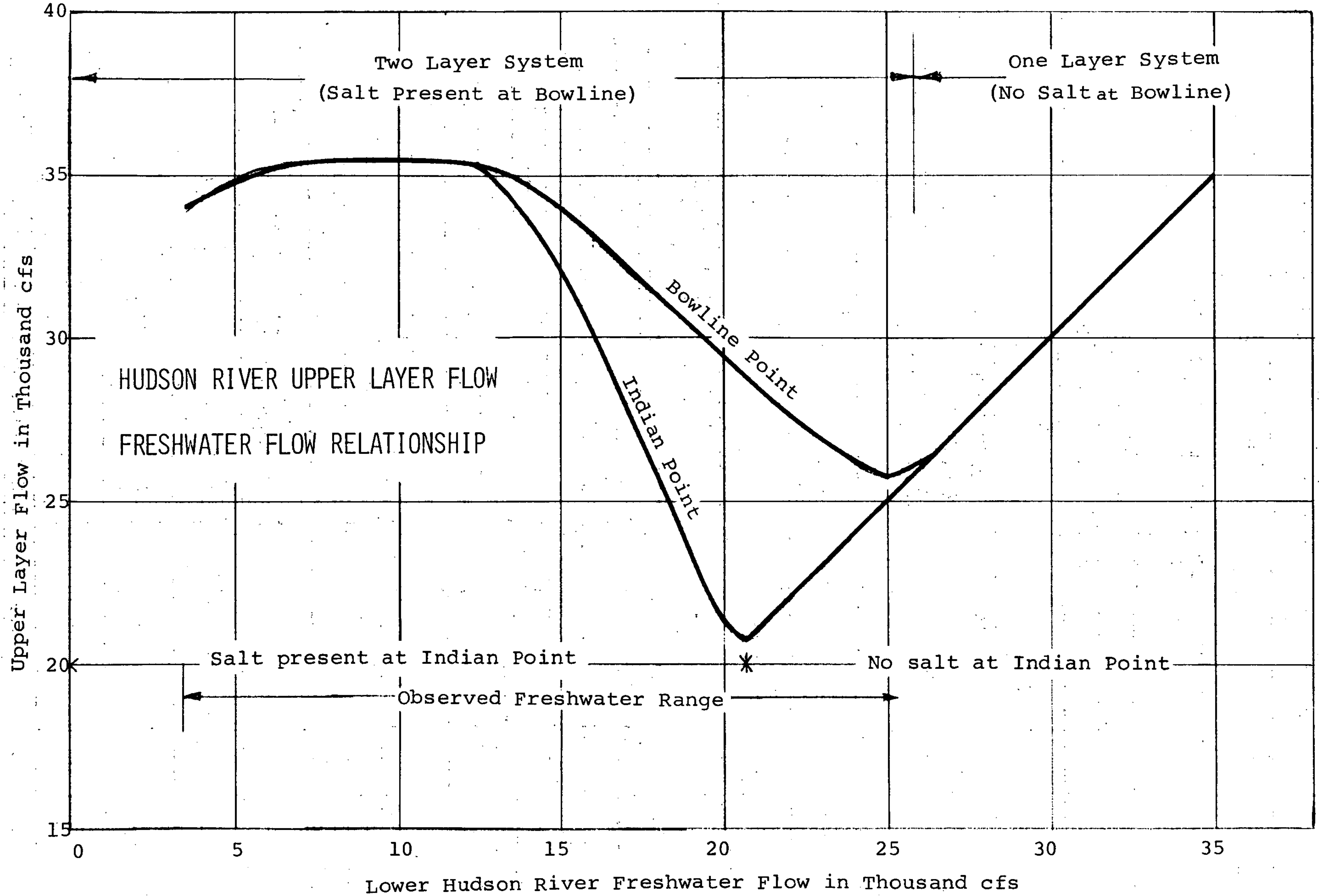
   - On the basis of the 1929 tidal current survey (used to establish Figure 8), the upper layer flow is 21,500 cfs at Indian Point and increases in the downstream direction. Reference 8 has established that values based upon current observations represent conservative estimates.

   Table 5 summarizes results of the density induced circulation studies detailed in Reference 8 and compares the velocity and salinity approaches. 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, and simplicity, ease 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 salt approach results 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.

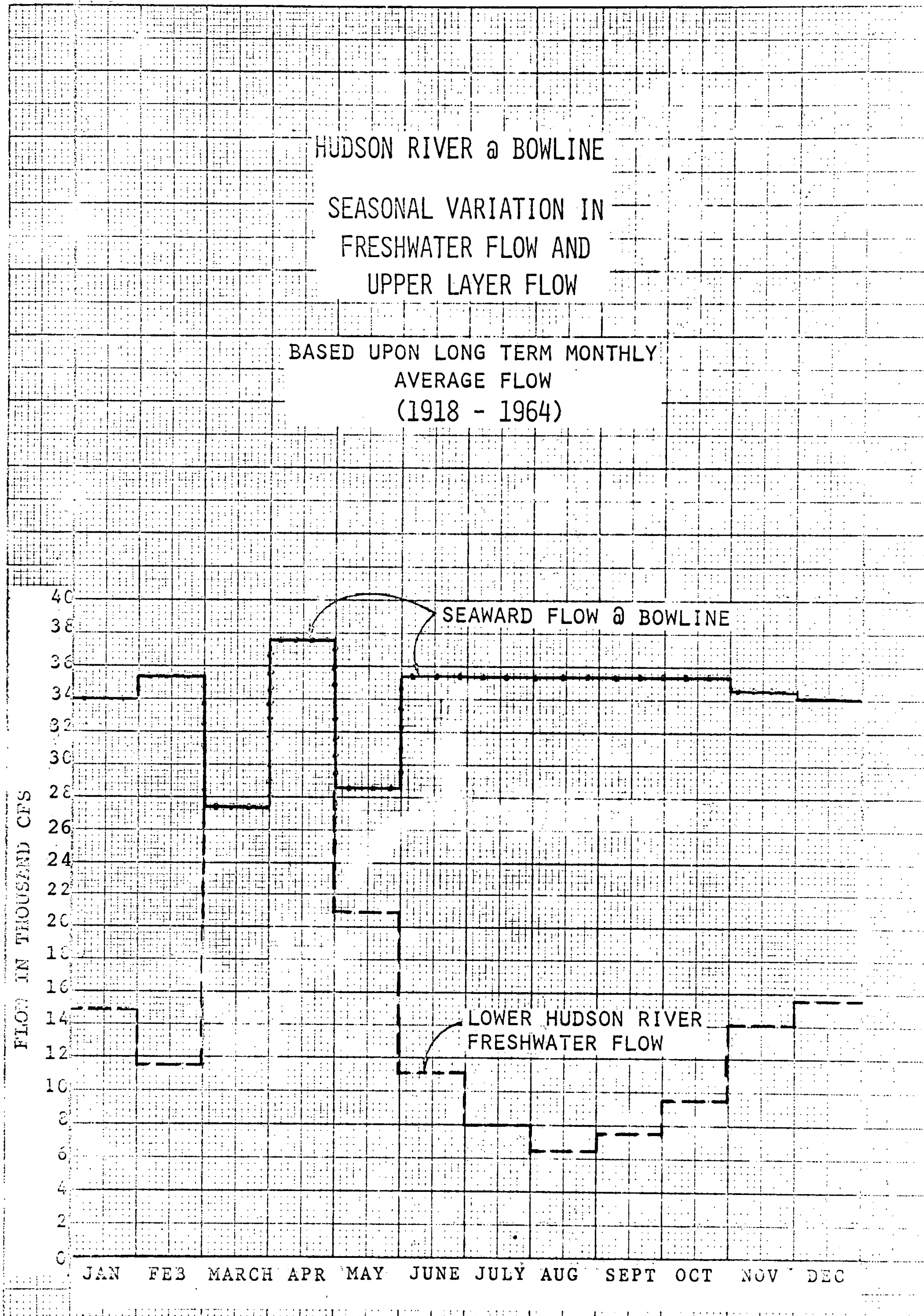

HUDSON RIVER @ BOWLINE
SEASONAL VARIATION IN FRESHWATER FLOW AND UPPER LAYER FLOW
BASED UPON LONG TERM MONTHLY AVERAGE FLOW
(1918 - 1964)
SEAWARD FLOW @ BOWLINE
LOWER HUDSON RIVER FRESHWATER FLOW
FLOW IN THOUSAND CFS
JAN
FEB
MARCH
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC



HUDSON RIVER UPPER LAYER FLOW
FRESHWATER FLOW RELATIONSHIP
Two Layer System
(Salt Present at Bowline)
One Layer System
(No Salt at Bowline)
Bowline Point
Indian Point
Salt present at Indian Point
No salt at Indian Point
Observed Freshwater Range
Upper Layer Flow in Thousand cfs
Lower Hudson River Freshwater Flow in Thousand cfs
40
35
30
25
20
15
0
5
10
15
20
25
30
35

FIGURE 5

FIGURE 4



HUDSON RIVER @ BOWLINE
SEASONAL VARIATION IN FRESHWATER FLOW AND UPPER LAYER FLOW
BASED UPON LONG TERM MONTHLY AVERAGE FLOW
(1918 - 1964)
SEAWARD FLOW @ BOWLINE
LOWER HUDSON RIVER FRESHWATER FLOW
FLOW IN THOUSAND CFS
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
JAN
FEB
MARCH
APR
MAY
JUNE
JULY
AUG
SEPT
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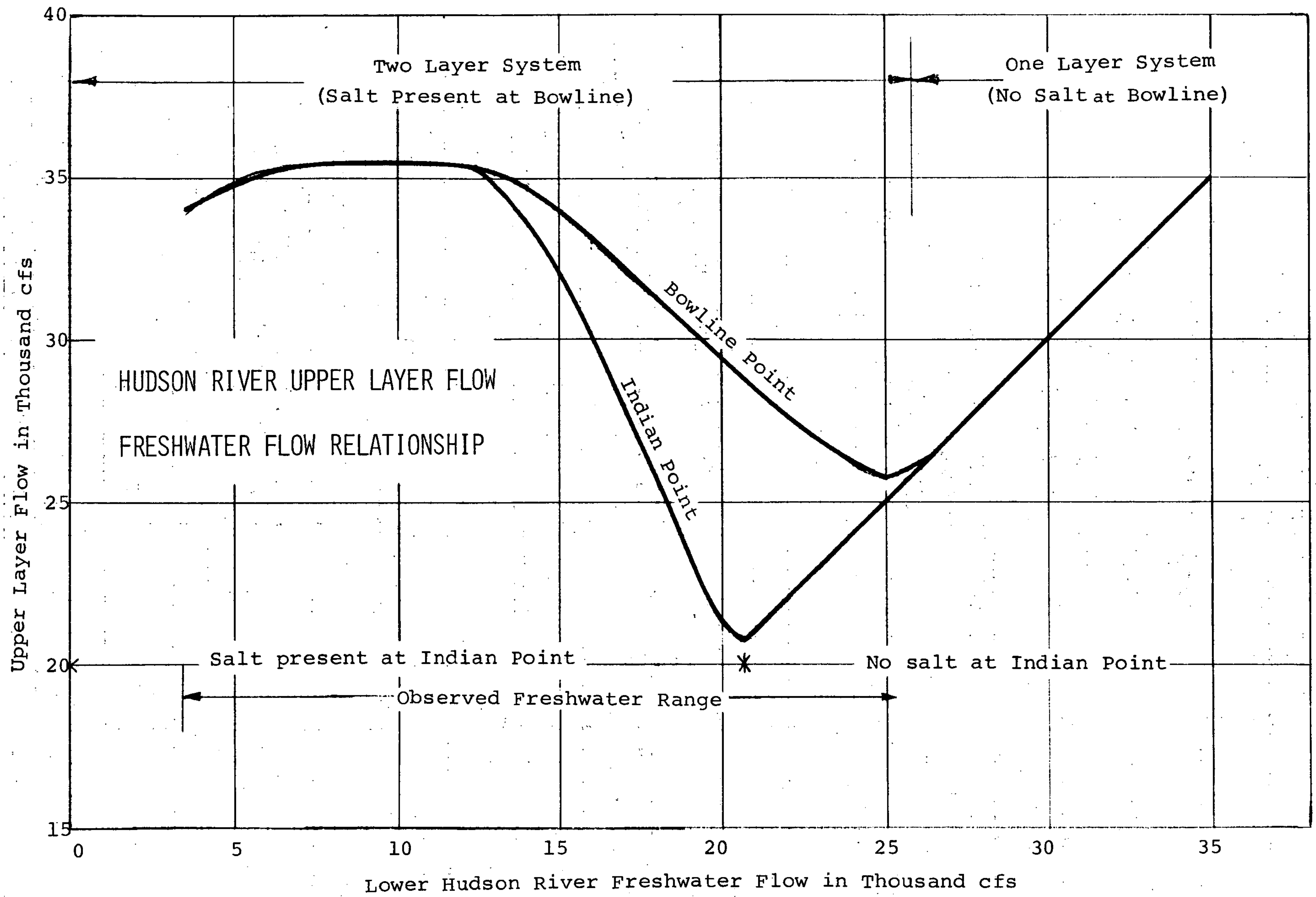


Two Layer System
(Salt Present at Bowline)
One Layer System
(No Salt at Bowline)
HUDSON RIVER UPPER LAYER FLOW
FRESHWATER FLOW RELATIONSHIP
Bowline Point
Indian Point
Salt present at Indian Point
No salt at Indian Point
Observed Freshwater Range
Upper Layer Flow in Thousand cfs
Lower Hudson River Freshwater Flow in Thousand cfs
40
35
30
25
20
15
0
5
10
15
20
25
30
35

FIGURE 5

FIGURE 6

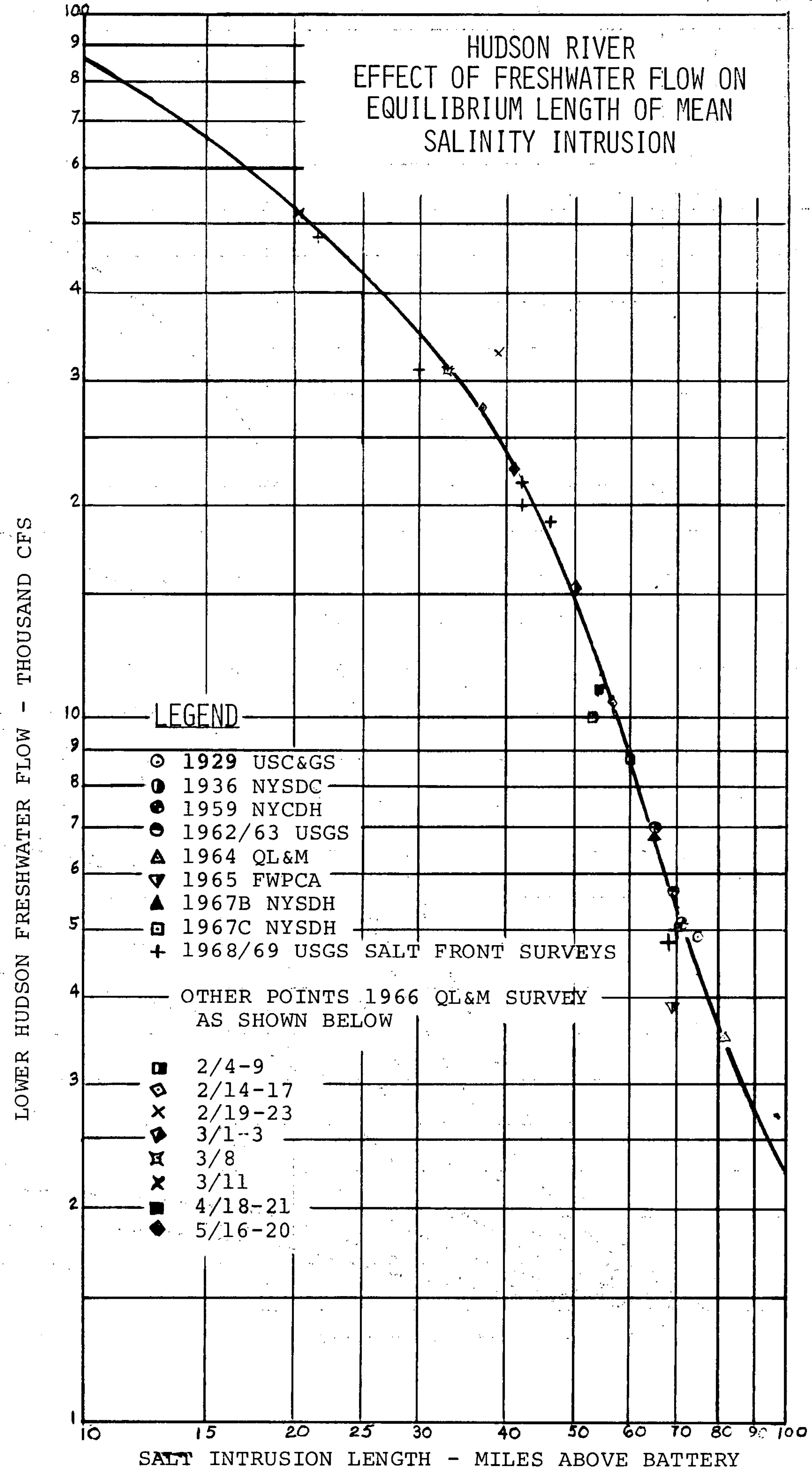
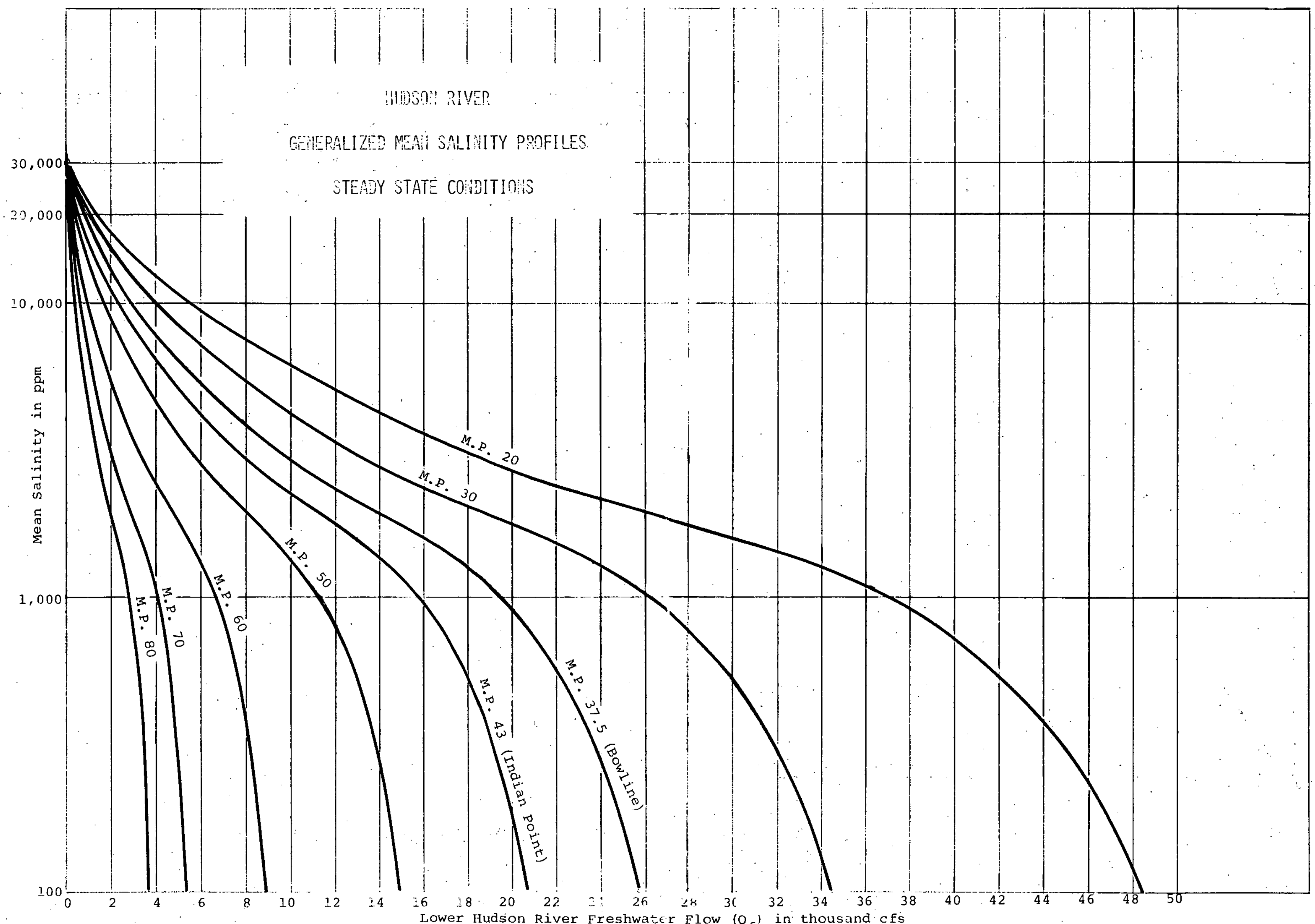

HUDSON RIVER
EFFECT OF FRESHWATER FLOW ON
EQUILIBRIUM LENGTH OF MEAN
SALINITY INTRUSION
LEGEND
1929 USC&GS
1936 NYSDC
1959 NYCDH
1962/63 USGS
1964 QL&M
1965 FWPCA
1967B NYSDH
1967C NYSDH
1968/69 USGS SALT FRONT SURVEYS
OTHER POINTS 1966 QL&M SURVEY
AS SHOWN BELOW
2/4-9
2/14-17
2/19-23
3/1-3
3/8
3/11
4/18-21
5/16-20
LOWER HUDSON FRESHWATER FLOW - THOUSAND CFS
SALT INTRUSION LENGTH - MILES ABOVE BATTERY
100
9
8
7
6
5
4
3
2
10
1
10
15
20
25
30
40
50
60
70
80
100

FIGURE 7



HUDSON RIVER
GENERALIZED MEAN SALINITY PROFILES
STEADY STATE CONDITIONS
Mean Salinity in ppm
30,000
20,000
10,000
1,000
100
M.P. 20
M.P. 30
M.P. 37.5 (Bowline)
M.P. 43 (Indian Point)
M.P. 50
M.P. 60
M.P. 70
M.P. 80
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
Lower Hudson River Freshwater Flow (Q_f) in thousand cfs

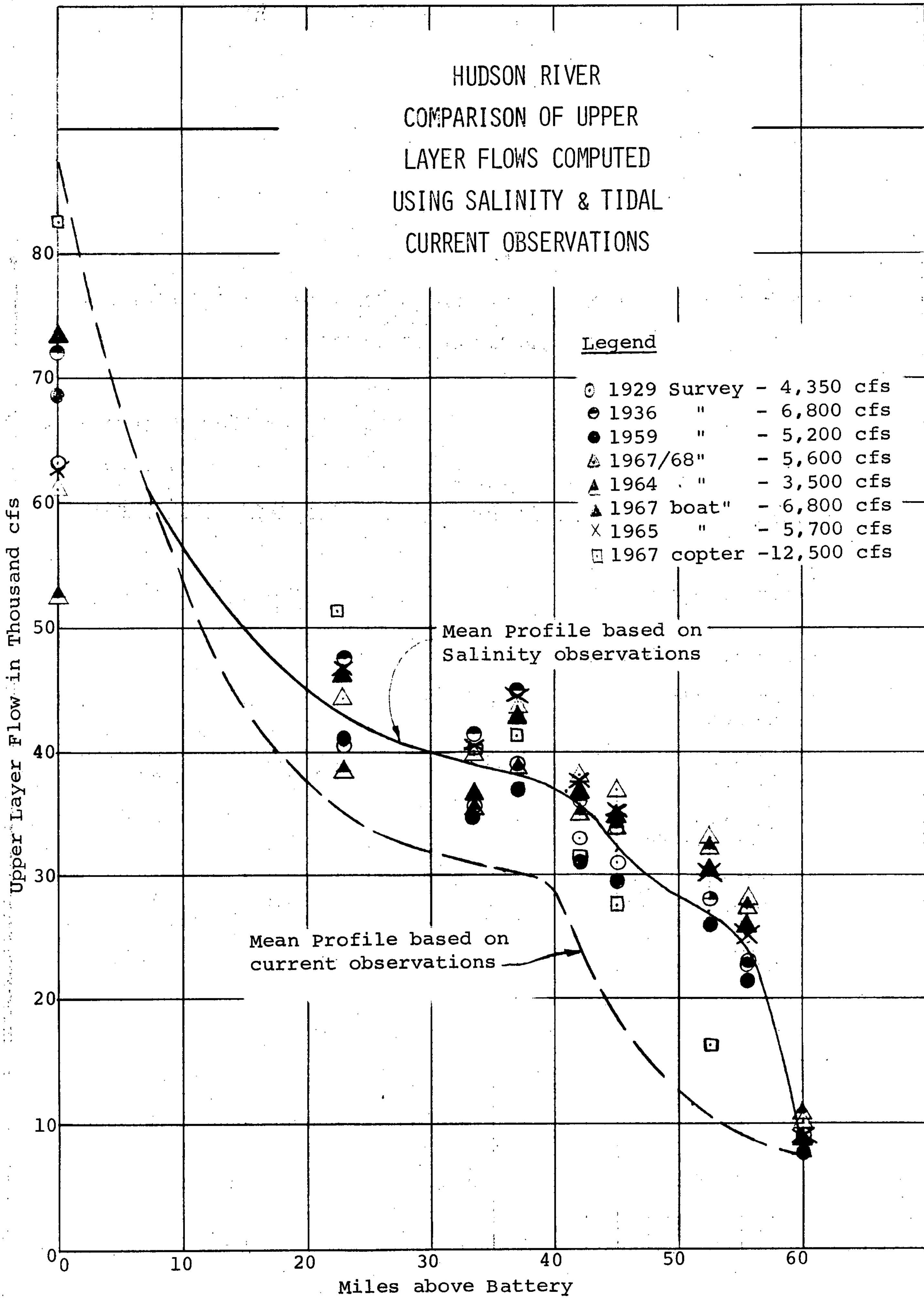

HUDSON RIVER
COMPARISON OF UPPER
LAYER FLOWS COMPUTED
USING SALINITY & TIDAL
CURRENT OBSERVATIONS
Legend
1929 Survey - 4,350 cfs
1936 " - 6,800 cfs
1959 " - 5,200 cfs
1967/68" - 5,600 cfs
1964 " - 3,500 cfs
1967 boat" - 6,800 cfs
1965 " - 5,700 cfs
1967 copter -12,500 cfs
Mean Profile based on Salinity observations
Mean Profile based on current observations
Upper Layer Flow in Thousand cfs
Miles above Battery
0
10
20
30
40
50
60
70
80

TABLE 5

COMPARISON OF LOWER HUDSON UPPER LAYER FLOW USING SALINITY AND CURRENT OBSERVATIONS

Method	Reference 8 Figure No.	Upper Layer Flow, Thousand cfs -- Summer Conditions -- Bowline	Indian Point
1. Current Observations	7	30.5	21.5
2. Salinity Surveys			
a) Salt Budget Method			
1964	22	124.0	90.0
1967	23	110.0	92.0
b) Two Layer Flow Method			
All Salinity Surveys	24	38.0	35.0
Generalized Salinity	26	35.4	35.4

Frequency distribution curves of upper layer flow have been constructed. They show that the probability of occurrence, during *any* calendar month, of values *higher* than those suggested by the current observations is 75 percent and that occurrence of *lower* values during *summer* months is a rather remote happenstance.

2. When the freshwater flow exceeds 20,800 cfs at Indian Point, the river changes from a two-layer to one-layer system having a net 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 value may also be obtained from Figures 5, 6 or 7.

3. On the basis of the long term monthly average behavior of Figure 4, less critical unidirectional flows occur during March (about 28,000 cfs) and April (about 38,000 cfs).

4. During the 1964 drought, the November Lower Hudson freshwater flow was 3,500 cfs. For this condition, Figure 8 gives an upper layer flow of 34,000 cfs at Indian Point.

D. Longitudinal Dispersion Coefficient

Longitudinal mixing is a kinematic effect in one-dimensional fluid flow systems in which the various portions of the flow take different times to traverse a given reach of the waterbody. In estuaries, transport by longitudinal dispersion consists of contributions due to :

1. tidal fluctuations
2. presence of lateral and vertical velocity profiles caused by the curvature of and shear at the flow boundaries
3. eddy diffusion caused by the flow turbulence
4. mixing due to density differences associated with salinity gradients
5. molecular diffusion
6. other causes such as man-made and wind induced currents

In general, the contribution of the last two mechanisms is in narrow estuaries and under normal meteorological conditions is negligible in comparison to the first four.

Freshwater regions of tidal estuaries, such as the Indian Point reach when the freshwater flow in the Hudson is in excess of 20,800 cfs, experience small density differences and transport by dispersion is due to the first three mechanisms. Various authors from Reynolds (1880) onwards, have proposed several theoretical expressions accounting for the influence of these mechanisms by introducing system coefficients to describe the degree of turblence. A list of the most common expressions and corresponding Hudson River coefficients at Indian Point are given below:

Method	Freshwater Dispersion Coefficient @ Indian Point, sq. miles/day
1- Four-thirds Law	5.20
2- Random Process Analogy	20.70
3- Taylor Type Dispersion	0.25
4- Kolmogoroff	1.60

Values ranging from zero to 6 square miles per day have been used for the Indian Point reach in conjunction with freshwater flows in excess of 20,800 cfs. The 6 smd value is somewhat higher than some published estimates corresponding to mass transfer within freshwater segments of estuaries. However, it represents a conservative, but reasonable, estimate of the longitudinal thermal dispersion coefficient as indicated by the following comments:

1. The overall mathematical models used in this study are lumped-parameter models applicable to reaches having constant parameters which recognize variation in the longitudinal direction only. In addition to accounting for true longitudianl dispersion, model values include contributions generated from using reach cross-sectional averages rather than discrete points.

2. Use of conventional formulae, such as the Four-Thirds Law and Random Process Analogy for determination of this dispersion coefficient, gives values up to 20 smd.

3. The dispersion models normally employ dispersion coefficients obtained using naturally occurring or introduced tracers. Most thermal models assume that the dispersion coefficients for heat are the same as those derived using mass or concentration tracers. In thermal discharge studies, use of such tracer-derived coefficients may not be valid.

   The increase in upper layer temperatures due to a thermal discharge causes an increase in vertical density gradients. This increases the system's stability and reduces vertical turbulent mass and convective heat exchange. This increases the longitudinal dispersion coefficient because this coefficient is inversely proportional to the vertical dispersion coefficient.

4. Selection of higher values than obtained through tracer analysis may also be justified on the basis that they incorporate contributions resulting from differences

between estimated and actual values of other system variables, particularly the heat transfer coefficient The heat transfer coefficients used in the analysis are based on lake measurements and neglect the higher order terms in computation of the back radiation difference.

Recent analysis suggests that river heat transfer coefficients are higher than their lake counterparts. Had higher heat transfer coefficients been used in the computation, this final justification of a higher dispersion coefficient would not be valid.

In addition, field temperature measurements at the existing Danskammer Plant in 1969 and Albany Steam Station in 1970 conducted by QL&M, tend to support lumped-parameter thermal dispersion coefficients on the order of 6 to 8 square miles/day in non-saline segments of the river.

In salt-intruded reaches of estuaries, such as the Indian Point reach when the freshwater flow is less than 20,800 cfs in the lower Hudson River, transport by dispersion has been shown to be markedly higher than in freshwater segments of estuaries, as indicated by the dispersion coefficient values. This is ascribed to vertical and longitudinal density differences which are associated with salinity gradients and which cause significant circulation. This phenomenon can be expressed in terms of the previously described density induced circulation concept, i.e., use of upper layer flows and low dispersion coefficients instead of freshwater flows coupled with high longitudinal dispersion coefficients. As indicated earlier, the former approach results in good agreement with field observations.

The latter approach using a longitudinal dispersion coefficient of 14.3 sq. miles/day at Indian Point (See Appendix B of Reference 2) was used in Reference 2. This value was obtained using the 1964 salinity profile. Reference 3, however, indicated that the convection-dispersion model had to be adjusted to yield the observed values when operating at the Unit No. 1 heat load. This suggests existence of mixing in excess of that computed using dispersion coefficients obtained from salinity profiles.

Both of these approaches, as will be shown in item IV, were employed in this study to predict the distribution of temperature for two unit operation.

E. Heat Transfer Coefficient ($\bar{K}$)

Numerical values of this parameter depend on prevailing meteorological conditions. They range from a minimum of about 80 BTU/ft^2/day/°F in the winter, to a maximum of about 140 BTU/ft^2/day°/°F in the summer.

As mentioned in Reference 2, the above listed values have been established by extensive study of lakes. Recent FWPCA evaluation suggests that in rivers these values may be increased by a factor of 1.5. For purposes of this study, however, the more conservative lake values have been used, since higher values have not yet been verified for the Hudson Valley.

Figure 9 shows monthly average heat transfer coefficient, computed using 1964 Weather Bureau data applicable to the Hudson River at Indian Point. Yearly variation in each monthly value is not great. To be consistent, the long term monthly flow variations in the Hudson River, as depicted in Figure 4, have been used in this study to aid in the selection of appropriate surface heat transfer coefficients.

In other words, once a Lower Hudson River flow (freshwater, incipient salt or upper layer value) has been established, Figure 4 may be used to select the appropriate month and Figure 9 to determine the prevailing heat transfer coefficient for that particular month.

F. <u>Thermal Parameters</u>

These parameters include river parameters and discharge design parameters and are discussed below:

River Parameters: These include density (ρ), heat capacity (C_p), ambient temperature (T_a) and thermal stratification factor (TSF). Values used in this study are:

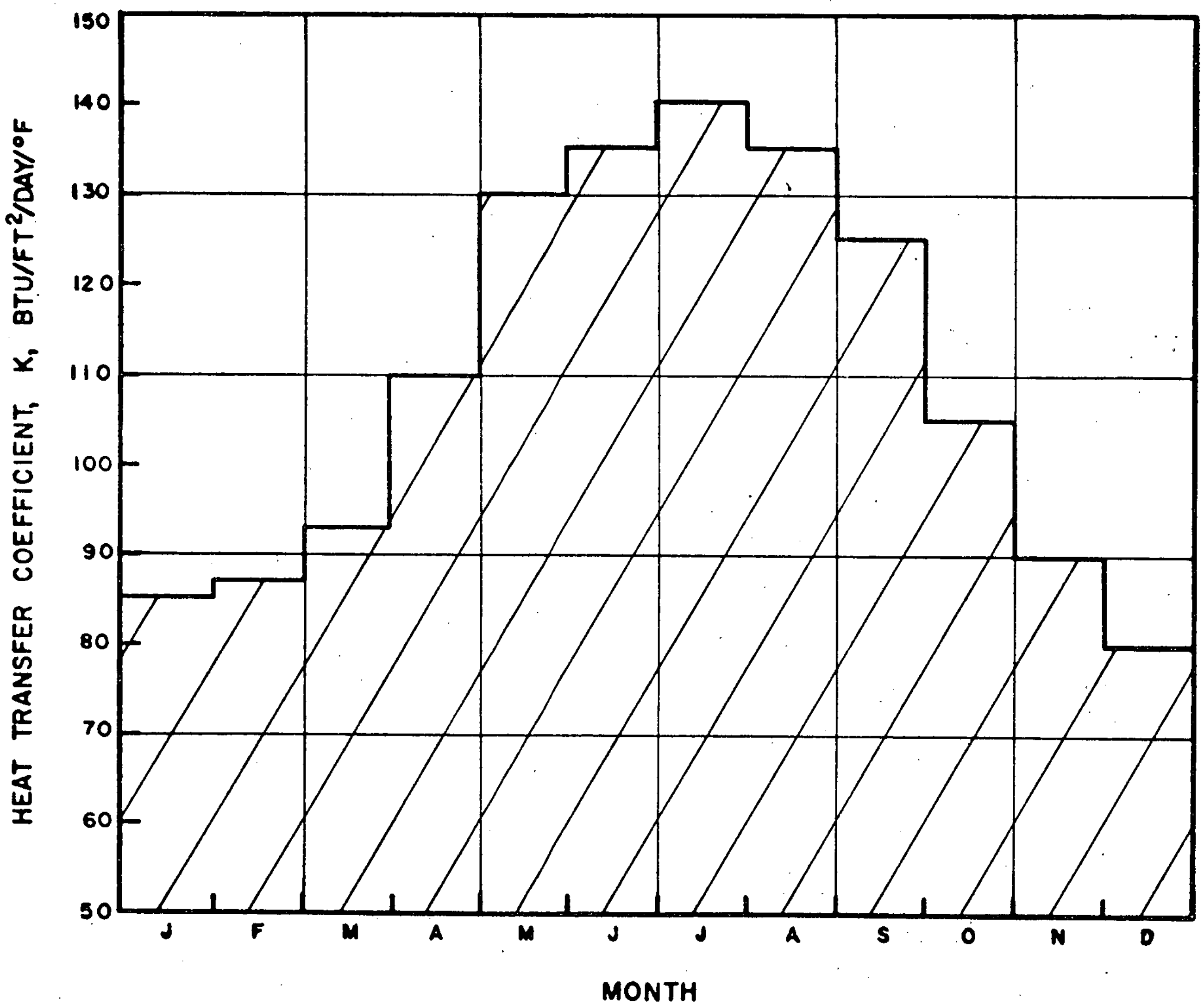
$$\rho = 62.4 \text{ lb/ft}^3$$
$$C_p = 1 \text{ BTU/lb °F}$$
$$T_a = 79\text{°F}$$
$$TSF = 1.5$$

The ρ and C_p values are for freshwater. Values applicable to saline waters (such as the river portion under study for river flows of less than 20,800 cfs) possess somewhat lower C_p values. However, the decrease is insignificant (0.982 for waters having a salinity of 5,000 ppm versus 1.00 for freshwater).

The maximum naturally occurring river water ambient temperature used in this evaluation is 79°F. This value is considered to be the highest water temperature that can be experienced by the Indian Point intake at any time. Review of available Hudson River channel temperature data given in Reference 8 shows that this maximum temperature of 79°F in the Hudson River is reached around mid-August of certain years. Ambient temperature does not reach this value every year. For example, the maximum ambient water temperature observed in the vicinity of Indian Point in 1969 occurred on two days in August and was 77.6°F. Available temperature measurements, depicted in Figure 9a, over a ten year period from 1956 through 1965 show that the 79°F monthly average is reached only once in eight years. The values shown in Figure

WATER SURFACE HEAT TRANSFER

HUDSON RIVER NEAR INDIAN POINT



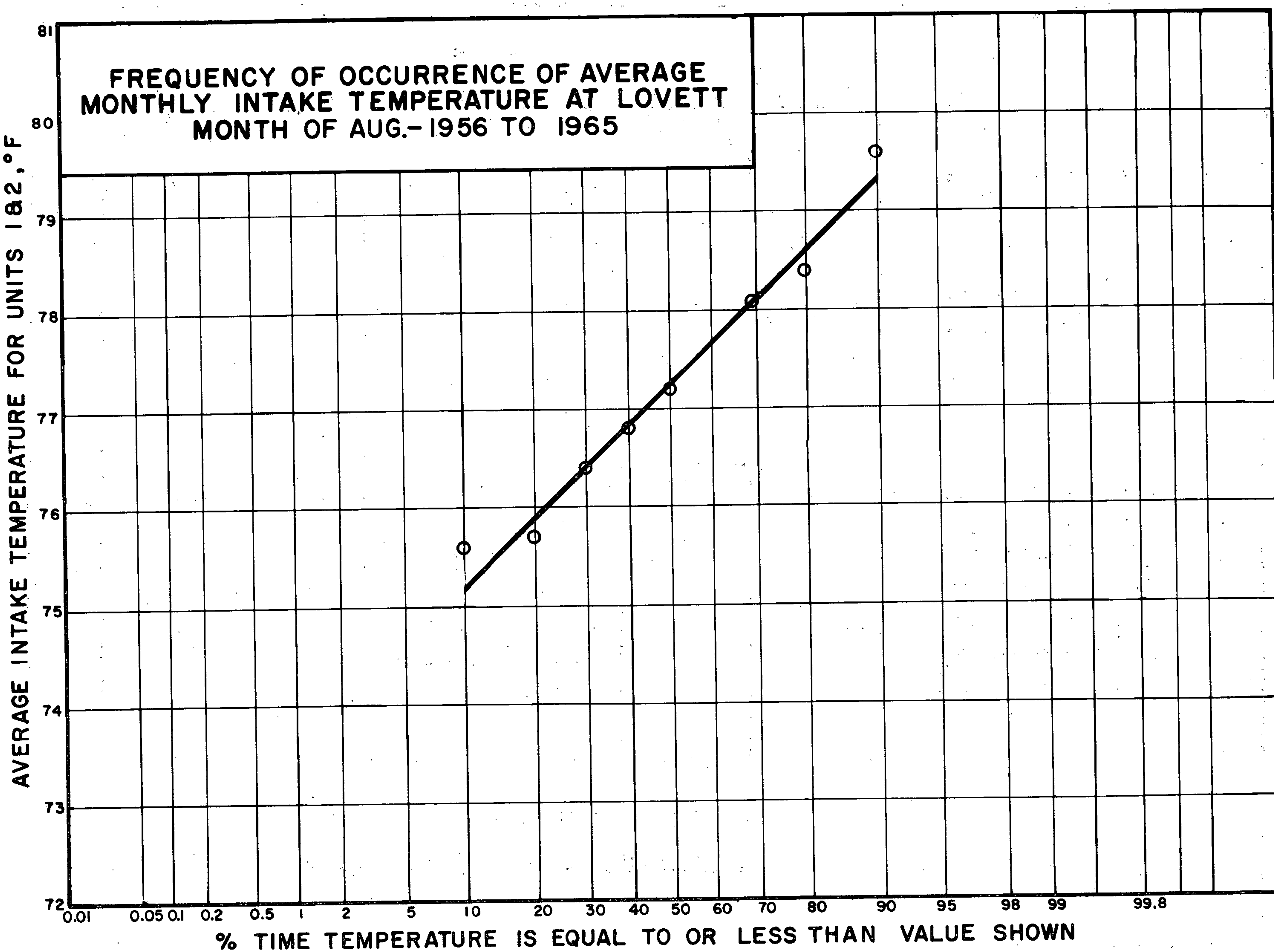
K̄ IS A FUNCTION OF:

- AIR TEMPERATURE, T_A
- SOLAR RADIATION, H_S
- ATMOSPHERIC RADIATION, H_A
- WIND SPEED, W
- RELATIVE HUMIDITY, R_H
- AIR VAPOR PRESSURE, e_a

SOURCE OF DATA:

AGENCY	YEAR
U.S. WEATHER BUREAU	1951 TO 1964
U.S. AIR FORCE AIR WEATHER SERVICE	1942 TO 1965

FIGURE 9



FREQUENCY OF OCCURRENCE OF AVERAGE MONTHLY INTAKE TEMPERATURE AT LOVETT MONTH OF AUG.- 1956 TO 1965
AVERAGE INTAKE TEMPERATURE FOR UNITS 1&2, °F
81
80
79
78
77
76
75
74
73
72
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
% TIME TEMPERATURE IS EQUAL TO OR LESS THAN VALUE SHOWN

FIGURE 9A

9a are based upon temperature measurements of intake cooling water at Lovett. Although these temperatures may be somewhat high because of recirculation of effluent cooling water, they represent the most extensive survey of ambient river temperatures for the Indian Point-Lovett area. These measurements were grouped into monthly averages and statistically analyzed for the August months. Data subsequent to 1965 were not included in the analysis because they represent a significantly greater degree of heat recirculation as a result of the Lovett Unit No. 4 being operational.

Several Hudson River temperature profiles** and additional support of the 79°F value are given in Reference 8.

A thermal stratification factor (the ratio of the surface average temperature rise ($\Delta\overline{T}_s$) to the area average temperature rise ($\Delta\overline{T}$) of 1.5 has been used in this study. This value represents strong to moderate mixing of the effluent with river water at the plane of discharge. This can be accomplished using a submerged discharge design. Available Indian Point hydraulic model results shown in Figure 10 support selection of a TSF value of 1.5 at Indian Point. In addition, results of recent undistorted hydraulic model studies* suggest that submerged outfalls can effect almost complete mixing.

A discussion of the controls used to obtain an appropriate upper layer stratification factor (F_o) and growth coefficient (f) appears in Reference 8. F_o values ranging between 1 and 2 and growth coefficients of 0.2, 0.25 and 0.3/mile have been tested. Results of these tests favored selection of F_o of 1.0 and f of 0.2 and 0.3.[8]

F_o of unity is equivalent to a constant total cross-section thermal stratification factor (TSF) of 1.5 to 1.7 since it is equal to TSF Q_d/Q_u. This number is quite consistent with the above presented TSF values and estimates that have been used in previous reports for submerged discharges. The growth coefficient of 0.3 was obtained using the thermal stratification data given in Reference 10 and interpolating this over a distance of five miles.

G. Discharge Design Parameters

These include plant heat load (H), maximum plant temperature rise (ΔT_m), maximum surface temperature rise (ΔT_{sm}), ratio (n) of thermal criteria parameters such at % width (%B) or % area (%A) bounded by a given isotherm (ΔT_s or ΔT) during critical tidal phase (CTP) - usually slack conditions - to their tidal average (TA) counterparts. The following numerical values have been used in this study:

* Quirk, Lawler & Matusky Engineers. "Effect of Circulating Water Systems on Lake Ontario and Oswego Harbor Water Temperature and Aquatic Biology." Report to Niagara Mohawk Power Corporation, April 1971.

** Figure 9b shows the ambient temperature at Indian Point for the meteorological conditions of 1964.

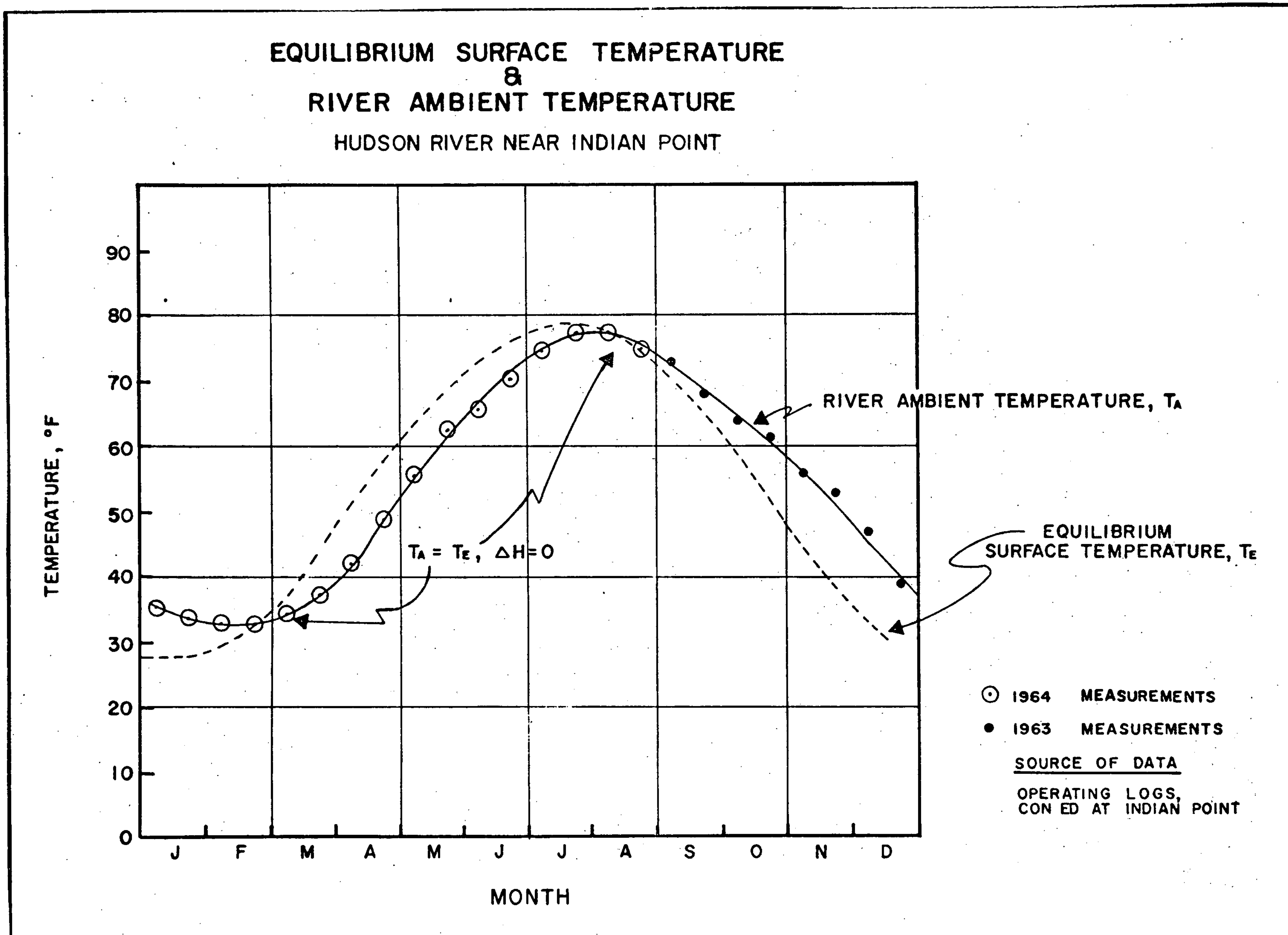
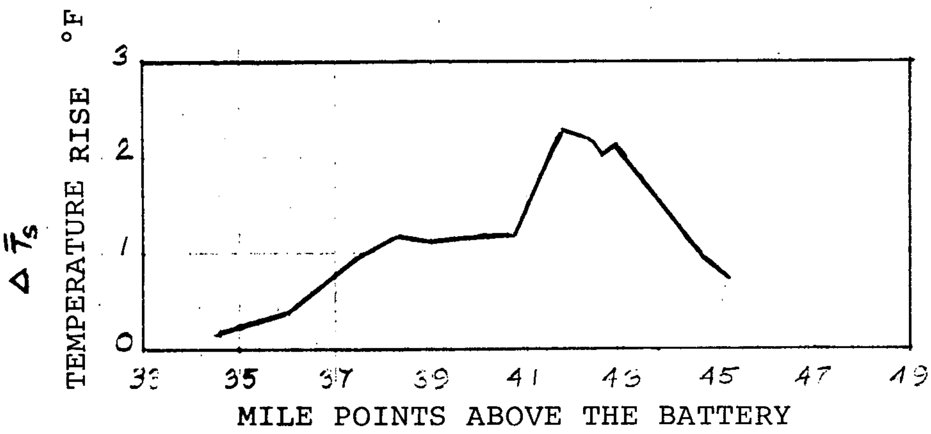
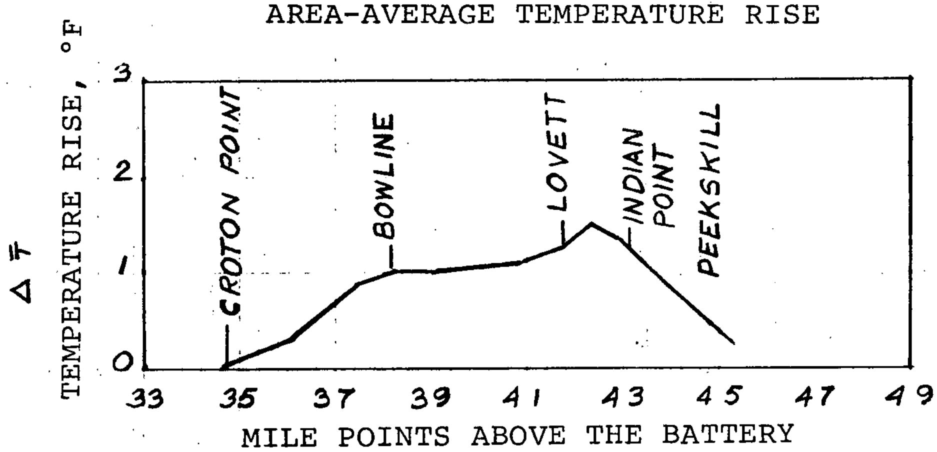

EQUILIBRIUM SURFACE TEMPERATURE
&
RIVER AMBIENT TEMPERATURE
HUDSON RIVER NEAR INDIAN POINT
TEMPERATURE, °F
90
80
70
60
50
40
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
RIVER AMBIENT TEMPERATURE, TA
EQUILIBRIUM SURFACE TEMPERATURE, TE
TA = TE, ΔH=0
1964 MEASUREMENTS
1963 MEASUREMENTS
SOURCE OF DATA
OPERATING LOGS, CON ED AT INDIAN POINT

FIGURE 9B

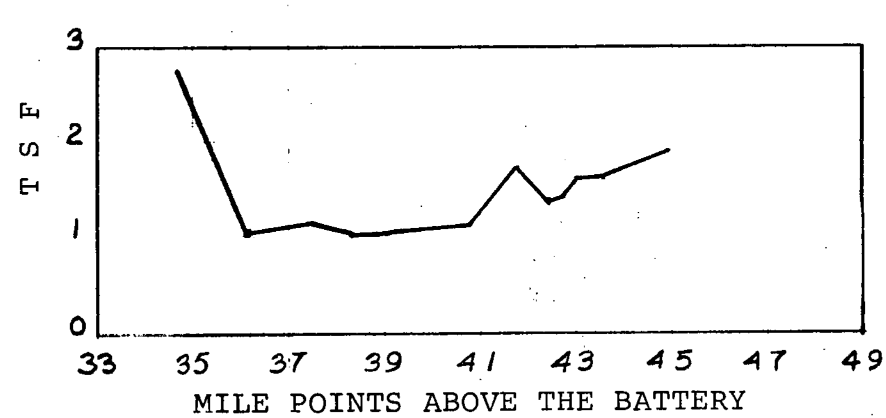
SURFACE-AVERAGE TEMPERATURE RISE



AREA-AVERAGE TEMPERATURE RISE



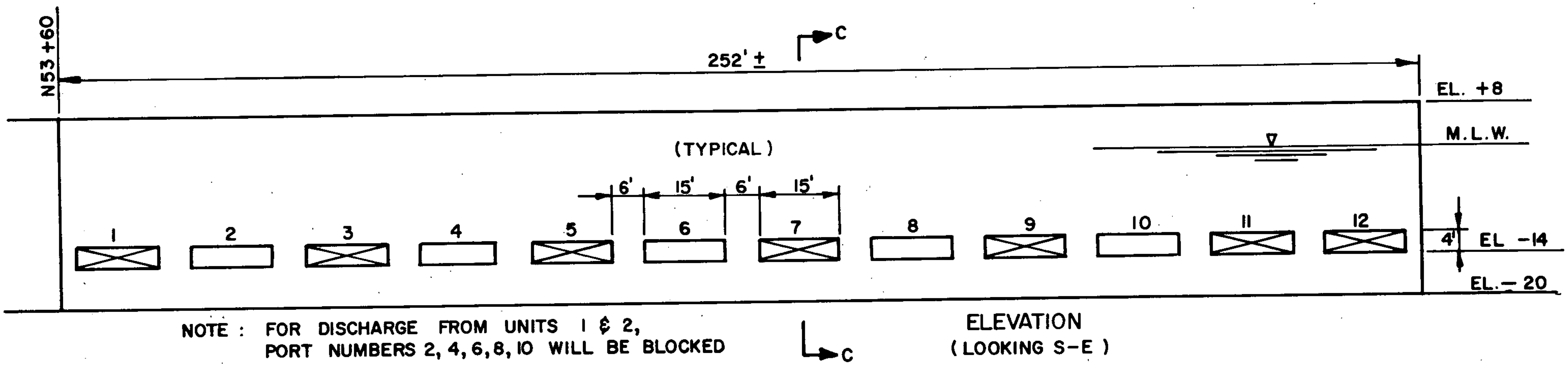
THERMAL STRATIFICATION FACTOR



INDIAN POINT HYDRAULIC MODEL RESULTS

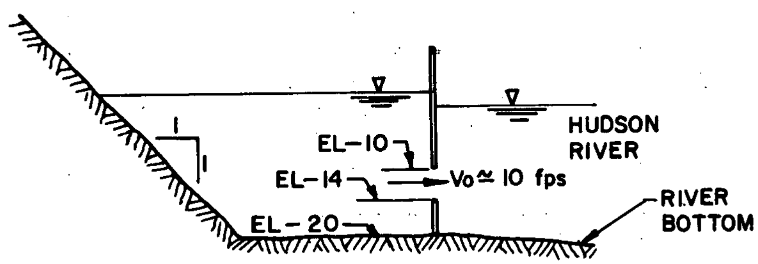
(RATED CAPACITY OPERATION OF INDIAN POINT UNITS 1 & 2,
LOVETT UNITS 1-5 & BOWLINE UNIT 1)

DETAILS OF INDIAN POINT UNITS 1 & 2 DISCHARGE STRUCTURE



NOTE : FOR DISCHARGE FROM UNITS 1 & 2, PORT NUMBERS 2, 4, 6, 8, 10 WILL BE BLOCKED

ELEVATION
(LOOKING S-E)



AS SECTION C-C
(REVISED DESIGN)

FIGURE 10-A

Rated Capacity Parameter	Indian Point Unit 1	2	1 & 2	Lovett Units 1-5
Elect. output, MWE	265	873	1138	503
Heat Load, BBTU/day	47	153	200	57
Cooling Water Flow,** thousand gpm	312	870	1182	323
Condenser Temperature Rise, (ΔT_p), °F (Full Flow)	14	15.1	14.8	14.8
Maximum Surface Temperature Rise @ Plane of Discharge (ΔT_{sm})* °F	-	-	8	12
$n = \frac{CTP}{TA}$	-	-	1.35	1.35

The ΔT_{sm} value at the plane of discharge depends upon outfall design. The values used in this study have been established assuming that the Indian Point discharge design+ is capable of attaining a dilution of the heated water of 1.8 to 1 by the time the discharge reaches the surface. This dilution ratio has been developed using an undistorted hydraulic model of the revised design. Recent hydraulic model and analytical studies suggest higher dilution ratios.

In addition, the 1969 Lovett submerged discharge field measurements (see Figure 9 of Reference 4) showed that jets similar to the

* The 8°F was observed in the Indian Point undistorted model and the 12°F was observed in the vicinity of the Lovett Plant during the summer of 1970.

\+ The revised Indian Point outfall system is 270 feet long and includes 12 discharge ports with rectangular openings 4 feet high by 15 feet long, spaced 20 feet apart (center to center) discharging horizontally and normal to the river flow, and located 12 feet at centerline of port below the mean low water elevation. Ten of these slots are equipped with fully adjustable gates to insure a submerged jet velocity of 10 fps for any combination of units in operation.

The original 18' depth of submergence was changed to 12' to improve mixing of the effluent with the ambient water and minimize river bottom scour action. Recent hydraulic model tests showed that the revised outfall design produced lower overall temperatures.

** Including service water

Lovett Unit No. 4 discharge, characterized by a low exit velocity of less than 3 ft/sec and a low depth of submergence of less than 12 ft. below mean high water, are capable of attaining dilution ratios up to 3 with an average of 2.2. Estimates based upon these measurements and adjusted to account for smaller jet cross-sectional area and higher depth of submergence indicate that the Indian Point jets could result in dilution ratios up to 3.0 or more with an average of 2.75. Employment of these dilution ratios yeilds maximum surface temperature rises of less than 5.5°F in the vicinity of Indian Point.

The conservative nature of the ΔT_{sm} value of 8°F is also supported by the results of the submerged discharge mathematical model, given in Reference 4 for a condition of maximum two unit condenser rise of 14.8°F and a depth of submergence of 12 feet. Reference 4 treated a three unit discharge and a depth of submergence of 18 ft. However, the computed results can be used to compute the two unit revised design values by employing the results corresponding to the new depth of submergence of 12 ft.

Figure 16 of Reference 4 shows that the dilution ratio corresponding to a 12 ft. submergence is expected to be 2.4. Employment of the procedure described in Reference 4 yields a ΔT_{sm} of 8°F[(14.8/2.4 - 3)π/2 + 3] for the present case.

Notice that this dilution ratio corresponds to the upper boundary control described in Reference 4 and that the jet interference dilution ratio does not control in this case since only seven of the twelve available slots would be used for flow from Units 1 and 2.* In other words, Units 1 and 2 slots could be spaced 42' apart (center to center) by blocking the intermediate slots.

However, to make the analysis conservative, the maximum surface temperature rise of 8°F, which corresponds to a dilution ratio of 1.8, has been utilized throughout this study.

Thermal recycling studies indicate that two unit rated capacity operation may result in recirculation effects ranging from less than 0.1°F to less than 1.2°F, depending upon the prevailing tidal conditions. The tidal average increase in intake temperature rise over the entire water column due to recirculation of heated water will be about 0.75°F. This value has been rounded off to 1°F and used in this study to account for the recirculation effect.

---

* Details of a planned two unit discharge scheme are depicted in Figure 10a. Selection of a final scheme capable of producing the above mentioned maximum surface temperature rise of 8°F or lower will depend upon results of a proposed pre-operational evaluation study of the outfall.

The n ratio of 1.35 is reasonable and is supported by the observed behavior of several existing Hudson River plants as shown below:

Plant	Year	Observed n values** Min.	Max.	Ave.
Lovett	1969	1.14	1.38	1.26
	1970	1.15	1.30	1.23
Danskammer	1969	1.00	1.32	1.16
Albany	1970	1.18	1.22	1.20

The effect of the Lovett Plant on the Indian Point site has been incorporated in this study. This consisted of including a rated capacity operation heat input of 57 BBTU/day (503 MW) at Mile Point 42 (location of the existing Lovett Plant).

** These represent ratios of the 50% frequency values and correspond to the location of the 4°F isotherm. These values apply to surface discharges. Establishment of a similar ratio applicable to a submerged discharge is not possible at present. However, the intense mixing and high velocity characteristics of submerged discharges indicate that this ratio may be lower than 1.35, since the submerged jets should entrain sufficient water so that the bulk of the surface plume, in the immediate vicinity of the discharge, may be close to 4°F.

IV. Temperature Distribution for Two Unit Operation

This item utilizes the mathematical models presented in item II and the various values of the system parameters documented in item III to predict the effect of two unit operation at Indian Point and five unit operation at Lovett on the distribution of temperature in the Hudson River. Previous studies[6] showed that the effect of the Roseton-Danskammer complex will have been dissipated to the atmosphere well before it reaches Indian Point.

As an additional support to the approach adopted in this study, further discussion of applicability of the mathematical models to thermal discharges is also given in this item.

A. Applicability of the Overall Mathematical Models to Thermal Discharges

The previously described mathematical models, and in some cases modified versions of these models, have been used to evaluate a number of existing and planned effluents and waterbodies, including the following:

1. Existing Plants

   - Albany Steam Station
   - Danskammer Station
   - Lovett Units 1 - 5
   - Indian Point Unit 1
   - Arthur Kill Plant
   - Astoria units 1 - 5
   - Ravenswood Plant

2. Proposed Plants

   - Roseton
   - Indian Point Units 2 & 3
   - Standard Brands Inc.
   - Bowline Point
   - Astoria Unit 6
   - a number of other future generation sites

3. Water Quality Models

   - The Hudson River - NYSDEC
   - The New York - New Jersey Estuarine Complex - ISC, NYC, NJDH
   - The East River - NYC
   - several waterbodies outside New York State

Use of these models has resulted in good agreement with numerous dissolved oxygen, BOD, salt and temperature field surveys in a number of New York State waterbodies. Details of the capability of these models to reproduce observed water quality profiles appear in several QL&M reports.[6,8] Reference 6 discusses applicability of the Convection-Dispersion model to water quality, (dissolved oxygen) profiles. On the other hand, Reference 3 and the previously presented discussion, indicate that this model (without the adjustment introduced in Reference 3) yielded results too conservative by comparison to observed Indian Point Unit 1 temperature distribution profiles, necessitating use of the density induced circulation or net non-tidal model. A brief discussion of this difference in reproducing D.O. and temperature profiles is given below.

Classical estuarine water quality models are often one dimensional models, which describe pollutant and water quality area-averaged concentrations along the River's longitudinal axis. The river temperature models employed in the January 1968[2] and February 1969[3] QL&M reports are of this type.

In models of this type, the net non-tidal flow is lumped together with several other estuary mixing and dilution mechanisms into an overall effect termed longitudinal dispersion, which is handled quantitatively by the longitudinal dispersion coefficient. This parameter is usually estimated from salinity profiles, and its use in one dimensional models yields reasonably good predictions of of the area-averaged concentrations of pollutants and water quality parameters.

Most pollutant discharges are small, volumewise, by comparison to estuary flows, and do not ordinarily exhibit a marked tendency to stratify. In the case of heated discharges however, the large flow of the fluid whose density is significantly less than that of the receiving waters results in the heated liquid rising to the surface and remaining there. Vertical mixing is resisted by the inherent stability between the lighter heated surface layer riding atop the denser, cooler river water.

Thus, the heated discharge will be located in the upper seaward moving layers of the estuary, and will be subject to straight dilution by the net non-tidal flow in the upper layer. Unlike the non-stratifying pollutant, this dilution will not be diminished by vertical mixing and subsequent recirculation of the pollutant back past the plane of discharge.

It is this enhanced dilution which is not accounted for in the unadjusted mathematical model, which is one-dimensional and employs salinity-derived dispersion coefficients.

Thus, the salinity-induced circulation, or net non-tidal flow, is believed to be the reason for the observed rapid and high dilution of heat effluent at Indian Point.

The net non-tidal flow or density induced circulation concept explained the measured area-averaged temperature rise at Indian Point. The predicted area-averaged temperature rise at the Indian Point plane of discharge, taking into account the net non-tidal flow concept, was report in the October 1969 report[5] to be only 9% less than the area-averaged temperature rise measured in July 1966. Subsequent refinements in the estimates of the heat load and net non-tidal flows occurring at that time show a 3% difference in these values.[10]

In addition, subsequent analysis, summarized in the following tabulation, of available temperature measurements in the vicinity of other Hudson River existing plants indicated existence of upper layer flows close to those computed using the above described tidal current and salinity approaches. These results support the capability of the density induced circulation concept to explain temperature observations.

Plant	Survey	Observed $\Delta\overline{T}_o$, °F	Heat Load, BBTU/Day	Upper Layer* flow, cfs
Danskammer	1969 QL&M	0.146	47.3	33,000
Lovett	1969 QL&M	0.152	57.0	37,800
Lovett	1970 QL&M	0.175	41.7	26,200
Indian Pt. 1	1966 NBI	0.200	37.4	20,900

B. <u>Presentation of Study Results</u>

In order to select the most severe set of hydrology and meteorology that can occur in the vicinity of Indian Point and to compare results of the various models used in this study, a plane of discharge counterpart of the mathematical model given in Table 1 may be used. For a given location outfall design and known fluid characteristics, this model reduces to:

* Computed using temperature observations

$$\Delta\overline{T}_o = \frac{\alpha H}{\sqrt{Q^2 + \beta \overline{K} E}} = \frac{\alpha H}{Q_d}$$

in which:

$\Delta\overline{T}_o$ = Area-average temperature rise at the plane of discharge, °F. It is used here as a measure of the response of the Hudson River to thermal discharges.

H = Thermal discharge, BBTU/Day

$\overline{K}$ = Heat transfer coefficient, BTU/sq. ft. day °F It is used in this model to define the influence of meteorological conditions on the distribution of temperature

Q = River freshwater flow, thousand cu. ft./sec.

E = Longitudinal dispersion coefficient, sq. miles/day

Q_d = A heat dissipation parameter reflecting the influence of flow available for dilution of thermal discharges and of heat transfer to the atmosphere. In the case of the convection-dispersion mathematical models, Q_d combines the influence of Q, $\overline{K}$ and E. In dealing with a tidal smoothed temperature rise averaged over the entire cross-section within a salt-intruded reach of an estuary, Q_d reflects the influence of the seaward directed upper layer flow, Q_u , and landward directed lower layer flow, Q_L. This definition of Q_d has been selected to insure consistent comparison of the convection-dispersion and density induced circulation model results. However, since an inherently stratifying discharge, such as is a thermal effluent, rises to the surface and tends to stay in the upper layer, only the upper layer flow may be used to predicted the distribution of temperature in the seaward directed layer.

α & β = Constants defining the influence of river geometry (A,B), outfall design (TSF), and water quality (ρ, C_p). At Indian Point, use of A, B, TSF, ρ, C_p of 160,000 sq. ft. , 4,000 ft., 1.5, 62.4 lb/cu ft and 1 BTU/#°F respectively, yields α= 0.185 and β= 0.23.

A comparison between the various hydrological and meteorological conditions and models presented in items II and III using this equation is given in Table 6. The study results of Table 6 indicate that an incipient salt flow condition occurring during certain winter months represents the most severe set of hydrology and meteorology that can be expected at Indian Point. The thermal effect is less critical during other months due to availability of high freshwater flow and heat transfer rate and/or density induced circulation associated with ocean-derived salt intrusion. In order to predict the maximum expected effect, the incipient salt flow conditions were used in this study.

The combined effect of rated capacity operation of Lovett Units 1 through 5 and of Indian Point Unit 1 and 2 is expressed in terms of and compared with the New York State thermal discharge criteria.

These values have been computed using an overall convection-dispersion model capable of handling variable system parameters, including heat loads, within a number of consecutive river segments. To convert the overall response to near field behavior and to permit evaluation in terms of the NYSDEC thermal discharge criteria, the previously described exponential decay model has been employed.

Notice that due to the interaction between the Lovett and Indian Point Plant, the maximum effect occurs at Lovett.

Of the three criteria, and as found in previous Hudson River studies, the 67% surface width 4°F temperature rise criterion is controlling in this reach.

The 90°F maximum surface temperature criterion at any point can be met via the high velocity, multiple port submerged discharge design. As indicated earlier, employment of such a design will result in a maximum surface temperature rise of 8°F and a recirculation effect of 1°F, and that during summer months, ambient temperatures in this portion reach a maximum of 79°F. During such periods, the maximum surface temperatures will reach 88°F. This criterion, therefore, is not controlling.

The 83°F absolute temperature criterion for the surface width or cross-sectional area is not controlling since the maximum ambient temperature is equal to or less than 79°F.

As in previous Hudson River experience, results of Table 7 show that the 50% cross-sectional area 4°F temperature rise criterion is not controlling.

TABLE 6

COMPARISON BETWEEN VARIOUS HYDROLOGICAL & METEOROLOGICAL

CONDITIONS AT INDIAN POINT & STUDY MODELS

Condition	Model[1]	Q tcfs	Q_u tcfs	E smd	$\overline{K}$ BTU/ft^2°Fday	$\Delta\overline{T}_o$ °F/100BBTU/day
A. Indian Point within Salt-Intruded Reach						
Drought-Fall Conditions	C-D[2]	4.0	-	12	90	0.84
	DICC	-	21.5	0	-	0.48
	DICS	-	35.4	0	-	0.28
	Average....					...0.53
Summer Conditions	C-D[3]	4.0	-	12	135	0.69
	DICC	-	21.5	0	-	0.48
	DICS	-	35.4	0	-	0.28
	HYD[4]	4.0	-	0.2	130	0.58
	Average....					...0.51
B. Indian Point outside Salt-Intruded Reach						
Incipient salt flow	C-D	20.8	-	6	120	0.76
	C-D	20.8	-	6	90	0.78
Winter or Spring flow	C-D	28.0	-	6	90	0.62

1 C-D = Convection-Dispersion model
DICC = Density induced circulation model - upper
DICS = layer flow computed using tidal current and salinity measurements, respectively.
HYD = Indian Point hydraulic model

2 Based upon Table 10 of Reference 3
3 Based upon Table 12 of Reference 3
4 See Figure 9 of this report

The surface width criterion, that no more than 67% of the river's surface width may experience temperature rises in excess of 4°F, is the most difficult of the criteria to meet. This conclusion has been found to be valid in numerous cases including Albany, Danskammer, Roseton, Lovett, Bowline, Arthur Kill, Ravenswood and Astoria Plants.

The results of Table 7 indicate that in all cases, the predictions are substantially less than the New York State thermal discharge criteria. Table 7 results correspond to rated capacity operation of Indian Point Units 1 and 2 as well as the existing Lovett Units 1 through 5. However, to generalize the results, the following tabulation relates extent of compliance with the controlling NYSDEC criterion with different Unit 2 power levels and rated capacity operation of Unit 1 and Lovett Units 1 through 5.

Indian Point Unit 2 Power Level		Combined Heat* Load, BBTU/Day	Maximum % Surface Width Bounded by 4°F	
MWE	% full capacity		Critical tidal phase	% of NYS criterion
0	0	104	12	18
218	25	142	17	25
437	50	181	21	31
655	75	219	26	39
785	90	241	30	45
873	100	257	32	48

* Including rated capacity operation of Lovett Units 1 - 5 (503 MWE or 57 BBTU/Day) and of Indian Point Unit 1 (265 MWE or 47 BBTU/Day).

TABLE 7

PREDICTION OF 4°F AREA AND SURFACE

BOUNDARIES AT INDIAN POINT

FOR THE MAXIMUM SEVERE CONDITIONS

A. Conditions

Incipient Salt Flow	... 20,800	cfs
Heat Transfer coefficient	... 90	BTU/ft^2 day °F
Dispersion coefficient	... 6	sq. miles/day
Thermal Stratification factor	... 1.5	
Critical tidal phase to tidal average location ratio	... 1.35	
Heat Load (Rated Capacity)		
Indian Point Unit 1	... 265 MWE or 47 BBTU/Day	
Indian Point Unit 2	... 873 MWE or 153 BBTU/Day	
Lovett Units 1 - 5	... 503 MWE or 57 BBTU/Day	

B. Study Results

Parameter	Tidal Phase	Percentage at Lovett	Percentage at Indian Point	NYSDEC Criterion
% Width bounded by 4°F	Tidal Average	24	23	67
	Critical Tidal Phase	32 *	31	
% Area bounded by 4°F	Tidal Average	16	15	50
	Critical Tidal Phase	22	21	
Maximum surface Temperature, °F	Critical Tidal Phase	87		90
Area average Temp. rise, °F	Tidal Average	1.79	1.75	-
Surface average Temp. rise, °F	Tidal Average	2.69	2.62	-

* This value is based upon a maximum surface temperature rise (ΔT_{sm}) of 8°F. To generalize the results, other rises have been investigated. Use of ΔT_{sm} of 6, 7, 9 & 10°F would yield a maximum critical tidal phase % width bounded by 4°F of 28, 30, 33 and 33.5%, respectively.

APPENDIX A

APPENDIX A

LIST OF QUIRK, LAWLER & MATUSKY ENGINEERS

INDIAN POINT REPORTS AND RELATED PUBLICATIONS *

1. Quirk, Lawler & Matusky Engineers. "Effect of Contaminant Discharge at Indian Point on Hudson River Water Intake at Chelsea, New York," Report to Consolidated Edison of New York, Inc., May 1966

2. Quirk, Lawler & Matusky Engineers. "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., January 1968

3. Quirk, Lawler & Matusky Engineers. "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., February 1969

4. Quirk, Lawler & Matusky Engineers. "Effect of Submerged Discharge of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., October 1969

5. Quirk, Lawler & Matusky Engineers. "Influence of Hudson River Net Non-Tidal Flow on Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., October 1969

6. Quirk, Lawler & Matusky Engineers. "Hudson River Water Qualtiy and Waste Assimilative Capacity Study," Report to the State of New York Department of Environmental Conservation, Division of Pure Waters, December 1970.

7. Quirk, Lawler & Matusky Engineers. "Hudson River Assimilation Capacity Study," Report to the New York State Department of Health, March 1970

8. Quirk, Lawler & Matusky Engineers. "Circulation in the Hudson Estuary," a technical bulletin prepared by QL&M in 1971.

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* References 1, 2, 3, 4, 5, 11, 12 and 13 appear in Con Ed's Environmental Report as Appendices A, I, J, L, M, K, N and O respectively.

9. Abood, Karim A. and John P. Lawler. "Evaluation of Estuarine Thermal Discharges using Mathematical, Hydraulic and Ecological Models," Presented at the fourth Mid-Atlantic Industrial Waste Conference, University of Delaware, Newark, Delaware, Nov. 18 - 20, 1970

10. Lawler, John P. and Karim A. Abood. "Thermal State of the Hudson River & Potential Changes," Presented at the Second Symposium on Hudson River Ecology, Sterling Forest Conference Center, Tuxedo, New York, October 28 - 29, 1969

11. Alden Research Laboratories. "Indian Point Model Studies," March 1969.

12. Alden Research Laboratories. "Indian Point Cooling Water Studies: Model No. 2," May 1969

13. Alden Research Laboratories. "Hydraulic Survey of Hudson River: The Haverstraw Bay Area," February 1970

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

SUPPLEMENTAL STUDY
OF
EFFECT OF SUBMERGED DISCHARGE
OF INDIAN POINT COOLING WATER ON
HUDSON RIVER TEMPERATURE DISTRIBUTION

MAY, 1972

QL&M Project No.: 115-17

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COMPUTER APPLICATIONS

May 8, 1972
File: 115-17

Mr. Alan Cheifetz
Office of Environmental Affairs
Room 1142
Consolidated Edison Company
of New York, Inc.
4 Irving Place
New York, New York 10003

Subject: Indian Point Submerged Discharge - Supplemental Study

Dear Mr. Cheifetz:

Pursuant to your request of May 5, 1972, we are submitting herewith a memorandum report presenting our response to the submerged discharge questions set forth in the May 2, 1972, letter from the AEC to Con Edison.

For convenience of presentation and since most of these questions are interrelated, our answers appear in the order of presentation given in Section III-E-1-g-2 of the "Draft Detailed Statement" of April 13, 1972, prepared by the U.S. AEC, rather than the order given in the May 2, 1972, letter. QL&M's response to these questions is given in a set of six items, as outlined below. For convenience, however, our specific answers to the individual AEC questions are located in the following outline.

QL&M item number and title	AEC Letter Question No.
1. Submerged discharge model and Evaluation parameters	1, 6, 7, 9, 10
2. Expansion of submerged discharge jet boundaries - literature review	2

Letter to: Mr. Alan Cheifetz
Date: May 8, 1972

3.	Sensitivity analysis of jet growth parameters using Indian Point units 1 & 2 discharge conditions	4,6
4.	Relationship between entrainment coefficient and slopes of jet boundaries	2, 3, 6
5.	Distribution of temperature rises over jet cross-sectional area	8, 6
6.	Interference between adjacent jets	5, 6

The theoretical treatment presented in this memorandum report employes a new version of our previously developed submerged discharge model. This version of the model is capable of handling submerged slots as well as ports. Rectangular slots as well as circular ports have been used to evaluate the sensitivity of the model to study input parameters.

Study results have been computed using this model and the final outfall design parameters. In particular, these results take the influence of the revised depth of submergence of 12 feet and the recirculation effects into account.

Computed results for a condition of a maximum ambient temperature, two unit condenser rise and recirculation conditions showed that the maximum surface temperature in the immediate vicinity of the outfall can be expected to be less than the New York State Criterion of 90°F.

We would be pleased to review the report with you if you desire additional discussion.

Very truly yours,

Karim A. Abood
Associate

KAA:gsf
enc. 1

I. Submerged Discharge Model and Evaluation Parameters*

In 1969, Quirk, Lawler & Matusky Engineers (QL&M) developed and successfully programmed for computer solution a three-dimensional mathematical model describing the behavior of a submerged circular jet in an estuary. Detailed description of this hydraulic phenomenon and formulation of the mathematical model and computer program are given in Reference 1.

Additional development and modification of this model has occurred since 1969.[6] In addition to the improvements discussed in Reference 6, the theoretical analysis has been recently modified to make the mathematical model capable of handling rectangular slots as well as circular ports. This modification permits use of the model to directly describe the behavior of a submerged rectangular slot without having to convert the slot to an equivalent circular port.

Since a program deck is not available at present, we are enclosing a listing of the modified submerged discharge program, used in this study, as an Appendix to this Report.

This model was used to evaluate the expected behavior of the revised Indian Point outfall slots. Details of the revised design are given in Reference 5. For convenience, a brief description of the design is given below.

**Dr. Karel A. Konrad of QL&M performed many of the calculations and investigations reported herein and prepared the original draft of these notes.*

Details of the revised Indian Point outfall system are shown in Figure 1. The system consists of 12 discharge ports with rectangular openings 4 feet high by 15 feet long, spaced 20 feet apart (center to center) discharging horizontally and normal to the river flow, and located 12 feet at centerline of port below the mean low water elevation. Ten of these slots are equipped with fully adjustable gates to insure a submerged jet velocity of 10 fps for any combination of units in operation.

The original 18' depth of submergence was changed to 12' to improve mixing of the effluent with the ambient water and minimize river bottom scour action. Recent hydraulic model tests showed that the revised outfall design produced lower overall temperatures.

As shown in Figure 1, the combined Unit No. 1 & 2 effluent will be discharged through seven of the twelve slots of the three unit outfall.

Indian Point Units 1 & 2 design parameters are summarized in Table 1. As requested by the AEC, Table 2 summarizes the exposure time predictions corresponding to single and combined unit operation. These values have been computed by Consolidated Edison personnel.

The combined operation values correspond to two unit operation at rated capacity. This study employed the rated capacity summertime two unit operation values since the objective of this report is to compare the performance of the outfall with the 90°F criterion. During summer months, when ambient temperatures reach a maximum value, this criterion may control.

The Table values corresponding to cooling water flow reduction are associated with non-summer periods and may occur during some fall and winter months when the river ambient temperature is equal to or less than 50°F. A wintertime plant temperature rise of 25°F would yield maximum surface temperatures of less than 75°F. Therefore, the 90°F criterion is not controlling during such periods.

The controlling criterion during flow reduction periods may be the 67% surface width 4°F criterion. However, evaluation of the effect of two unit operation during wintertime conditions indicates that the 67% criterion will not be contravened. A summary of wintertime predictions is given in Figure 2.

In addition to the two unit rated capacity operation outfall temperature rise, this study includes the recirculation effects into account.

Hydraulic model thermal recycling studies indicate that two unit rated capacity operation may result in recirculation effects ranging from less than 0.1°F to less than 1.2°F, depending upon the prevailing tidal conditions. The tidal average increase in intake temperature rise over the entire water column due to recirculation of heated water will be about 0.75°F. This value has been rounded off to 1°F and used in this study to account for the recirculation effect.

The maximum naturally occurring river water ambient temperature used in this evaluation is 79°F. This value is considered to be the highest water temperature that can be experienced by the Indian Point intake at any time. Review of available Hudson River channel temperature data given in Reference 6 shows that this maximum temperature of 79°F in the Hudson River is reached around mid-August of certain years. Ambient temperature does not reach this value every year. For example, the maximum ambient water temperature observed in the vicinity of Indian Point in 1969 occurred on two days in August and was 77.6°F. Available temperature measurements, depicted in Figure 3, over a ten year period from 1956 through 1965 show that the 79°F monthly average is reached only once in eight years. The values shown in Figure 3 are based on temperature measurements of intake cooling water at Lovett. Although these temperatures may be somewhat high because of recirculation of effluent cooling water, they represent the most extensive survey of ambient river temperatures for the Indian Point-Lovett area. These measurements were grouped into monthly averages and statistically analyzed for the August months.

Data subsequent to 1965 were not included in the analysis because they represent a significantly greater degree of heat recirculation as a result of the Lovett Unit No. 4 being operational.

Figure 4 depicts the ambient temperature seasonal variation at Indian Point for the meteorological conditions of 1964. This Figure indicates that the maximum ambient temperature in this area was less than 79°F in 1964.

Several Hudson River temperature profiles and additional support of the 79°F value are given in Reference 6.

Section III-E-1-g-2 of the Draft Detailed AEC Statement and the AEC May 2, 1971 letter to Consolidated Edison refer to the 81°F August ambient temperature reported by New York University.

As explained during our several meetings with the AEC personnel, these NYU measurements were conducted in conjunction with a biological survey of the River and reflect the effect of recirculation due to Unit No. 1 operation. Biological surveys usually employ conventional temperature instruments rather than precision thermometers (since the major objective was the biological activity rather than temperature distribution, per se) using Centigrade rather than Fahrenheit units (a 10% error in °C is equivalent to about 20% error in °F). Moreover, the maximum ambient temperature measured by NYU in the Indian Point vicinity (east bank of the Hudson River) averaged 26.75°C or about 80°F rather than 81°F.

The 79°F value, used in this study, is based upon the above mentioned observations, does not include any recirculation effects (since these are treated separately in this study) and is indicative of overall intake water column rather than shore or surface conditions.

II. Expansion of Submerged Discharge Jet Boundaries - Literature Review

The previously developed Quirk, Lawler & Matusky Engineers' submerged discharge mathematical model utilizes jet boundary slopes (C_1 & C_2) to account for plume growth within the zones of flow establishment (initial zone) and established flow. Numberical values employed in Reference 1 are given below.

	Circular Port	Slot
Zone of flow establishment, C_1	0.16	0.15
Zone of established flow, C_2	0.20	0.25

As indicated in Reference 1, the length of the initial zone has been defined as 6.2 x D_o (initial jet diameter), for a circular jet, and as 5.3 x W_o (initial jet width), for a rectangular jet. A definition diagram of both zones is given in Figure 5.

A comprehensive literature review of reported observations of the slopes of expanding jets is given in T.R. Camp's "Water and Its Impurities"[(2)] on pages 238 and 239. For convenience, a sample of these observations is reproduced below.

Albertson and co-workers* found that the boundary of the expanding

* *Albertson, M.L., Dai, Y.B., Jensen, R.A. and Rouse, Hunter, Trans. Am. Soc. Civil Engrs., 115, 630 (1950).*

jet from a circular orifice diverged at a slope of approximately 1 to 5 (or a slope of 0.2) from the centerline.

Tallmien, working with air, found that the boundary diverged at a slope of 1 to 3.92 (or a slope of 0.25). Rice working with freswater in salt water, with differences in specific gravity ranging from 0.01 to 0.035, found that the boundary diverged at a slope of 1 to 4.8 (or a slope of less than 0.21).

According to Person*, Folsom and Ferguson, who worked with gasoline, the boundary of the expanding jet diverged at a slope of 1:4.31 (or a slope of 0.23).

Rawn and Palmer, in experiments with freshwater jets in sea water, found that the boundary of the expanding jet diverged at a slope of 1 over 6 to 8 (or slopes of 0.17 to 0.13, respectively).

One of the best known investigators in the field of turbulent jets, G.N. Abramovich, has presented an analysis of spread of a turbulent submerged jet and its geometric features in his text, The Theory of Turbulent Jets.[3] On pages 505 through 509 of this publication, Abramovich reports a jet boundary slope of 0.158, for the initial zone, and of 0.22 for the zone of established flow. The length of the initial zone used in Reference 3 is equivalent to nine initial radii.

* *Person, E.A. "An Investigation of the Efficacy of Submarine Outfall Disposal of Sewage and Sludge," Publication No. 14, State Water Pollution Control Board, Sacremento, California, 1956.*

Lohn-Nien Fan[4] employes an initial zone lenth of 6.2 diameters for a nozzle (in referencing Albertson's results).

The brief literature review indicates that the slopes of jet boundaries, incorporated in the QL&M mathematical model agree very well with those observed and reported by many investigators.

III. Sensitivity Analysis of Jet Growth Parameters Using Indian Point Discharge Conditions

A. Circular Jets

In order to determine the effect of boundary slope on jet characteristics within the initial zone three computer runs* were conducted using QL&M submerged discharge model and initial jet slopes (C_1) of 0.10, 0.16 and 0.25.

Table 3 and Figure 6 summarize the variation in jet flow, velocity and dilution ratio corresponding to these three slopes. As to be expected, the results indicated that a higher slope of boundary results in a higher jet flow and dilution ratio and a lower average velocity. The differences between the jet characteristics increase with increasing distance from the outfall.

Effects of the jet boundary slope within the zone of established flow (C_2) was evaluated by using three C_2 values (0.15, 0.20, 0.30), while keeping slope C_1 and length of the initial zone (S_2) constant.

Table 4 and Figure 7 depict the variation of jet flow, velocity and dilution ratio with jet path distance, for $C_1 = 0.16$ $S_2 = 6.2\ D_o$ and $C_2 = 0.15$, 0.20 and 0.30.

Study results indicate that the effect of slope C_2 is similar to that of C_1, i.e., a higher slope C_2 results in a higher jet flow and dilution ration and a lower jet velocity.

* *All computer runs reported herein and after were conducted for water slack conditions.*

The effect of length of the jet initial zone (or zone of establishment) is shown in Table 5. This table summarizes the influence of three initial zone lengths (4.0 D_o, 6.2 D_o, and 8.0 D_o) on jet flow, velocity and dilution ratio. Jet boundary slopes were kept constant during these runs. C_1 and C_2 values of 0.16 and 0.20 were used for this purpose.

As to be expected, the above presented results of the sensitivity runs indicate that the slopes, C_1 and C_2 of the jet boundaries significantly affect the jet growth characteristics. The jet characteristics are less significant to changes in length of the initial zone.

The main objective of this sensitivity analysis, however, is to determine variation of dilution ratios and subsequently average temperature rises at controlling jet critical sections, described in Reference 1, i.e., upper boundary, interference, lower boundary or centerline controls.

These jet controls have been defined, in Reference 1, as locations where the jet boundary interfere with boundaries of receiving water body (such as water surface, river bottom, etc.) or with the adjacent jet boundary. The control resulting in the lowest value of dilution ratio, i.e., the highest temperature rise, has been defined as the critical control.

In all sensitivity runs, reported in this study and including rectangular jet runs conducted for the revised outfall design, the critical control was the location where the upper boundary reaches the water surface.

Table 6 summarizes dilution ratios and average temperature rises at the critical controls for jets with different boundary slopes and different lengths of the initial zone. Although the variable coefficients spanned large intervals, the variation in dilution ratio and average temperature rise was small. The difference between the highest and lowest calculated temperature rises was about 1°F.

According to the literature survey presented in Item I, the uncertainties in determination of the coefficients C_1, C_2 and S_2 could be expressed by smaller intervals of these coefficients than those used for the above reported sensitivity analyses. It is concluded, therefore, that these uncertainties have an insignificant effect as far as the average jet temperature rise at the critical control is concerned. This value is the major objective of the submerged discharge model analysis.

B. Rectangular Jet Sensitivity Analysis and Comparison with Equivalent Circular Jets

The length of the initial zone of submerged jets used in the QL&M model has been taken as 5.3 times the initial width of the jet. This relationship has given results similar to those used for circular jets.

QL&M had used the jet initial width rather than height for determination of the initial zone of a rectangular jet. This assumption is conservative, i.e., yields lower dilution ratios.

of width. We agree with the AEC's statement and question No. 3 in the May 2, 1972, letter that the jet height instead of width is more applicable for determination of the initial zone of the Indian Point jets.

Table 7 summarizes and compares computed jet flow, velocity and dilution ratio for two jets having initial zone lengths determined using 5.3 widths (5.3 W_o) and 5.3 heights (5.3 H_o) respectively. In both cases, boundary slopes were kept the same, i.e., $C_1 = 0.15$, $C_2 = 0.25$. The differences between calculated values of study variables are given in Table 7.

Table 8 compares dilution ratios and average temperature rises at the critical control of the two rectangular jets with three circular jets having different initial zone lengths. The table indicates that the dilution ratios at the critical controls are higher for rectangular jets (3.4 and 3.8) than those for circular jets (2.8, 2.8 and 2.9) and that the dilution ratio at the critical control of the rectangular jet is higher if the jet initial zone length is calculated using the jet initial height instead

IV. Relationship Between Entrainment Coefficient and Slopes of Jet Boundaries

The concept of the entrainment coefficient, as defined in the following expression, has been introduced by several authors:

$$\frac{dQ}{ds} = 2\pi b \alpha u \qquad \ldots(1)$$

in which:

- Q = jet flow
- s = distance measured along the jet centerline
- b = characteristic length
- u = characteristic velocity (usually centerline velocity)

The characteristic length, b, is determined using jet velocity profiles. Approximation of jet velocity profiles by a Gaussian function:

$$u(r) = u_c e^{\frac{r^2}{b^2}} \qquad \ldots(2)$$

yields a characteristic length determined by the following equation:

$$\sqrt{2b} = (2\sigma) = R \qquad \ldots(3)$$

in which, R is assumed to be nominal radius of the jet.

Some of the investigators* prefer use of slopes of jet boundaries rather than entrainment coefficients because these slopes are directly observable during physical experiments and also because the concept of entrainment coefficient requires predetermination of the type of velocity distribution.

Furthermore, the type of velocity distribution within the initial zone is not stable and may not be represented by a Gaussian function. The definition of the entrainment coefficient given in Equation 1 is not clear in this region. If the entrainment coefficient α is to be used in this region then Equation 1 should be changed to:

$$\frac{dQ}{ds} = 2\pi R \alpha u_o \qquad \ldots(4)$$

in which:

R = radius of the jet

u_o = initial jet velocity ($u_c = u_o$ = const. throughout the initial region)

The entrainment coefficients corresponding to the study jets may be determined by using computer printout of variables for finite segments of a jet. This is described below.

Use of finite jet segments within the flow establishment zone requires the following modification to Equation 4.

* *For example, Abramovich does not introduce the entrainment coefficient at all.*

$$\alpha = \frac{\Delta Q}{2\pi R^* u_o \Delta S} \quad \text{...(5)}$$

in which:

R^* = average radius in a given segment

Similarly, for the zone of established flow, Equation 1 becomes:

$$\alpha = \frac{\Delta Q}{2\pi b^* u_c^* \Delta S} \quad \text{...(6)}$$

in which:

b^* = average characteristic length in a given segment $(b^* = \frac{R^*}{\sqrt{2}})$

u^* = average centerline velocity in the segment. Variation in the centerline velocity within a segment (10 ft. segments have been used in this study) is assumed to be linear.

Because the velocity distribution is assumed to follow a Gaussian function, it can be shown that the relationship between the centerline velocity and cross-sectional velocity is given by:

$$u_c = 3.27\overline{u}$$

Calculation of entrainment coefficients within the initial zone of a circular jet are shown in Table 9 for boundary slopes C_1 = 0.10, 0.16 and 0.25. The table indicates that the values of the entrainment coefficient decrease with increasing distance from the discharge port and that the entrainment coefficients generally are higher for a higher slope of jet boundary.

Calculation of entrainment coefficients within the zone of established flow for a circular jet ($C_1 = 0.16$, $C_2 = 0.20$, $S_2 = 6.2\ D_o$) is shown in Table 10. The table shows the variation in the entrainment coefficient along the path of the jet.

Figure 8 depicts variation in the entrainment coefficient along the path of a circular jet ($C_1 = 0.10$, $C_2 = 0.16$, $S_2 = 6.2\ D_o$). The values of the entrainment coefficient shown in this figure correspond to QL&M's basic coefficients, C_1, C_2 and S_2. All of these entrainment coefficient values are lower than the value of 0.082 reported in the literature[4] as representing an entrainment coefficient for buoyant jets. Therefore, the QL&M model gives somewhat more conservative results than those corresponding to reported values of entrainment coefficients.

$$\alpha = \frac{\Delta Q}{2\pi R^* u_o \Delta S} \qquad \ldots(5)$$

in which:

R^* = average radius in a given segment

Similarly, for the zone of established flow, Equation 1 becomes:

$$\alpha = \frac{\Delta Q}{2\pi b^* u_c^* \Delta S} \qquad \ldots(6)$$

in which:

b^* = average characteristic length in a given segment $\left(b^* = \frac{R^*}{\sqrt{2}}\right)$

u^* = average centerline velocity in the segment. Variation in the centerline velocity within a segment (10 ft. segments have been used in this study) is assumed to be linear.

Because the velocity distribution is assumed to follow a Gaussian function, it can be shown that the relationship between the centerline velocity and cross-sectional velocity is given by:

$$u_c = 3.27\overline{u}$$

Calculation of entrainment coefficients within the initial zone of a circular jet are shown in Table 9 for boundary slopes C_1 = 0.10, 0.16 and 0.25. The table indicates that the values of the entrainment coefficient decrease with increasing distance from the discharge port and that the entrainment coefficients generally are higher for a higher slope of jet boundary.

Calculation of entrainment coefficients within the zone of established flow for a circular jet (C_1 = 0.16, C_2 = 0.20, S_2 = 6.2 D_o) is shown in Table 10. The table shows the variation in the entrainment coefficient along the path of the jet.

Figure 8 depicts variation in the entrainment coefficient along the path of a circular jet (C_1 = 0.10, C_2 = 0.16, S_2 = 6.2 D). The values of the entrainment coefficient shown in this figure correspond to QL&M's basic coefficients, C_1, C_2 and S_2. All of these entrainment coefficient values are lower than the value of 0.082 reported in the literature[(4)] as representing an entrainment coefficient for buoyant jets. Therefore, the QL&M model gives somewhat more conservative results than those corresponding to reported values of entrainment coefficients.

V. Distribution of Temperature Rises over Jet Cross-sectional Area

Most mathematical models of submerged jets do not determine the cross-sectional area distribution of velocity and temperature. These distributions are approximated by some functions which more or less fit observed data.

Many authors have used a Gaussian function to simulate velocity distribution and some of them have assumed similarity between velocity and temperature distributions.

However, many observations indicate quite different shapes of these two distributions as can be seen for example, on three graphs reproduced in Figure 9 from The Theory of Turbulent Jets, by G.N. Abramovich.[3] These three figures indicate that the observed temperature distribution values follow a cosine, rather than a Gaussian, function. Such a cosine function (shown on these figures) can have a form similar to:*

$$\frac{\Delta T}{\Delta T_m} = 0.2 + 0.8 \cos \frac{Y}{Y_c} \frac{\pi}{4} \qquad \ldots(7)$$

---

* *The equation for calculation of maximum surface temperature rise used in Reference 1 is:*

$$\Delta T_m = 3.0 + (\Delta T_{avg} - 3.0) \cos \frac{\pi d}{D/2} \qquad \ldots(10)$$

This function represents an empirical approach. QL&M mathematical model was applied to the Lovett Unit #4 and Indian Point Hydraulic model submerged discharges to calculate the average temperature rises at the critical controls. Equation 10 was derived in an attempt to covert computed average temperature rises over jet corss-sectional area to the surface temperature distributions observed at Lovett Unit #4 and on the Indian Point hydraulic model.

in which,

ΔT = temperature rise above the ambient temperature at the distance Y from the jet centerline

ΔT_m = maximum temperature rise at given section (at the centerline)

Y = distance between given point and centerline of jet

Y_c = distance at which the velocity is equal to 0.5 V_m

If we assume that the boundary of the jet is located at $Y = 2Y_c$ (this is a reasonable assumption considering that the velocity at this location is about 0.05 V max), then the average temperature over the jet cross-sectional area can be expressed as a fraction of ΔT_m in the following manner:

<u>For a Circular Jet:</u>

$$\frac{\Delta T_{avg}}{\Delta T_m} = \frac{\int_0^{2\pi}\int_0^{2} [0.2 + 0.8 \cos (Y^* \frac{\pi}{4})] \, dY^* d\theta}{\int_0^{2\pi}\int_0^{2} Y^* \, dY^* d\theta}$$

Where $Y^* = \frac{Y}{Y_c}$

$$\frac{\Delta T_{avg}}{\Delta T_m} = \frac{1}{4\pi}\int_0^{2\pi}\int_0^{2} [0.2 + 0.8 \cos (Y^* \frac{\pi}{4})] \, dY^* d\theta$$

$$\frac{\Delta T_{avg}}{\Delta T_m} = \frac{1}{4\pi} (0.2 \times 4\pi + 0.744 \times 2\pi) = 0.572$$

From this equation we can express the maximum temperature rise as a function of jet cross-sectional average temperature rise in the following equation:

$$\Delta T_m = \frac{\Delta T_{avg}}{0.572} = 1.75 \, \Delta T_{avg} \qquad \ldots(8)$$

For a Rectangular Jet:

If we assume similarity between the temperature distributions in both directions, then the dimensionless cross-sectional average temperature rise will be:

$$\frac{\Delta T_{avg}}{\Delta T_m} = \frac{\int_0^2 \int_0^2 \left[0.2 + 0.8 \cos\left(Y^*\frac{\pi}{4}\right) \cos\left(Z^*\frac{\pi}{4}\right)\right] dY^* dZ^*}{\int_0^2 \int_0^2 dY^* dZ^*}$$

Where: $Z^* = \frac{Z}{Z_c}$

Z and Z_c are defined in a manner similar to Y and Y_c.

$$\frac{\Delta T_{avg}}{\Delta T_m} = \frac{1}{4}\left\{4 \times 0.2 + 0.8 \int_0^2 \int_0^2 \left[\cos\left(Y^*\frac{\pi}{4}\right) \cos\left(Z^*\frac{\pi}{4}\right)\right] dY^* dZ^*\right\}$$

$$\frac{\Delta T_{avg}}{\Delta T_m} = \frac{1}{4}\left(4 \times 0.2 + 0.8 \frac{16}{\pi^2}\right) = 0.524$$

Maximum temperature rise can be expressed as a function of jet average temperature rise as follows:

$$\Delta T_m = \frac{\Delta T_{avg}}{0.524} = 1.91\ \Delta T_{avg} \qquad \text{...(9)}$$

Applying equations 8 and 9 at the critical control sections of the study jets, the maximum temperature rises corresponding to these sections are as indicated in the following tabulation:

Description of Jet	Avg. Temp. Rise at the Upper Boundary Control (3) °F	Max. Temp. Rise at the Upper Boundary Control (Eq. 8 & 9) °F	Max. Temp. Rise at the Upper Boundary Control Including Effect of Recirculation °F
Circular C_1=0.16, C_2=0.20, S_2=6.2D_o	5.30	9.3	10.3
Rectangular C_1=0.15, C_2=0.25, S_2=5.3H_o	3.90	7.5	8.5

Notes: 1. H_o is initial height of discharge slot.

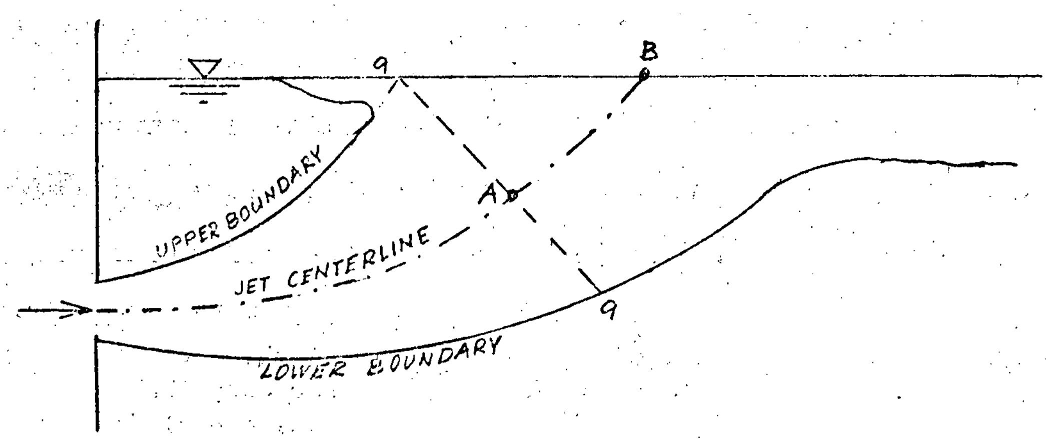
2. Average temperature rises were calculated using plant temperature rise of 14.8°F. An additional 1°F was added to final results, i.e., maximum surface temperature rises, to account for recirculation. This is tantamount to adding 1°F X dilution ratio to the plant temperature rise.

3. The values of average temperature rises taken from Table 8.

4. The upper boundary control is the critical control.

Once the upper boundary reaches the surface, entrainment of ambient water into the jet is limited to the lower boundary and partially to the sides of the jet and the velocity and temperature distribution are distorted. A mathematical determination of the jet behavior after jet interference with the surface is beyond the present knowledge of art.

The maximum temperature rise at the upper boundary control (section a-a in the schematic diagram below) shown in the tabulation above occurs at point A.



The temperature of water particles at location "A" will be decreased as those particles move upward to the surface (Location

"B") by additional dilution of the jet water by ambient water. Because of uncertainties in determination of such additional dilution, the maximum temperature rise at the upper boundary control is used, in this study, as a conservative estimate of the maximum surface temperature rise.

Therefore, the maximum surface temperature rise at Indian Point during rated operation of Units #1 and #2 is estimated to be approximately 8.5°F(see the tabulation above - rectangular jet). This maximum surface temperature rise agrees very well with the previously reported results.[5]

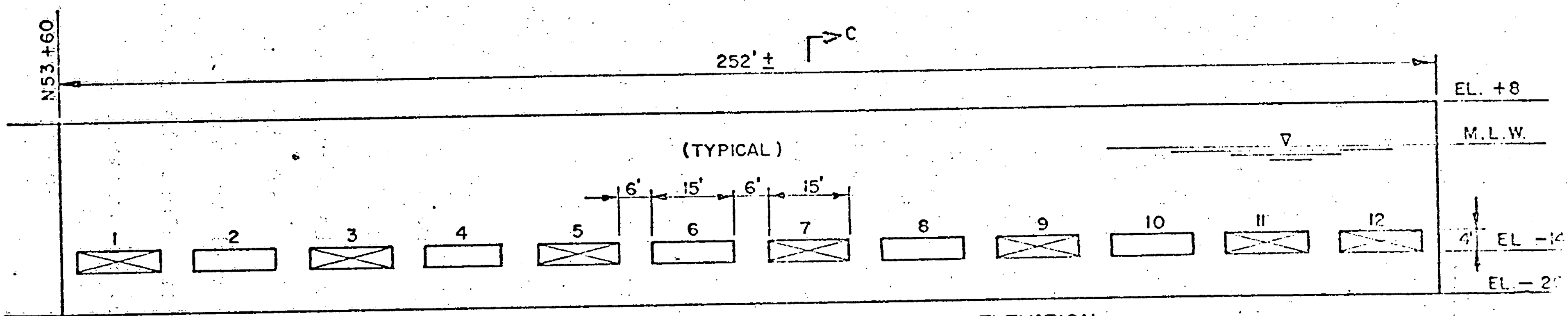
VI. Interference Between Adjacent Jets

As shown on Figure 1, full flow operation of Units 1 & 2 will require 7 of the 12 submerged slots. The outfall two unit operation arrangement depicted in Figure 1 provides a spacing of 42 feet between the centerlines of the jets.

The interference between jets will occur, wherever the jet widths reach 42 ft. In all computer runs made for the sensitivity analyses, the interference between jets occured at a greater distance from the discharge than that where the upper boundary reached the surface. Because the maximum temperature rise at the upper boundary control was shown to be the maximum surface temperature rise, the interference control value not controlling in 6 out of 7 jets (jets no. 1, 3, 5, 7, 9 and 11 of Figure 1).

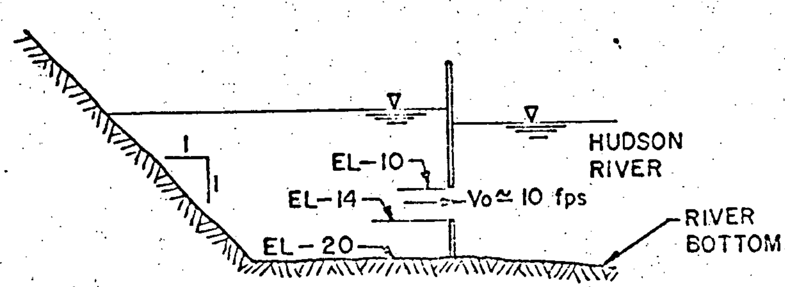
More interference will occur between the last two jets (no. 11 & 12), since these two slots may be employed. In this case, interference between these jets may occur at a distance of about 20 feet from the discharge slots, where the dilution ratio is about 2.1 and the average temperature rise is 7.5°F. For this case, Equation 9 gives a maximum temperature rise of 14.3°F. However, use of this temperature as the maximum surface temperature rise is extremely conservative and somewhat unrealistic. This temperature occurs at a depth of 11.7 ft. and the additional path of water particles before they reach the surface is about 50 ft. The additional entrained water, along the 50 foot path of the jet, will result in additional temperature rise reduction.

DETAILS OF INDIAN POINT UNITS 1 & 2 DISCHARGE STRUCTURE



NOTE : FOR DISCHARGE FROM UNITS 1 & 2, PORT NUMBERS 2, 4, 6, 8, 10 WILL BE BLOCKED

ELEVATION
(LOOKING S-E)



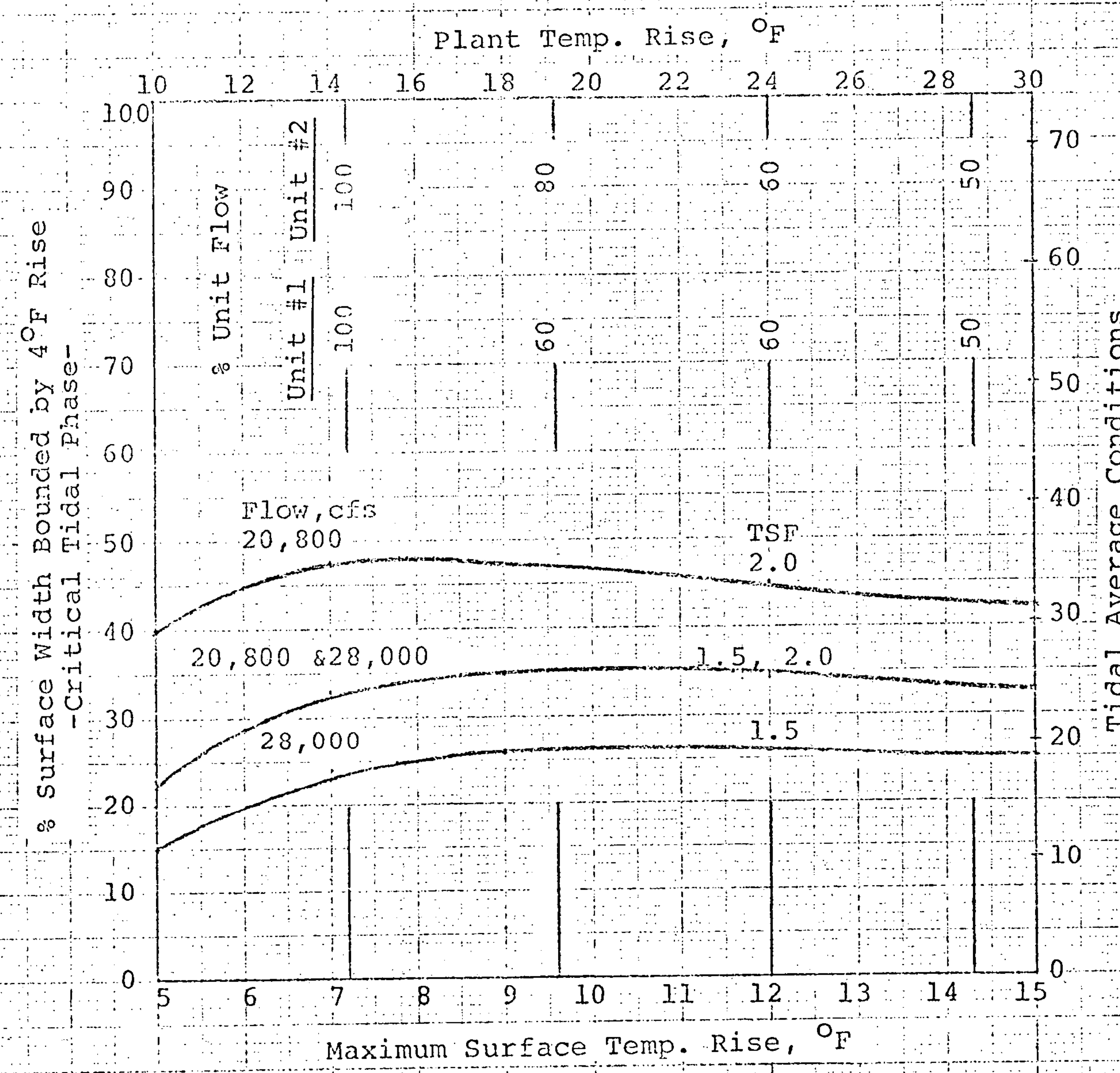
AS SECTION C-C
(REVISED DESIGN)

FIGURE 1

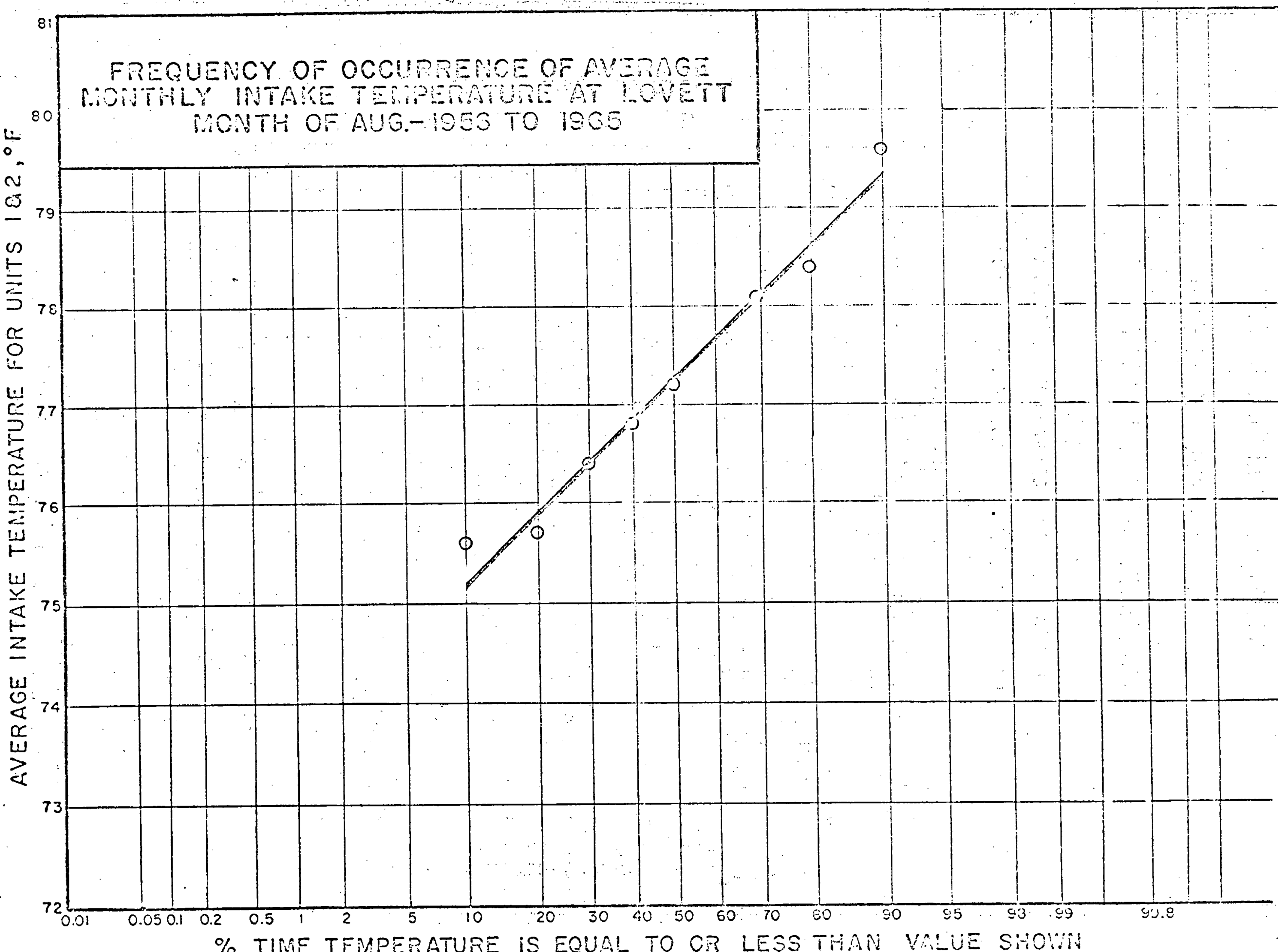
FIGURE 2

SURFACE WIDTH AT INDIAN POINT PLANE OF DISCHARGE SUBJECTED TO TEMPERATURE RISES IN EXCESS OF 4°F

-RATED CAPACITY OPERATION OF INDIAN PT. UNITS 1&2 AND LOVETT UNITS 1-5-



$\overline{K}$=90 BTU/ft² day °F
E= 6 smd
Dilution Ratio=1:2



FREQUENCY OF OCCURRENCE OF AVERAGE
MONTHLY INTAKE TEMPERATURE AT LOVETT
MONTH OF AUG.-1953 TO 1965
AVERAGE INTAKE TEMPERATURE FOR UNITS 1&2, °F
81
80
79
78
77
76
75
74
73
72
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
% TIME TEMPERATURE IS EQUAL TO OR LESS THAN VALUE SHOWN

FIGURE 3

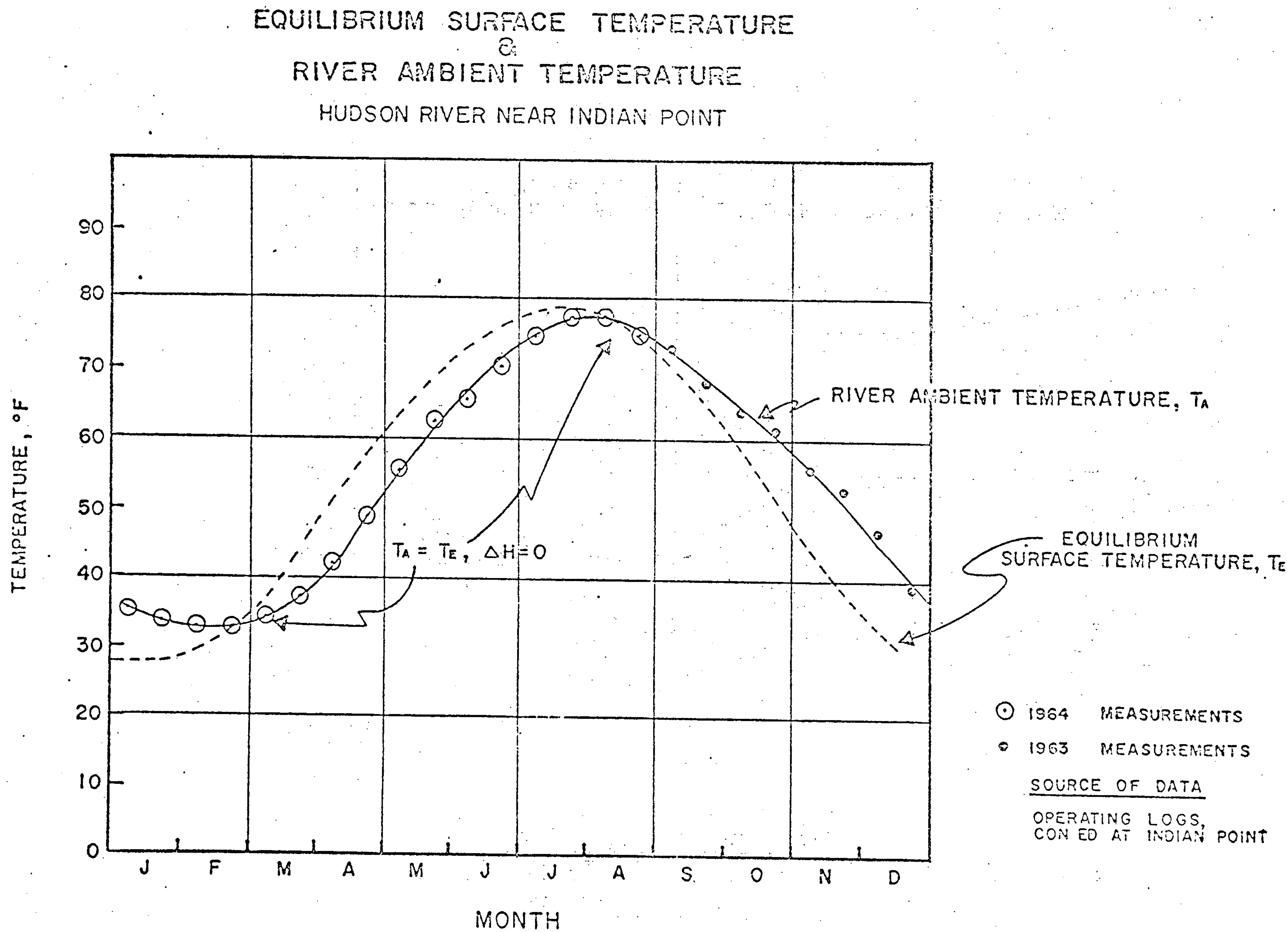

EQUILIBRIUM SURFACE TEMPERATURE
&
RIVER AMBIENT TEMPERATURE
HUDSON RIVER NEAR INDIAN POINT
TEMPERATURE, °F
90
80
70
60
50
40
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
RIVER AMBIENT TEMPERATURE, T_A
EQUILIBRIUM SURFACE TEMPERATURE, T_E
$T_A = T_E$, $\Delta H = 0$
1964 MEASUREMENTS
1963 MEASUREMENTS
SOURCE OF DATA
OPERATING LOGS, CON ED AT INDIAN POINT

FIGURE 4

DEFINITION SKETCH OF
ZONE OF FLOW ESTABLISHMENT AND
ZONE OF ESTABLISHED FLOW

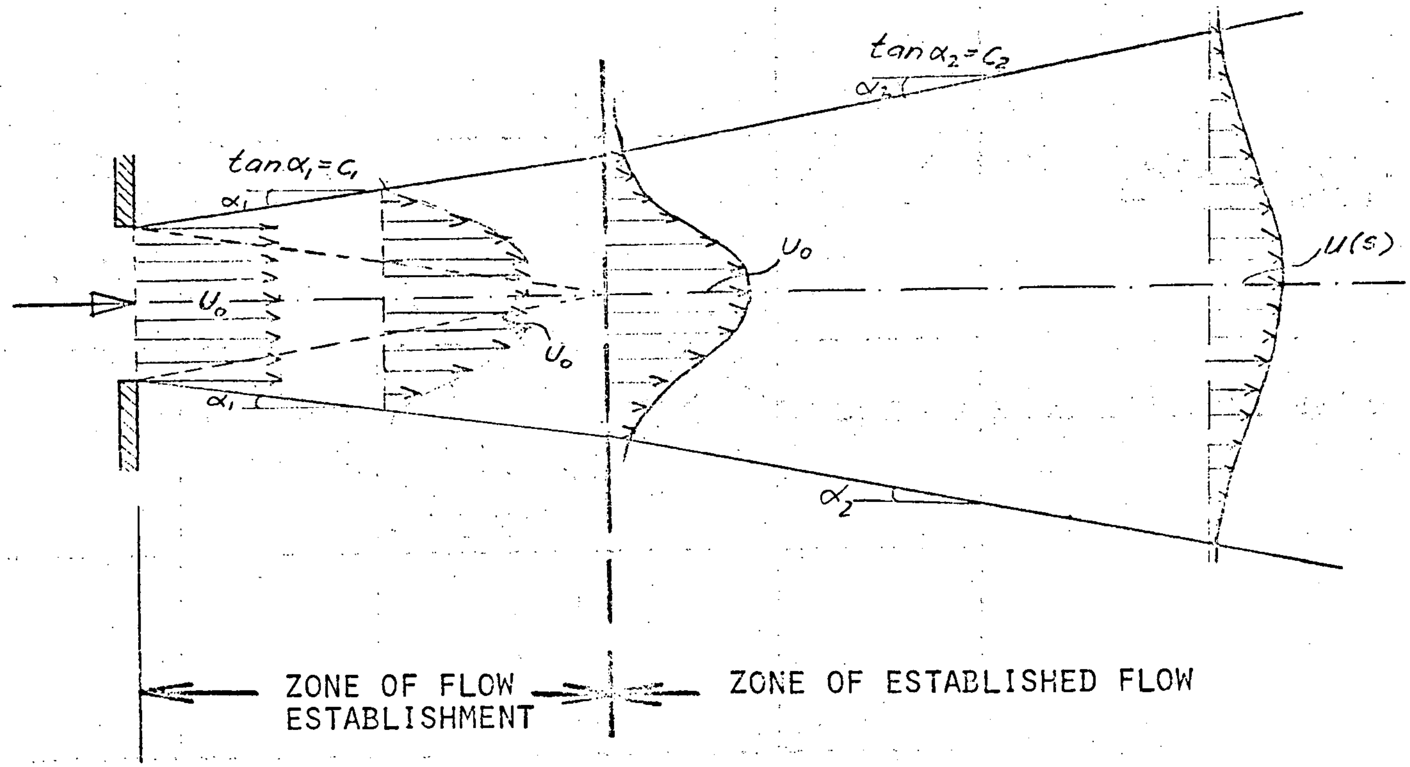


FIGURE 5

FIGURE 6

EFFECT OF ZONE OF ESTABLISHMENT JET BOUNDARY SLOPE (C_1) ON JET DILUTION AND FLOW

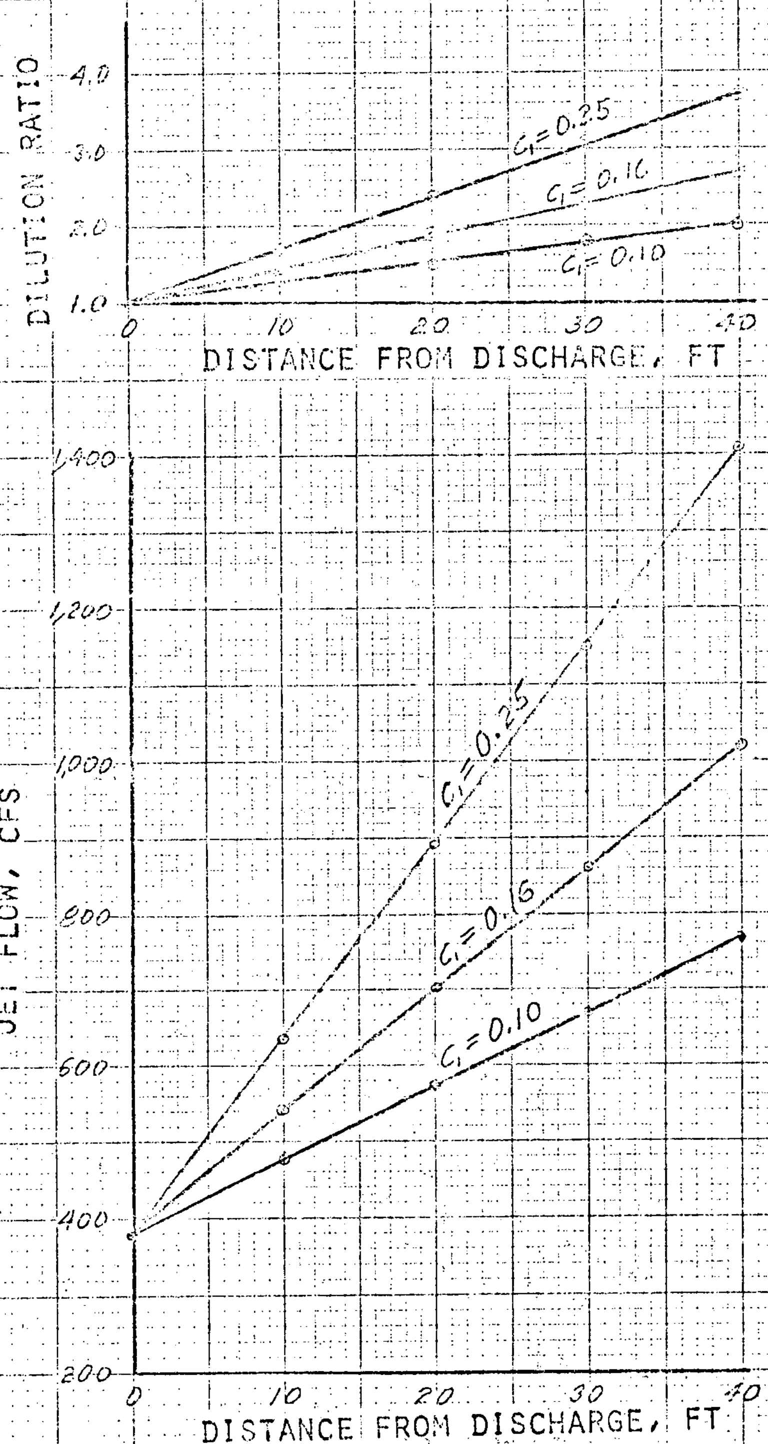
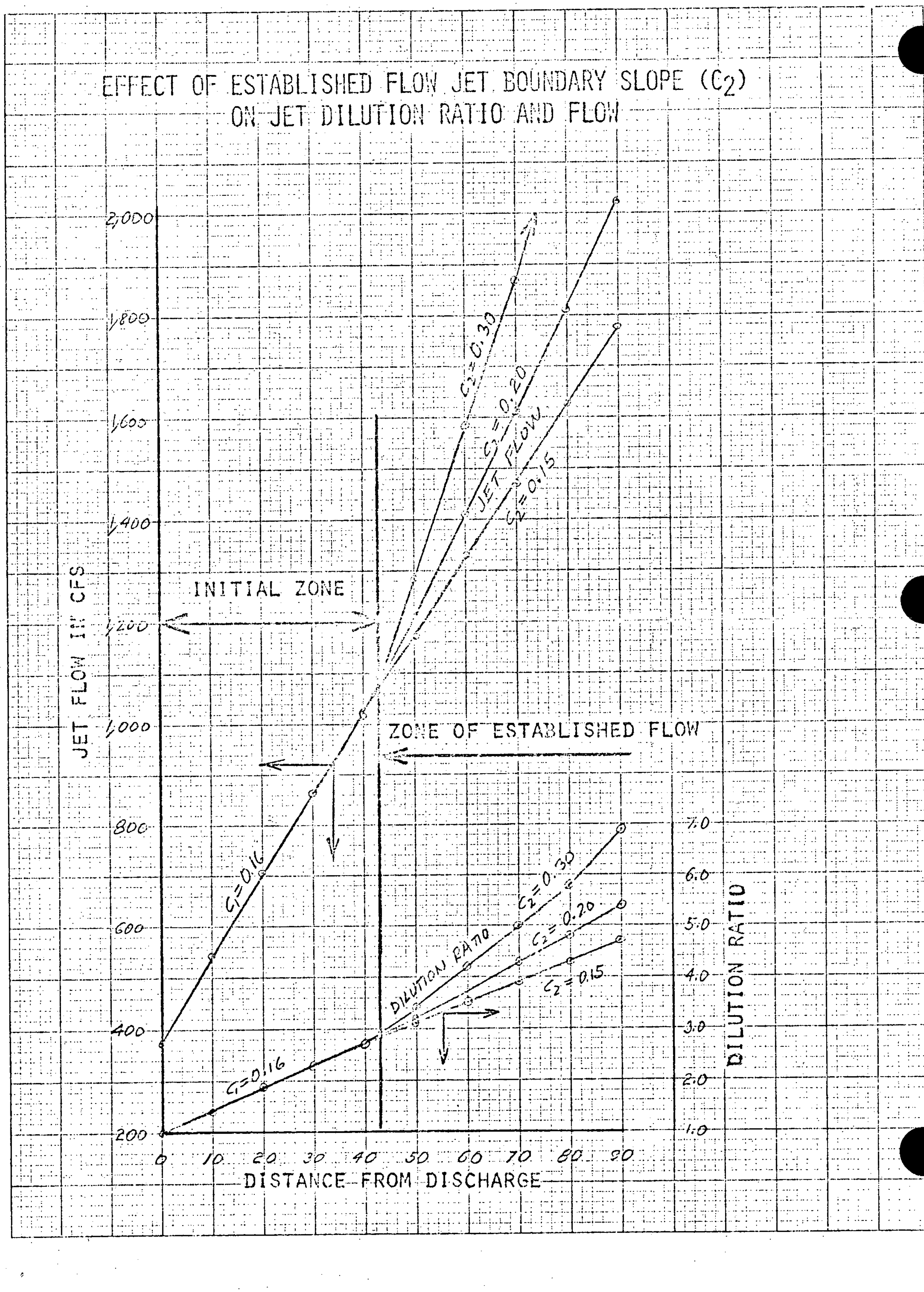
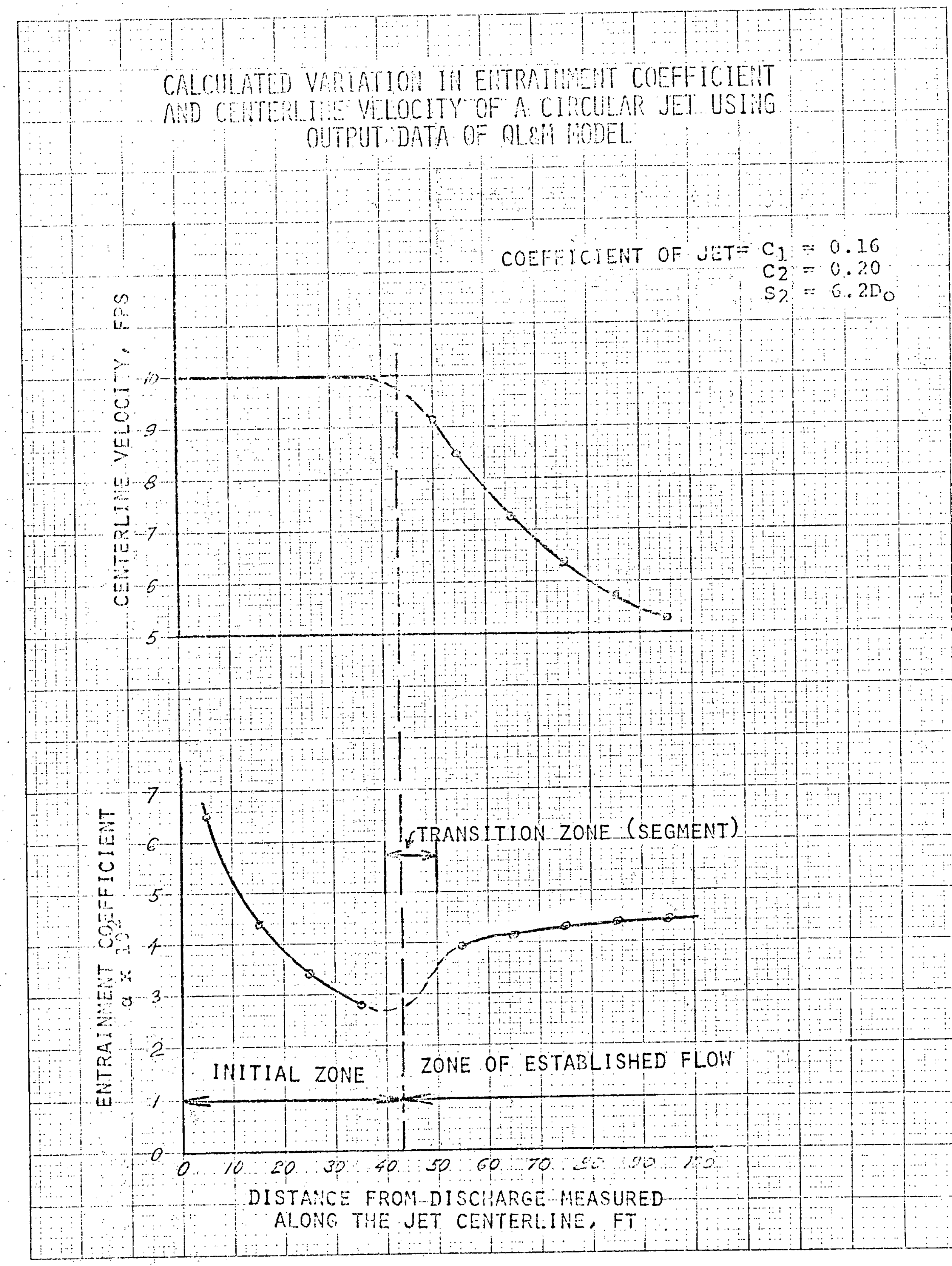


FIGURE 7


EFFECT OF ESTABLISHED FLOW JET BOUNDARY SLOPE (C2)
ON JET DILUTION RATIO AND FLOW
JET FLOW IN CFS
DILUTION RATIO
DISTANCE FROM DISCHARGE
INITIAL ZONE
ZONE OF ESTABLISHED FLOW
JET FLOW
DILUTION RATIO
C2=0.30
C2=0.20
C2=0.15
C1=0.16
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
10
20
30
40
50
60
70
80
90


CALCULATED VARIATION IN ENTRAINMENT COEFFICIENT AND CENTERLINE VELOCITY OF A CIRCULAR JET USING OUTPUT DATA OF QL&M MODEL
COEFFICIENT OF JET= C1 = 0.16
C2 = 0.20
S2 = 6.2Do
CENTERLINE VELOCITY, FPS
ENTRAINMENT COEFFICIENT α X 10-2
TRANSITION ZONE (SEGMENT)
INITIAL ZONE
ZONE OF ESTABLISHED FLOW
DISTANCE FROM DISCHARGE MEASURED ALONG THE JET CENTERLINE, FT

APPROXIMATION OF TEMPERATURE RISE DISTRIBUTION

OVER JET CROSS SECTION BY A COSINE FUNCTION

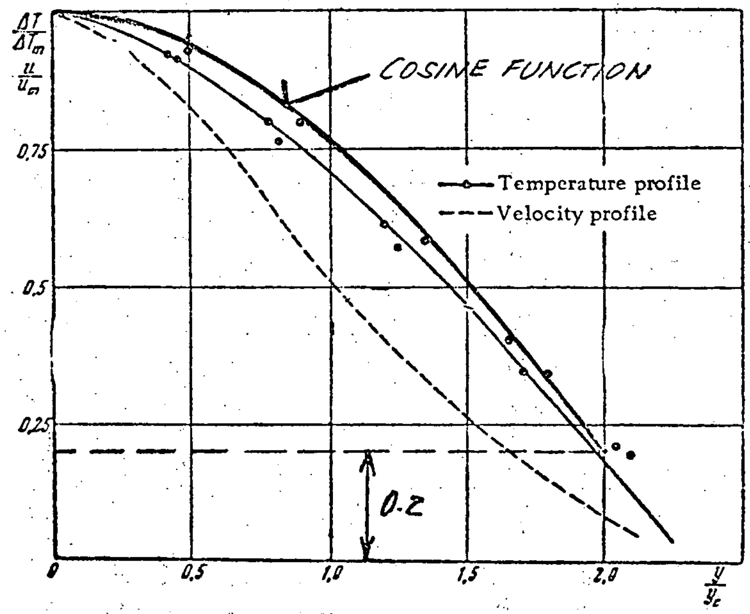


Fig. 1.16. Dimensionless temperature differences and velocity profiles in main region of axially symmetric jet according to Stark's data [11].

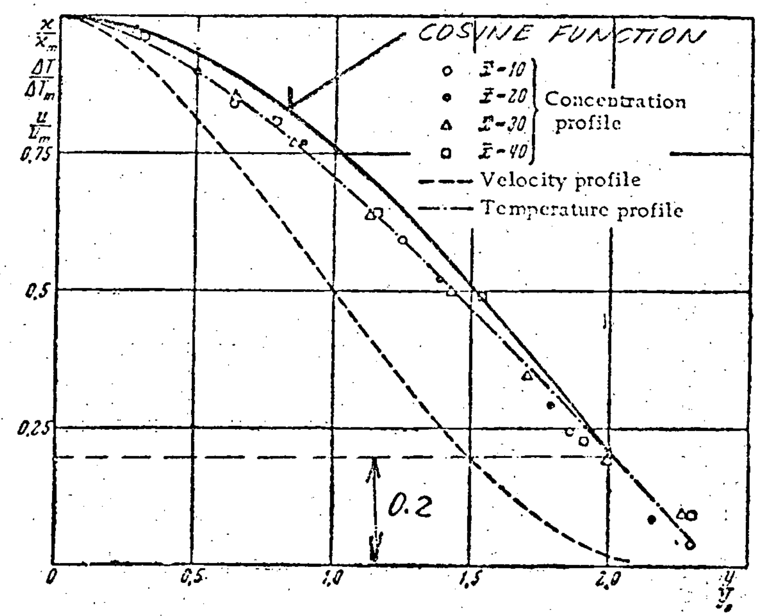


Fig. 1.17. Dimensionless profiles for temperature difference, concentration of admixture and velocity in main region of plane jet from data given by Abramovich and Borodachev ($\bar{x} = x/b_0$).

Note:

These figures were taken from Abramovich's text (Reference 3). The cosine function solid curves were computed using Equation 7 of this memo.

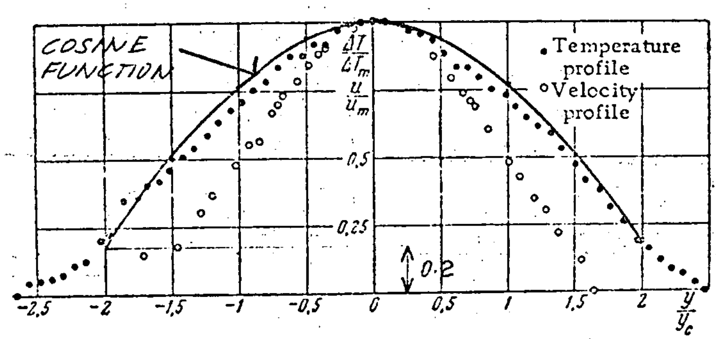


Fig. 1.15. Dimensionless temperature and velocity profiles in main region of plane jet according to Reichardt's experimental data [10].

FIGURE 9

TABLE 1

INDIAN POINT UNITS 1 & 2 THERMAL DISCHARGE PARAMETERS

Parameter	Unit #1	Unit #2	Units 1&2
Electrical Output @ Rated Capacity, MWE	265	873	1138
Waste Heat*, BBTU/day	47	153	200
Typical Summer Operation			
. Cooling Water Flow, thousands gpm	280	840	1120
. Service Water Flow, thousands gpm	38	30	68
. Condenser Temperature Rise, °F	14	15.1	--
. Temperature Rise at Outfall Structure Above Intake Temperature, °F	--	--	14.8
Typical Winter Operation			
. Cooling Water Flow, thousands gpm	168	504	672
. Service Water Flow, thousands gpm	38	30	68
. Condenser Temperature Rise, °F	23.4	25.2	--
. Temperature Rise at Outfall Structure Above Intake Temperature, °F	--	--	25

*Assuming no in-plant losses

TABLE 2

INDIAN POINT UNITS 1 & 2 EXPOSURE TIME CALCULATIONS*

Assumptions

1. MHW Condition = EL 2.2'

2. Head @ Discharge Port = 3.5'

3. Neglect Head Loss Gradient Up to the Canal (Balanced by Flow From Aux. Pumps)

4. Organism Is Discharged at Extreme Southern Port (Low Flow Conditions) or in Mid-Section of the Outfall (Normal Flow Conditions)

5. Unit 2 Low Flow = 3 Pumps @ 60% Flow
   Unit 1 Low Flow = 60% of 140,000 gpm

		Single Unit Operation		Two Unit Operation	
Flow Condition	Unit No.	Flow,gpm	Exposure time,min.	Flow,gpm	Exposure time,min.
Normal	1	280,000	39	1,120,000	9.5
Normal	2	840,000	14	1,120,000	11
Low (winter)	1	84,000	140	336,000	35
Low (winter)	2	252,000	54	336,000	40

*Computed by Con Edison Personnel

TABLE 3

EFFECT OF JET BOUNDARY SLOPE (C_1) ON JET FLOW VELOCITY AND DILUTION RATIO WITHIN THE INITIAL ZONE

Distance from port along the Jet ℄, ft	$C_1 = 0.10$			$C_1 = 0.16$			$C_1 = 0.25$		
	Flow cfs	Velocity fps	Dil. ratio	Flow cfs	Velocity fps	Dil. ratio	Flow cfs	Velocity fps	Dil. ratio
0*	378.0	10.0	1.0	378.0	10.0	1.0	378.0	10.0	1.0
10	477.5	7.6	1.3	542.1	6.7	1.4	638.9	5.7	1.7
20	575.4	6.1	1.5	703.8	5.0	1.9	896.6	4.0	2.4
30	672.1	4.4	1.8	863.9	4.0	2.3	1152.4	3.0	3.1
40	767.8	3.7	2.0	1023.0	3.3	2.7	1407.5	2.5	3.7

* *Vena contracta*

TABLE 4

EFFECT OF JET BOUNDARY SLOPE (C_2)
ON JET FLOW, VELOCITY AND DILUTION
RATIO WITHIN THE ZONE OF ESTABLISHED FLOW

Conditions: Slope of the jet boundary within the initial zone $C_1 = 0.16$

Length of initial zone $S_2 = 6.2\ D_o$

Distance from port along the Jet ℄, ft	$C_2 = 0.15$			$C_2 = 0.20$			$C_2 = 0.30$		
	Flow cfs	Velocity fps	Dilution Ratio	Flow cfs	Velocity fps	Dilution Ratio	Flow cfs	Velocity fps	Dilution Ratio
40	1023.0	3.3	2.7	1023.0	3.3	2.7	1023.0	3.3	2.7
50	1174.0	2.9	3.1	1210.6	2.8	3.2	1282.0	2.6	3.4
60	1333.2	2.5	3.5	1410.9	2.4	3.7	1586.3	2.1	4.2
70	1473.0	2.3	3.9	1612.7	2.1	4.3	1872.5	1.8	5.0
80	1624.7	2.0	4.3	1817.4	1.8	4.8	2204.2	1.5	5.8
90	1779.4	1.9	4.7	2026.6	1.7	5.4	2524.6	1.3	6.9

TABLE 5

EFFECT OF LENGTH OF JET INITIAL ZONE
ON JET FLOW, VELOCITY AND DILUTION RATIO

Conditions: Slopes of jet boundaries: $C_1 = 0.16$
$C_2 = 0.20$

Distance* from the discharge port along the Jet ℄, ft	$S_2 = 4.0\ D_o$			$S_2 = 6.2\ D_o$			$S_2 = 8.0\ D_o$		
	Flow cfs	Velocity fps	Dilution Ratio	Flow cfs	Velocity fps	Dilution Ratio	Flow cfs	Velocity fps	Dilution Ratio
0	378.0	10.0	1.0	378.0	10.0	1.0	378.0	10.0	1.0
10	542.1	6.7	1.4	542.0	6.7	1.4	542.0	6.7	1.4
20	703.8	5.0	1.9	703.8	5.0	1.9	703.8	5.0	1.9
30	874.3	4.0	2.3	863.9	4.0	2.3	863.9	4.0	2.3
40	1075.0	3.2	2.8	1023.0	3.3	2.7	1023.0	3.3	2.7
50	1275.3	2.7	3.4	1210.0	2.8	3.2	1181.7	2.9	3.1
60	1478.0	2.4	3.9	1410.9	2.4	3.7	1361.3	2.5	3.6
70	1580.1	2.1	4.5	1612.7	2.1	4.3	1562.6	2.1	4.1
80	1884.6	1.8	5.0	1817.4	1.8	4.8	1766.6	1.9	4.7
90	2095.0	1.6	5.6	2026.6	1.7	5.4	1974.8	1.7	5.2

* *from vena contracta*

TABLE 6

VARIATION IN DILUTION RATIO AND AVERAGE TEMPERATURE RISE AT THE CRITICAL CONTROL

Jet Coefficient C_1	C_2	S_2	Distance of critical control from discharge port along the jet ℄ Sc ft	Lateral Distance of critical control from Discharge Xc ft	Dilution Ratio at Critical Control	Average Temp. Rise at Critical Control °F
0.10	0.15	6.2 D_o	55.0	54.9	2.6	5.70
	0.20		53.0	52.9	2.6	5.70
	0.30		50.5	≃50.5	2.7	5.50
0.16	0.15	6.2 D_o	43.0	≃43.0	2.8	5.30
	0.20		43.0	≃43.0	2.8	5.30
	0.30		43.0	≃43.0	2.8	5.30
0.25	0.30	6.2 D_o	30.0	≃30.0	3.1	4.75
0.16	0.20	4.0 D_o	40.5	≃40.5	2.9	5.10
		6.2 D_o	43.0	≃43.0	2.8	5.30
		8.0 D_o	43.0	≃43.0	2.8	5.30

NOTES: 1. *The critical control was upper boundary control for all conducted runs.*

2. *Average temperature rises were calculated using plant temperature rise of 14.8°F, which includes a recirculation effect of 1°F.*

TABLE 7

COMPARISON OF JET FLOWS, VELOCITIES AND DILUTION RATIOS OF TWO RECTANGULAR JETS

Distance from the slot along the jet ft	$S_2 = 5.3 \times W_o$			$S_2 = 5.3 \times H_o$		
	Jet Flow cfs	Velocity cfs	Dilution Ratio	Jet Flow cfs	Velocity fps	Dilution Ratio
0	378.0	10.0	1.0	378.0	10.0	1.0
10	576.2	6.3	1.5	576.2	6.3	1.5
20	758.0	4.6	2.0	802.0	4.4	2.1
30	933.7	3.7	2.5	1091.8	3.1	2.9
40	1105.6	3.0	2.9	1387.9	2.4	3.7
50	1275.7	2.6	3.3	1676.3	2.0	4.4

Note: $C_1 = 0.15$, $C_2 = 0.25$ *in both cases*

W_o = *initial width of jet*

H_o = *initial depth of jet*

TABLE 8

COMPARISON OF DILUTION RATIOS AND AVERAGE TEMPERATURE RISES AT THE CRITICAL CONTROLS CORRESPONDING TO RECTANGULAR AND CIRCULAR JETS, FOR DIFFERENT LENGTHS OF THE INITIAL ZONE

Conditions				Distance along the jet ℄ (S_c) ft	Lateral Distance Xc ft	Dilution ratio at critical control	Average Temp. Rise (T_O-T_I=15.8°F) °F
Rectangular	0.15	0.25	5.3 W_o	51.5	≃51.4	3.4	4.35
Rectangular	0.15	0.25	5.3 H_o	41.5	≃41.5	3.8	3.90
Circular	0.16	0.20	4.0 Do	40.5	≃40.5	2.9	5.10
Circular	0.16	0.20	6.2 D_o	43.0	≃43.0	2.8	5.30
Circular	0.16	0.20	8.0 D_o	43.0	≃43.0	2.8	5.30

NOTES: 1. Critical control was upper boundary control for all reported jets.

2. Average temperature rises were calculated using plant temperature rise of 15.8°F which includes a recirculation effect of 1°F.

TABLE 9

CALCULATION OF ZONE OF FLOW ESTABLISHMENT ENTRAINMENT COEFFICIENT

a) Slope of boundary C_1 = 0.10

S (ft)	ΔS (ft)	Q (cfs)	ΔQ (cfs)	U_c (fps)	D (ft)	R* (ft)	α
0		378.0			6.9		
	10		99.5	10		3.96	0.040
10		477.5			8.9		
	10		97.9	10		4.95	0.0314
20		575.4			10.9		
	10		96.7	10		5.95	0.0259
30		672.1			12.9		
	10		95.7	10		6.95	0.0220
40		767.8			14.9		

b) Slope of boundary C_1 = 0.16

S (ft)	ΔS (ft)	Q (cfs)	ΔQ (cfs)	U_c (fps)	D (ft)	R* (ft)	α
0		378.0			6.9		
	10		164.1	10		4.01	0.0653
10		542.1			10.1		
	10		161.7	10		5.85	0.0440
20		703.8			13.3		
	10		160.1	10		7.45	0.0342
30		863.9			16.5		
	10		159.1	10		9.05	0.0280
40		1023.0			19.7		

c) Slope of boundary C_1 = 0.25

S (ft)	ΔS (ft)	ΔQ (cfs)	ΔQ (cfs)	U_c (fps)	D (ft)	R* (ft)	α
0		378.0			6.9		
	10		260.9	10		4.7	0.0900
10		638.9			10.1		
	10		257.7	10		7.2	0.0570
20		896.6			13.3		
	10		255.8	10		9.7	0.0420
30		1152.4			16.5		
	10		255.1	10		12.2	0.0332
40		1407.5			19.7		

TABLE 10

CALCULATION OF ZONE OF ESTABLISHED FLOW ENTRAINMENT COEFFICIENT

S (ft)	ΔS (ft)	Q (cfs)	ΔQ (cfs)	$\bar{U}$ (fps)	$\bar{U}^*$ (fps)	U_c^* (fps)	R (ft)	R* (ft)	b* (ft)	α
60		1410.9		2.4			13.75			
	10		201.8		2.25	7.36		14.75	10.42	0.0418
70		1612.7		2.1			15.75			
	10		204.7		1.95	6.38		16.75	11.15	0.0433
80		1817.4		1.8			17.75			
	10		209.2		1.75	5.72		18.75	13.26	0.0440
90		2026.6		1.7			19.75			
	10		215.5		1.60	5.23		20.75	14.68	0.0445
100		2242.1		1.5			21.75			

APPENDIX

Plate B-1

Submerged Discharge
Program

```
      INTEGER OF1,OF2,OF3,OF4,DENCT
       CALL OPENF(1,"TH1")
      CALL OPENF(2,"TH1")
      CALL OPENF(3,"TH2")
       IF1=1
      OF1=2
      OF2=3
       NR=0
       DTOL=1.E-05
       PI=3.14159265
       PI1=PI/180.
       TOL=.05
       ITOL=100
       JRHO=1
       RHOTL=1.E-2
       IBOUND=.2
      READ (IF1,) NRUNS
  200 READ (IF1,) DS,KT,YLIM,DEPTH,SLOPE,FFACT
      READ (IF1,) ISHAPE,IDILAD,DHL,DHLMIN,XLL
       IF (ISHAPE.EQ.0) READ (IF1,) DO,VO,CA
       IF (ISHAPE.EQ.1) READ (IF1,) HO,WO,VO,CA
       READ (IF1,) ANGX,ANGY,ANGZ
       READ (IF1,) VTMAX,VRIV,ANGT,ANG
       READ (IF1,) TO,TRIV,SALO,SALR
       IF (ISHAPE.EQ.0) AO=PI*DO*DO/4.
       IF (ISHAPE.EQ.1) AO=HO*WO
       QO=AO*VO
        PRINT 150
       WRITE (OF1,100)
  100  FORMAT (///,2X,15HPORT DIMENSIONS)
       IF (ISHAPE.EQ.0) WRITE (OF1,101) DO,AO,VO,QO
       IF (ISHAPE.EQ.1) WRITE (OF1,102) HO,WO,AO,VO,QO
  101  FORMAT (7X,8HCIRCULAR,/,9X,10HDIAMETER  ,F6.2,4H FT.,/,
&      9X,4HAREA,5X,F6.1,7H SQ.FT.,/,9X,10HVELOCITY  ,F5.1,
&      9H FT./SEC.,/,9X,6HFLOW  ,F7.1,5H CFS.)
  102  FORMAT (7X,11HRECTANGULAR,/,9X,8HHEIGHT  ,F5.1,4H FT.,
&      /,9X,8HWIDTH   ,F5.1,4H FT.,/,9X,4HAREA,4X,F6.1,
&      7H SQ.FT.,/,9X,10HVELOCITY  ,F5.1,9H FT./SEC.,/,9X,
&      6HFLOW  ,F7.1,5H CFS.)
       A=AO*CA
       V=VO/CA
       Q=A*V
       IF (ISHAPE.EQ.0) D=SQRT (4.*A/PI)
       IF (ISHAPE.EQ.1) W=SQRT (A*WO/HO)
       IF (ISHAPE.EQ.1) H=W*HO/WO
       WRITE (OF1,103) CA,A,V,Q
  103  FORMAT (2X,14HVENA CONTRACTA,/,7X,21HDISCHARGE COEFFICIENT,
&         /,10X,8HFOR AREA,6X,F4.2,
&      /,7X,4HAREA,6X,F6.1,7H SQ.FT.,/,7X,10HVELOCITY  ,
&       F5.1,9H FT./SEC.,/,7X,6HFLOW  ,F6.1,4H CFS,/,7X,
&      10HDIMENSIONS)
       IF (ISHAPE.EQ.0) WRITE (OF1,104) D
       IF (ISHAPE.EQ.1) WRITE (OF1,105) H,W
  104  FORMAT (10X,8HDIAMETER,F6.2,4H FT.)
  105  FORMAT (10X,8HHEIGHT  ,F5.1,4H FT.,/,10X,8HWIDTH   ,
&      F5.1,4H FT.)
```

```
      WRITE (OF1,106) ANGX,ANGY,ANGZ,FFACT
 106 FORMAT (2X,29HANGLE OF PORT WITH RESPECT TO,/,7X,
&     8HX-AXIS  ,F5.1,5H DEG,,/,7X,8HY-AXIS  ,F5,1,5H DEG,,/,7X,
&     8HZ-AXIS   ,F5.1,5H DEG,,/,2X,17HFRICTION FACTOR  ,
&     F5.3)
      COSX=COS(ANGX*PI1)
      COSY=COS(ANGY*PI1)
      COSZ=COS(ANGZ*PI1)
      WRITE (OF1,107) VRIV,VTMAX,ANG,ANGT
 107 FORMAT (2X,14HRIVER VELOCITY,2X,F5.2,9H FT,/SEC,,/,2X,
&     14HTIDAL VELOCITY,2X,F5.2,9H FT,/SEC,,/,5X,
&     21HINITIAL PHASE ANGLE  ,F4.0,5H DEG,,/,
&     5X,11HINCREMENT  ,F4.0,5H DEG,)
      WRITE (OF1,108) TO,TRIV,SALO,SALR
 108 FORMAT (28H  INITIAL JET TEMPERATURE   ,F5,1,7H DEG,F,,/,
&     28H  INITIAL RIVER TEMPERATURE ,F5,1,7H DEG,F,,
&     /,23H  INITIAL JET SALINITY ,F6.3,7H  0/000,
&     /,25H  INITIAL RIVER SALINITY ,F6.3,7H  0/000)
      WRITE (OF1,109) DEPTH,SLOPE,YLIM
 109 FORMAT (35H  BOTTOM DEPTH AT VENA CONTRACTA   ,F6.2,
&     4H FT,,/,8X,12HBOTTOM SLOPE,3X,F6.2,2X,10HFT,/100FT,,
&     /,21H  SURMERGENCE OF PORT,2X,F6.2,4H FT,)
      A0=A
      V0=V
      D0=D
      H0=H
      W0=W
      90=9
      Q0=Q0
       TANG=270.
      IF (ANGT.EQ.0.) TANG=0.0
C
C      TIDAL RIVER VELOCITY FUNCTION
C
 1091 VR=VRIV+VTMAX*SIN(ANG*PI1)
      WRITE (OF1,110) VR,ANG
      WRITE (OF2,110) VR,ANG
 110 FORMAT (//,2X,20HNET RIVER VELOCITY  ,F5.2,9H FT,/SEC,,/,
&     5X,11HTIDAL PHASE,F6.2,5H DEG,//)
       I=0
       J=0
       JSURFT=0
  147 IF (IDILAD.EQ.0) WRITE (OF1,131) DHL
       IF (IDILAD.EQ.0) WRITE (OF2,131) DHL
       IF (IDILAD.EQ.1) WRITE (OF1,132)
       IF (IDILAD.EQ.1) WRITE (OF2,132)
       IF (IDILAD.LT.0) WRITE (OF1,130)
       IF (IDILAD.LT.0) WRITE (OF2,130)
       IF (IDILAD.EQ.1) GO TO 148
  130 FORMAT (2X,"DILUTIONS NOT CORRECTED FOR BOUNDARY",
&      " INTERFERENCES")
  131 FORMAT (2X,"DILUTIONS CORRECTED FOR BOUNDARY",
&      " INTERFERENCES",/,2X,"DEPTH OF HEATED LAYER",
&      " CONSTANT AT",F5.2," FT,")
  132 FORMAT (2X,"DILUTIONS WILL BE CORRECTED BASED ON",
&      " BOTTOM",/,5X,"DETERMINATION BY ITERATION")
```

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      IF (ISHAPE.EQ.0) WRITE (OF1,112)
      IF (ISHAPE.EQ.1) WRITE (OF1,113)
 112  FORMAT (//" DIST.",/," ALONG CTR. CTR.  CTR.",/,
&     "  JET  LINE LINE  LINE  JET   JET  JET  JET",/,
&     " CTR.  LAT. VERT. LONG  DIAM  VEL. FLOW TEMP DILU-",/,
&     " LINE DIST. DIST. DIST.                     DEG.  TION",/,
&     "  FT.  FT.   FT.   FT.   FT.  FPS. CFS.  F.")
 113  FORMAT (//" DIST.",/," ALONG CTR. CTR.  CTR.",/,
&     "  JET  LINE LINE  LINE  JET   JET   JET  JET  JET",/,
&     " CTR.  LAT. VERT. LONG  HEI-  WID-  VEL. FLOW TEMP DILU-"
&     ,/,
&     " LINE DIST. DIST. DIST.  GHT   TH             DEG.  TION"
&     ,/,
&     "  FT.  FT.   FT.   FT.   FT.   FT.  FPS. CFS.  F.")
      WRITE (OF2,114)
 114  FORMAT (6H DIST.,5X,9HDIRECTION,6X,7HLATERAL,5X,
&     8HVERTICAL,4X,12HLONGITUDINAL,/,6H ALONG,6X,7HCOSINES,
&     7X,8HDISTANCE,4X,8HDISTANCE,4X,8HDISTANCE
&     ,/,5H  JET,7X,7H OF JET,8X,9HFROM PORT,3X,4HFROM,7X,
&     9HFROM PORT,/,6H CENT-,7X,6HCENTER,9X,6HTO JET,5X,
&     7HSURFACE,5X,13HCENTERLINE TO,/,5H  TER,8X,4HLINE,
&     23X,6HTO JET,5X,
&     12HJET BOUNDARY,/,5H LINE,8X,3HWRT,10X,
&     35HTOP  BOTTOM TOP  BOTTOM UP     DOWN,/,7X,
&     17HXAXIS YAXIS ZAXIS,26X,13HSTREAM STREAM,/,5H  FT.,22X,
&      34HFT.   FT.   FT.   FT.    FT.   FT.)
C
C      TEMPERATURE CONVERSION
C
  148 CO=(5./9.)*(TO-32.)
      CR=(5./9.)*(TRIV-32.)
C
C      LEAST-SQUARES EVALUATION OF MASS DENSITY FROM TEMP.
C
      COF1=9.991638E-01
      COF2=7.7364515E-04
      COF3=-7.6762273E-07
      DROSO=COF1+COF2*SALO+COF3*SALO**2.
      DROSR=COF1+COF2*SALR+COF3*SALR**2.
      F1=1.0000512
      F2=3.5764685E-05
      F3=-6.8972574E-06
      F4=2.8117132E-08
      DENO=F1+F2*CO +F3*CO**2. +F4*CO**3.
      DENR=F1 +F2*CR +F3*CR**2. +F4*CR**3.
      RHOO=1.93869627*(DENO+DROSO-.9991)
      RHOR=1.93869627*(DENR+DROSR-.9991)
C
C      END OF MASS DENSITY EVALUATION
C
C
C      VARIOUS INITIAL VALUES
C
      VOL=A0*DS
      OMENO=RHOO*A0*VO*VO
      XMO=OMENO*COSX
```

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```
      YMO=OMENO*COSY
      ZMO=OMENO*COSZ
      XL=DO
      CORR=1.0
      DMOM=0.
      RHOI=ZIO
      BOUY=0.
      B=0.
      S=0.
      SX=0.
      SY=0.
      X=0.
      Y=0.
      K=0
      ISS=0
      VHAVE=0.
      DILAV=0.
      Z=0.
      D=DO
     H=HO
     W=WO
      V=VO
      A=AO
      QO=A*V
      RHO=RHOO
      TEMP2=TO
      SAL2=SALO
      ANGX=COSX
     ANGY=COSY
      ANGZ=COSZ
C
C
C
C
C
C
C
C
C     MAJOR LOOP TO INCREMENT JET CENTER LINE DISTANCE
C
      IF (ISHAPE.EQ.0) C1=0.16
      IF (ISHAPE.EQ.0) C2=0.20
      IF (ISHAPE.EQ.0) S2=6.2*DO
      IF (ISHAPE.EQ.1) C1=.15
      IF (ISHAPE.EQ.1) C2=.25
      IF (ISHAPE.EQ.1) S2=5.3*WO
    1 S=S+DS
      TEMP1=TEMP2
      SAL1=SAL2
      A1=A
      RHO1=RHO
      V1=V
     H1=H
     W1=W
      D1=D
      VOL1=VOL
```

```
      IF(S-S2)20,21,21
   20 C3=C1
      GO TO 23
   21 C3=C2
   23 IF (ISHAPE.EQ.1) GO TO 25
      DD=C3*2.*DS
      D=D+DD
      A=(PI/4.)*D*D
      VOL=(PI/12.)*DS*(D*D+D1*D+D1*D1)
      ASUR=(PI/2.)*(D+D1)*SQRT(DS*DS+(D-D1)*(D-D1)/4.)
      GO TO 24
   25 DD=C3*2.*DS
      H=H1+DD
      W=W1+DD
      A=H*W
      DSP=DS*SQRT(1.0+C3*C3)
      AW=2.*W1*DSP+2.*C3*DS*DSP
      AH=2.*H1*DSP+2.*C3*DS*DSP
      ASUR=AW+AH
      VOL=H1*W1*DS+(H1+W1)*C3*DS*DS+(4./3.)*C3*C3*DS*DS*DS
   24 SHEAR=FFACT*RHO1*V1*V1/8.
      SHEARX=SHEAR*ANGX*ASUR*CORR
      SHEARY=SHEAR*ANGY*ASUR*CORR
      SHEARZ=SHEAR*ANGZ*ASUR*CORR
      SX=SX+SHEARX
      SY=SY+SHEARY
      RMOM=RMOM+DMOM
      B=32.2*(RHOR-RHO)*VOL
      BOUY=BOUY+B
      RHO=(RHO1*VOL1+RHOR*(VOL-VOL1))/VOL
      YM=YMO+BOUY-SY
      XM=XMO-SX
C
C       TRIAL AND ERROR SOLUTION FOR ENTRAINED FLOW INCR.
C
      DQC=1.0
      CORR=1.0
   70 DQ=DQC
      I=I+1
      JJ=1
 2050 TEMP2=(RHO1*TEMP1*V1*A1+RHOR*DQ*TRIV)/((V1*A1+DQ)*RHO)
      TC2=(5./9.)*(TEMP2-32.)
      SAL2=(SAL1*V1*A1*RHO1+SALR*DQ*RHOR)/((V1*A1+DQ)*RHO)
      RHOC=F1+F2*TC2+F3*TC2**2+F4*TC2**3
      DRO=COF1+COF2*SAL2+COF3*SAL2**2
      RHOC=1.9386927*(RHOC+DRO-.9991)
      IF(ABS(RHOC-RHO)-RHOTL)2000,2000,2010
 2010 IF(JJ-JRHO)2030,2020,2020
 2030 JJ=JJ+1
      RHO=RHOC
      GO TO 2050
 2020 WRITE(OF1,2021)RHO,RHOC,TEMP2
 2021 FORMAT(1H ,5HRHO= ,E15.9,6HRHOC= ,E15.9,8HTEMP2 = ,E15.9,///)
      GO TO 910
 2000 RHO=RHOC
      DMOM=RHOR*VR*DQ
```

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      ZM=RMOM+DMOM
      ZM=ZM-SHEARZ
      TM=SQRT(XM*XM+YM*YM+ZM*ZM)
      V=SQRT(TM/(RHO*A))
      DQC=(RHO*V*A-RHO1*V1*A1)/RHOR
C
C     COMPUTATION OF ANGLES AND DIST. FOR JET CENTERLINE.
C
C     ANGX,ANGY,ANGZ,,ARE DIRECTIONAL COSINES OF MOMENTUM
C     VECTOR AND POSITIVE (+) X,Y AND Z AXIS RESPECTIVELY.
C
      ANGX=XM/TM
      ANGY=YM/TM
      ANGZ=ZM/TM
      SANGX=SQRT(1.-ANGX**2)
      SANGY=SQRT(1.-ANGY**2)
      SANGZ=SQRT(1.-ANGZ**2)
      DX=ANGX*DS
      DY=ANGY*DS
      DZ=ANGZ*DS
     IF (ISHAPE.EQ.0) PROJRX=SANGX*(D/2.)
     IF (ISHAPE.EQ.0) PROJRY=SANGY*(D/2.)
     IF (ISHAPE.EQ.0) PROJRZ=SANGZ*(D/2.)
     IF (ISHAPE.EQ.1) PROJRX=SANGX*(H/2.)
     IF (ISHAPE.EQ.1) PROJRY=SANGY*(H/2.)
     IF (ISHAPE.EQ.1) PROJRZ=SANGZ*(W/2.)
      X=X+DX
      Y=Y+DY
      Z=Z+DZ
      TZ=Z+PROJRZ
      BZ=Z-PROJRZ
      TY=Y+PROJRY
      TY=YLIM-TY
      BY=Y-PROJRY
      BY=YLIM-BY
      XL=TZ-BZ
      IF (TZ.LT.0.) XL=ABS(TZ)-ABS(BZ)
      IF (TZ.GT.0..AND.BZ.LT.0.) XL=TZ+ABS(BZ)
     DC=YLIM-Y
      DEPTS=DEPTH
      IF (SLOPE.EQ.0.) GO TO 49
C       DEPTS=PSEUDO DEPTH FOR A SLOPED BOTTOM WITH DILUTION
C          CORRECTIONS
      IF (X.LE.50.) DEPTS=DEPTH+X*SLOPE
      IF (X.GT.50..AND.X.LE.100.) DEPTS=DEPTH+3.5+(X-50.)*0.02
      IF (X.GE.100.) DEPTS=DEPTH+4.5
  49 SANGA=SANGY
     IF (IDILAD.GE.0) CALL DILADJ(YLIM,DEPTS,DHL,D,SANGA,
&     X,V,DC,DQC,ASUR,CORR,ISHAPE,H,W,HE,WE,DE)
     T=ABS(DQ-DQC)
     IF (T-TOL) 40,40,50
  50 X=X-DX
     Y=Y-DY
     Z=Z-DZ
     IF (I-ITOL) 70,70,191
     I=0
```

```
      GO TO 70
   40 I=0
C     END OF TRIAL AND ERROR LOOP
      K=K+1
      DIL=(Q0+DQC)*RHO/(A0*V0*RHO0)
       VH=SQRT((V*ANGX)**2+(V*ANGZ)**2)
       IF (JSURFT.EQ.0) GO TO 280
       ISS=ISS+1
       XI=ISS
       XIM=ISS-1
       DHLL=0.
       VHAVE=(VHAVE*XIM+VH)/XI
       DHLL=(Q0+DQC)*RHO0/(VHAVE*XL*RHO)
       DILAV=(DILAV*XIM+DIL)/XI
       IF (IDILAD.NE.1) GO TO 280
       IF ((BY-DHL).GT.0.5) GO TO 1
       IF (DHLL.LT.DHLMIN) DHLL=DHLMIN
       TEST=ABS(DHLL-DHL)
       IF (TEST.LT.0.5) DHL=DHLL
       IF (TEST.LT.0.5) IDILAD=0
       IF (TEST.LT.0.5) GO TO 147
       DHL=DHLL
       GO TO 148
C
C      EVALUATION OF AVERAGE JET TEMPERATURE
C
  280  Q0=Q0+DQC
       TDIL=TO/DIL+(1.-(1./DIL))*TRIV
  800  TY=YLIM-Y-PROJRY
       BY=YLIM-Y+PROJRY
       DC=YLIM-Y
       ISW=1
       IF (JSURFT.EQ.0) GO TO 750
       GO TO (751,752,753,754,755),JSURFT
  750  IF ((TY-DHL).LT.0.5) JSURFT=1
       IF ((TY-DHL).LT.0.5) WRITE (OF1,140)
       IF ((TY-DHL).LT.0.5) WRITE (OF2,140)
       IF ((TY-DHL).LT.0.5) ISW=2
       GO TO 7100
  751  IF ((TY).LT.0.5) JSURFT=2
       IF ((TY).LT.0.5) WRITE (OF1,141)
       IF ((TY).LT.0.5) WRITE (OF2,141)
       IF ((TY).LT.0.5) ISW=2
       GO TO 7100
  752  IF ((DC-DHL).LT.0.5) JSURFT=3
       IF ((DC-DHL).LT.0.5) WRITE (OF1,142)
       IF ((DC-DHL).LT.0.5) WRITE (OF2,142)
       IF ((DC-DHL).LT.0.5) ISW=2
       GO TO 7100
  753  IF ((DC).LT.0.5) JSURFT=4
       IF ((DC).LT.0.5) WRITE (OF1,143)
       IF ((DC).LT.0.5) WRITE (OF2,143)
       IF ((DC).LT.0.5) ISW=2
       GO TO 7100
  754  IF ((BY-DHL).LT.0.5) JSURFT=5
       IF ((BY-DHL).LT.0.5) WRITE (OF1,144)
```

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          IF ((BY-DHL).LT.0.5) WRITE (OF2,144)
          IF ((BY=DHL).LT.0.5) ISW=2
          GO TO 7100
     755  GO TO 7100
     140  FORMAT( "  AT NEXT LINE OF OUTPUT TOP OF ",
&         "JET HITS HEATED LAYER")
     141  FORMAT ("  AT NEXT LINE OF OUTPUT TOP OF JET ",
&         "HITS SURFACE")
     142  FORMAT ("  AT NEXT LINE OF OUTPUT CENTERLINE",
&         " OF JET HITS HEATED LAYER")
     143  FORMAT ("  AT NEXT LINE OF OUTPUT CENTERLINE OF "
&         "JET HITS SURFACE")
     144  FORMAT ("  AT NEXT LINE OF OUTPUT BOTTOM OF"
&         " JET HITS HEATED LAYER OR SURFACE")
    7110  CONTINUE
          IF (ISHAPE.EQ.0) PRINT 8999,S,DIL,XL,VHAVE,VH,BY,DHLL,D,DE,DILAV
          IF (ISHAPE.EQ.1) PRINT 8999,S,DIL,XL,VHAVE,VH,BY,DHLL,H,W,HE,
&          WE,DILAV
    8999  FORMAT (1X,F5.1,11F6.2)
          IF (ISHAPE.EQ.0) WRITE (OF1,120) S,X,Y,Z,D,V,QO,TDIL,DIL
          IF (ISHAPE.EQ.1) WRITE (OF1,121) S,X,Y,Z,H,W,V,QO,TDIL,DIL
     120  FORMAT(F6.2,F5.1,F5.1,F5.1,F6.1,F5.1,F7.1,F5.1,F5.1)
     121  FORMAT(F6.2,F5.1,F5.1,F5.1,F6.1,F6.1,F5.1,F7.1,F5.1,F5.1)
          WRITE (OF2,123) S,ANGX,ANGY,ANGZ,TX,BX,TY,BY,TZ,BZ
     123  FORMAT (1X,F5.1,1X,3F6.3,4(1X,F5.1),2(1X,F6.1))
          ISW=1
          IF (DIL.GE.50.) GO TO 901
          GO TO 7140
    7100  IF ((K-KT).EQ.0) ISW=2
          IF ((K-KT).EQ.0) K=0
          VX=V*ANGX
          VY=V*ANGY
          IF(VX.GT.0..AND.VY.GT.0..OR.VX.LT.0..AND.VY.LT.0.)GO TO 7120
          TRX=PROJRX
          GO TO 7130
    7120  TRX=-PROJRX
    7130  TX=X+TRX
          BX=X-TRX
          TY=Y+PROJRY
          TY=YLIM-TY
          BY=Y-PROJRY
          BY=YLIM=BY
          TZ=Z+PROJRZ
          BZ=Z-PROJRZ
          GO TO (7140,7110),ISW
    7140  CONTINUE
          IF (JSURFT.LT.5) GO TO 1
     901  ANG=ANG+ANGT
          IF(ANG-TANG)1091,1091,900
     191  WRITE(OF1,192)
          WRITE(OF1,193)ITOL,DQ,DQC
     192  FORMAT (42H  TOO MANY TRIAL ITERATIONS FOR DQ........//)
     193  FORMAT (14H ITERATIONS = ,I5,5H DQ= ,E15.9,6H DQC= ,E15.9)
     900  NR=NR+1
          PRINT 150
          WRITE (OF1,151)
```

USER # 7546, PROB, THOUT9 SYS#2 17:52 MAR 26 71 FRI


```
      WRITE (OF2,151)
  151 FORMAT (4H FJT)
      IF(NR-NRUNS)200,910,910
  972 WRITE(OF1,973)DENCT
  973 FORMAT(1H ,///15H DENCT > LIMIT ,I10)
  910 WRITE (OF1,150)
      WRITE (OF2,150)
  150 FORMAT (/////)
      CALL CLOSEF(1,"THI")
      CALL CLOSEF(2,"TH1")
      CALL CLOSEF(3,"TH2")
      CALL EXIT
      END
     SUBROUTINE DILADJ(YLIM,DEPTH,DHL,DJ,SANGA,X,V,DC,DOC,ASUR,CORR,
    &  ISHAPE,H,W,HE,WE,DE)
C
C     PROGRAM CALCULATES CORRECTIONS FOR DILUTIONS PREDICTED
C     BY THERMAL DISCHARGE MODEL
C     CORRECTION TECHNIQUE RECOGNIZES PHYSICAL BOUNDARIES
C     (BOTTOM,DEPTH OF THERMAL LAYER, AND SURFACE) IN THE
C     ADJUSTMENT OF PREDICTED DILUTIONS WHICH ASSUME AN INFINITE
C     SOURCE OF DILUTION WATER
C
C     VARIABLE NAMES AND UNITS
C
C   YLIM= SUBMERGENCE DEPTH IN THE MODEL ANALYSIS(THOUT8)
C     X= LATERAL DISTANCE FROM DISCHARGE
C     DJ= JET DIAMETER
C     V= LOCAL JET VELOCITY
C     DC= DEPTH TO CENTERLINE OF JET
C     SANGA=DIRECTION SINE WRT Y AXIS
C     DEPTH= TOTAL DEPTH TO BOTTOM
C     DHL= DEPTH OF HEATED LAYER
C     XL=LENGTH OF DIFFUSER
C     AE= AREA REQ'D TO ATTAIN PREDICTED DILUTION
C     DE= DIAMETER OF REGION OF ENTRAINMENT
C     CORR= RATIO OF ENTRAINMENT ARE AVAILABLE TO AREA REQ'D
C     SCORR= ADJUSTED DILUTION
C
C
      IF (ISHAPE.EQ.1) GO TO 500
      ADJ   =(3.14159265/4.)*DJ   *DJ
     AE=ASUR
      DE    =SQRT((4.*AE    +DJ    *DJ    *3.1415)/(3.1416))
      IF (DE.LE.DJ) DE=DJ
      YDC   =DC    -DHL
      ZP   =DE    *0.5*SANGA
      IF(ZP    -YDC    )999,999,998
  999 T   =0.0
      GO TO 997
  998 T    =DE    *0.5-(YDC    /SANGA    )
  997 CONTINUE
      YDC    =DEPTH-DC
      IF(ZP    -YDC    )995,995,996
  995 H    =0.0
      GO TO 994
```

USER # Z546, PROB, THOUT9 SYS#2 17:52 MAR 26 71 FRI

```
996 H    =DE    *0.5-(YDC    /SANGA    )
994 CONTINUE
    ADE   =(3.14159265/4.)*DE    *DE
    D    =0.5*(DJ    -DE    )
    IF(H    )495,496,495
495 C1    =H    +D
    IF(C1    )496,370,370
496 C1    =0.0
370 IF(T    )497,498,497
497 C2    =T    +D
    IF(C2    )498,371,371
498 C2    =0.0
371 CONTINUE
    ZZ=DE    *0.5-H
    IF(ZZ)101,100,100
101 HH=DE    -H
    ZZ=DE    *0.5-HH
    X1=SQRT((DE    *0.5)**2.-ZZ*ZZ)
    THETA1=ATAN(X1/ZZ)
   AH    =ADE    -((DE    *DE    *THETA1/4.)-(X1*ZZ))
100 X1=SQRT((DE    *0.5)**2.-ZZ*ZZ)
C
C
C
C
C
C
    THETA1=ATAN(X1/ZZ)
    AH    =(DE    *DE    *THETA1/4.)-(X1*ZZ)
    YY=DJ    *0.5-C1
    IF(YY)103,102,102
103 CC1=DJ    -C1
    YY=DJ    *0.5-CC1
    X1P=SQRT((DJ    *0.5)**2.-YY*YY)
    THETA2=ATAN(X1P/YY)
    AC1    =ADJ    -((DJ    *DJ    *THETA2/4.)-(X1P*YY))
102 X1P=SQRT((DJ    *0.5)**2.-YY*YY)
    THETA2=ATAN(X1P/YY)
    AC1    =(DJ    *DJ    *THETA2/4.)-(X1P*YY)
    Z=DE    *0.5-T
    IF(Z)105,104,104
105 TT=DE    -T
    Z=DE    *0.5-TT
    X2=SQRT((DE    *0.5)**2.-Z*Z)
    B1=ATAN(X2/Z)
    AT    =ADE    -((DE    *DE    *B1/4.)-(X2*Z))
104 X2=SQRT((DE    *0.5)**2.-Z*Z)
    B1=ATAN(X2/Z)
    AT    =(DE    *DE    *B1/4.)-(X2*Z)
    Y=DJ    *0.5-C2
    IF(Y)107,106,106
107 CC2=DJ    -C2
    Y=DJ    *0.5-CC2
    X2P=SQRT((DJ    *0.5)**2.-Y*Y)
    B2=ATAN(X2P/Y)
    AC2    =ADJ    -((DJ    *DJ    *B2/4.)-(X2P*Y))
```

USER # Z546, PROB, THOUT9 SYS#2 17:52 MAR 26 71 FRI

```
 196 X2P=SQRT((DJ    *0.5)**2.-Y*Y)
     B2=ATAN(X2P/Y)
     AC2    =(DJ    *DJ    *B2/4.)-(X2P*Y)
     ATP    =AT    -AC2
     AHP    =AH    -AC1
     AS    =ATP    +AHP
     CORR    =(AE    -AS    )/AE
     DOC=DOC*CORR
     RETURN
 500 AE=ASUR
     T=0.
     HP=0.
     WE=SQRT((AE+W*H)*W/H)
     HE=WE*H/W
     YDC=DC-DHL
     ZP=HE*0.5*SANGA
     IF (ZP-YDC) 599,599,598
 599 T=0.0
     GO TO 597
 598 T=(ZP-YDC)/SANGA
 597 CONTINUE
     YDC=DEPTH-DC
     IF (ZP-YDC) 595,595,596
 595 HP=0.0
     GO TO 594
 596 HP=(ZP-YDC)/SANGA
 594 CONTINUE
     A1=0.
     A2=0.
     IF ((HP+T).GE.HE) HP=HE/2.
     IF ((HP+T).GE.HE) T=HE/2.
     IF (HP.LT.((HE-H)/2.)) GO TO 610
     A1=WE*(HE-H)/2.+2.*(HP-((HE-H)/2.))*((WE-W)/2.)
     GO TO 611
 610 A1=HP*WE
 611 CONTINUE
     IF (T.LT.((HE-H)/2.)) GO TO 612
     A2=WE*(HE-H)/2.+2.*(T-((HE-H)/2.))*((WE-W)/2.)
     GO TO 613
 612 A2=T*WE
 613 CONTINUE
     ATOT=A1+A2
     CORR=(AE-ATOT)/AE
     DOC=DOC*CORR
     RETURN
     END
```

REFERENCES

1. Quirk, Lawler & Matusky Engineers, "Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution", October 1969.

2. Camp, T.R., "Water and Its Impurities", Reinhold Publishing Corporation, 1963.

3. Abramovich, G.N., "The Theory of Turbulent Jets", Translation by Scripta Technica,Technical Editing by Leon H. Schindel, The MIT Press, Cambridge, Massachusetts, 1963.

4. Faw, Loh-Nien, "Turbulent Buoyant Jets Into Stratified or Flowing Ambient Fluids", California Institute of Technology, Pasadena, California, June 1967.

5. Testimony of John P. Lawler, Quirk, Lawler & Matusky Engineers, on "The Effect of Indian Point Units #1 and #2 Cooling Water Discharge on Hudson River Temperature Distribution", April 5, 1972.

6. Quirk, Lawler & Matusky Engineers, "Environmental Effects of Bowline Generating Station on Hudson River", March 1971.

APPENDIX FF

RESPONSE TO ATOMIC ENERGY COMMISSION QUESTIONS

This Appendix to the Environmental Report consists of responses by Consolidated Edison Company of New York to questions posed by the Environmental Projects Branch No. 1, Directorate of Licensing, United States Atomic Energy Commission in their letter of March 5, 1973 to Mr. William J. Cahill, Jr., Vice President, Consolidated Edison Company.

Question:

I. INTRODUCTION

A. Permits

1. The Federal Water Pollution Control Act was amended in 1972. The status of any water quality certification granted to the applicant from New York State should be presented in view of this new amendment.

Answer:

Since a State water quality certification is not required until commencement of operation, Con Edison has not yet applied to the New York State Department of Environmental Conservation for a water quality certification with respect to Indian Point Unit No. 3. In issuing its permit dated November 4, 1971 to construct the outfall structure, the Department of Environmental Conservation stated that to obtain an operating permit for Unit 3 it would be necessary to verify predictions made from mathematical and hydraulic models to correlate actual operations of Units 1 and 2 to conditions postulated for Unit 3. Con Edison has not been advised of any change in the State's position in this regard.

Question:

I. INTRODUCTION

A. Permits

2. Based on experience of fish kill problems at the intake structures at Indian Point Units Nos. 1 and 2, the status of any agreements made with the New York Department of Environmental Conservation regarding modification of the intake structures should be described.

Answer:

Enclosed is a copy of an Order dated April 28, 1972 from the New York State Department of Environmental Conservation together with accompanying letter dated May 31, 1972 from Francis X. Wallace, General Counsel of the New York State Department of Environmental Conservation, to Con Edison. These documents constitute the agreement referred to in the question. This agreement has not been amended or rescinded and is still in full force and effect.

New York State Department of Environmental Conservation
Albany, N. Y. 12201

Henry L. Diamond
Commissioner

May 31, 1972

Consolidated Edison Company
of New York, Inc.
4 Irving Place
New York, New York 10013

Gentlemen:

In accordance with my recent conversation with Ernest Williams, Esq. of your company, I am enclosing herewith Order issued in the above matter by this Department and consented to by your company thereon. Such Order is issued upon the express understanding and agreement as follows:

1. The Order does not in any way constitute an Operating Permit, nor shall it be deemed to authorize any operation of Indian Point Plant No. 2 except the circulators therefor on a test basis.

2. The Department of Environmental Conservation does not by the issuance of such Order, waive any rights which it can, shall or may have against your company with respect to Indian Point Plant #2, or any other plant, in respect of any and all environmental matters jurisdiction of which is charged to this Department.

If the foregoing correctly sets forth our understanding, please execute one copy of this letter at the place provided hereunder and return to the undersigned for the Department files, at which time the enclosed Order shall be and become effective.

Very truly yours,

Francis X. Wallace
Francis X. Wallace
General Counsel

Enclosure

Consented to and Agreed:
Consolidated Edison Company of New York, Inc.

By ______________________________

STATE OF NEW YORK

DEPARTMENT OF ENVIRONMENTAL CONSERVATION

---X

In the Matter of Alleged Violations of the Conservation Law, the Public Health Law and the Environmental Conservation Law of the State of New York by

File No. 1013

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
INDIAN POINT PLANT NO. 2
(Westchester County)

Respondent

---X

ORDER

An Order and Notice dated February 29, 1972 having been issued by the Commissioner of the Department of Environmental Conservation and duly served upon Consolidated Edison Company of New York, Inc., the Respondent herein, and

Pursuant to the provisions thereof, Respondent was ordere to cease the operation of cooling water circulators at its Indian Point Plant No. 2 in Buchanan, New York based upon the allegation that operation of said circulators caused the killing of over 100,000 fish in the Hudson River during the months of January and February 1972, and

Respondent having requested that the Order be vacated and consented to be bound by the provisions contained herein,

NOW, having considered this matter and being duly advised it is ORDERED;

I. THAT the Order and Notice issued by the Commissioner in this proceeding under date of February 29, 1972 shall be and the same is hereby vacated effective this date upon the following conditions:

A. Respondent shall complete the installation of by-pass systems on all circulators at Indian Point Plant No. 2 which shall be designed to maintain a water intake velocity at an average rate of 0.5 (1/2) feet persecond. The by-pass systems shall be operable by May 15, 1972 and shall be used at all times when the water temperature of the Hudson River in the area of said plant is below forty (40) degrees fahrenheit.

B. Respondent shall install facilities for maintaining a double air bubble screen in front of all circulator water intakes at Indian Point Plants number 1 and number 2 by December 1, 1972 and shall thereafter operate such air bubble system during all periods said Plants are in operation and the water temperature of the Hudson River in the area of said Plants is below forty (40) degrees fahrenheit, except for such times as shall reasonably be required to perform and make inspection, maintenance, repairs or replacements to such air bubble system.

C. Respondent shall cause hydraulic model studies of a screened lagoon adjacent to the cooling water intakes at its Indian Point Plants numbers 1, 2 and 3 to be conducted and completed by March 1, 1973 pursuant to its existing contract with LaSalle Laboratories, Montreal, Canada, or by such other recognized independent laboratory as Respondent may select. If after the completion of such studies it shall be determined by the Commissioner, after Public Hearing at which Respondent shall be noticed as a Party, that the air bubble system provided for above in paragraph B is not satisfactorily protecting the fish population of the Hudson River, and that the screened lagoon will provide a level of fish protection significantly higher than the air bubble system, Respondent shall upon final determination of the Commissioner forthwith apply for all permits, licenses, approvals and land rights required for the construction and operation of the screened lagoon and shall prosecute all such applications with due diligence. Upon the granting of all such applications, Respondent shall with due diligence construct and operate said screened lagoon.

D. Respondent shall submit monthly reports to the Department detailing daily records of fish collections at Indian Point Plants number 1 and number 2.

E. Respondent shall notify the Department of Environmental Conservation during normal business hours, at least 24 hours in advance, of Respondent's intention to conduct testing operations of the cooling water circulators at Indian Point Plant No. 2, until such time as Respondent shall receive authority from the Atomic Energy Commission to operate such Plant. The Department may during all such periods of testing of the circulators designate Department personnel to observe such testing operations, and to report the results of the same to the Commissioner.

F. By its consent to the foregoing Respondent does not admit any of the allegations set forth in the Notice and Order of February 29, 1972, and does not waive, relinquish or otherwise prejudice any defenses it may have or may have had, or any of its rights to assert such defenses, with respect to any violation of law or other cause of action alleged in said Notice and Order or hereafter/or heretofore alleged in any proceeding whatsoever.

DATED: April 28, 1972
Albany, New York

HENRY L. DIAMOND, Commissioner
New York State Department
of Environmental Conservation

Respondent hereby consents to the issuing and entering of the foregoing Order and agrees to be bound by the terms, provisions and conditions contained therein.

CONSOLIDATED EDISON COMPANY
OF NEW YORK, INC.

By
Title: President

Date April 24, 1972

State of New York)
) ss:
County of New York)

On this 24th day of April, 1972, before me personally came Louis H. Roddis, Jr. to me known, who being by me duly sworn did depose and say that he resides in 12 Philips Lane, Rye, New York, that he is the President of Consolidated Edison Company of New York, Inc., the corporation described in and which executed the foregoing instrument; and that he signed his name as authorized by said corporation.

Notary Public

CLOTILDE M. REGAZZI
Notary Public, State of New York
No. 41-8523650 Queens County
Cert. filed in New York County
Commission Expires March 30, 1974

Question:

I. INTRODUCTION

A. Permits

3. If available, the permit from the NYS Department of Environmental Conservation to discharge effluents through the discharge structure should also be provided.

Answer:

Since the permit to discharge effluents is not required until commencement of operations, an application has not yet been filed for such a permit with respect to Unit No. 3. The comments in response to Question I.A.1. are applicable to the issuance of this permit as well.

THE CONTRIBUTION OF THE HUDSON RIVER TO THE MID-ATLANTIC STRIPED BASS FISHERY AND THE IMPACT OF INDIAN POINT UNIT 3 ON THIS FISHERY

PREPARED BY TEXAS INSTRUMENTS, INC.

for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

NEW YORK, NEW YORK

5 OCTOBER 1973

Supp. 10
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ABSTRACT

Striped bass are distributed along the Atlantic coast from the St. Lawrence River to Florida in salt, brackish, and freshwater. Most stocks make coastal migrations and anadromous migrations into freshwater. These striped bass are subjected to fishing pressure all along the Atlantic coast with the major fishery existing in the Chesapeake Region. The scientific literature indicates that most of the striped bass taken in the mid-Atlantic fishery originate in the tributary rivers of Chesapeake Bay. The contribution of the Hudson River to the mid-Atlantic fishery is judged to be small. Analysis of tagging studies which are now in progress along with analysis of a proposed electrophoretic and morphometric study of the mid-Atlantic stocks will further clarify this point.

The normal operation of Indian Point Unit 3 will subject the Hudson River stock of striped bass to additional mortality. The economic impact of such a mortality on the mid-Atlantic fishery depends largely upon the contribution of the Hudson stock to the mid-Atlantic. The best available data suggest that this contribution is small.

TABLE OF CONTENTS

INTRODUCTION

This appendix considers the contribution of the Hudson River to the mid-Atlantic striped bass fishery and the impact of operation of Indian Point Unit 3 upon this fishery. The distribution of striped bass along the Atlantic Coast has been reviewed, and watersheds contributing to the mid-Atlantic fishery have been documented.[1] The contribution of the Hudson River commercial fishery (i.e. those fish taken in the Hudson per se) to the total Atlantic Coast fishery is also presented (Table 1). Additional studies are now in progress or have been planned to further quantify the contribution of the Hudson to the mid-Atlantic striped bass fishery. These studies are described and the time schedules presented.

During a hearing for an operating license for Indian Point Unit 2 there was considerable debate on the extent to which the operation of power units at Indian Point might reduce the striped bass population along the mid-Atlantic coast. Before any conclusion can be drawn, it is first necessary to determine the contribution of Hudson River striped bass to the mid-Atlantic fishery. For this purpose, the mid-Atlantic commercial fishery is defined as landings from New York, New Jersey, and Delaware.[2] The sport fishery includes landings from Connecticut as well as these three states. If the Hudson River does not contribute substantially to the coastal population, then plant operation is of minimal importance relative to this striped bass fishery.

The contribution of the Hudson River striped bass to the mid-Atlantic fishery has been estimated at 80 percent by the AEC on the basis of qualitative tagging assessment and linear regression analysis.[3,4] Con Edison, through expert testimony (including extensive literature review), has estimated this contribution at no more than 10%.

Table 1. Commercial Catches of Striped Bass in thousands of pounds (after Koo, 1970)[1]

Year	New England	Mid-Atlantic (NY, NJ, Del) Total	Hudson Only	Chesapeake	South Atlantic	Total	% of Atlantic Catch Taken From Chesapeake Bay	Mid-Atlantic	Hudson River
1930	89	205	1	1653	457	2404	68.8	8.5	.04
1931	90	135	5	1116	327	1668	66.9	8.1	.2
1932	42	52	4	1028	507	1629	63.0	3.2	.2
1933	61	40	14	833	-	(1369)[2]	60.8	2.9	.9
1934	-	-	11	642	362	(1097)	58.5	-	.9
1935	22	62	19	1302	-	(1951)	66.7	3.2	1.0
1936	-	-	20	2383	768	(3621)	65.8	-	.5
1937	450	405	29	3016	713	4584	65.8	8.8	.6
1938	301	311	25	2869	523	4004	71.6	7.8	.6
1939	285	446	30	2692	340	3763	71.5	11.9	.8
1940	147	382	35	1839	540	2908	63.2	13.1	1.2
1941	-	-	21	2089	-	(3213)	65.0	-	.7
1942	219	-	-	3286	-	(4464)	73.6	9.4	-
1943	216	514	31	-	-	(4186)	-	9.9	.6
1944	341	799	61	4545	540	6225	73.0	12.8	1.0
1945	317	782	79	3664	610	5373	68.2	14.6	1.4
1946	406	963	51	3699	-	(5772)	64.1	16.7	.9
1947	119	413	48	4063	-	(5299)	76.7	7.8	.9
1948	151	758	39	5102	-	(6715)	76.0	11.3	.6
1949	162	902	-	4542	-	(6310)	72.0	14.3	-
1950	167	897	-	6834	797	7695	75.8	11.7	-
1951	265	981	-	4140	702	6088	68.0	14.3	-
1952	179	1141	30	3413	647	5380	63.4	11.7	.6
1953	193	1023	19	3106	757	5079	61.2	16.1	.4
1954	184	636	-	3059	1122	5001	61.2	21.2	-
1955	106	629	73	3466	736	4937	70.2	20.1	1.4
1956	98	473	93	3145	764	4480	70.2	12.7	2.1
1957	80	701	84	2788	597	4166	66.9	9.8	2.0
1958	95	479	77	4422	1097	6093	72.6	16.8	1.3
1959	120	746	133	6446	872	8184	78.8	7.9	1.6
1960	211	870	133	6687	783	8551	78.2	9.1	1.6
1961	397	1252	71	7262	551	9462	76.8	10.2	.8
1962	682	1259	48	5923	747	8611	68.8	13.2	.6
1963	582	1474	47	6496	737	9289	69.9	14.6	.5
1964	632	2022	29	5189	717	8560	60.6	15.9	.3
1965	531	1533	37	5162	486	7712	66.9	23.6	.5
1966	843	1429	44	6150	654	9076	67.8	19.9	.5
1967	802	2023	55	5827	1817	10469	55.7	19.3	.5
1968	987	2059	61	6146	1913	11105	55.3	18.5	.6
1969	1182	1888	77	7759	1569	12398	62.6	15.2	.6
						Average	67.7	12.6	0.6

1. Figures later than 1966 obtained from the National Marine Fisheries Service Publication "Fishery Statistics of the United States".

2. Figures in parentheses were interpolated by Koo by adding the mean of two adjacent years for the missing statistic.

THE MID-ATLANTIC STRIPED BASS FISHERY

STRIPED BASS

The striped bass is distributed along the Atlantic coast from the St. Lawrence River to the St. Johns River in northern Florida and in the Gulf of Mexico from western Florida to Louisiana. Adults are found in salt, brackish and freshwater, with those in salt water being coastal in distribution and few are known to have been taken more than ten miles from shore. Freshwater groups usually consist of stragglers or of spawning groups which are usually found near the mouths of rivers just above brackish waters. However, in some cases they may move far upstream to spawn and at times may be found as much as 200 miles from salt water.

Most stocks of striped bass make an anadromous migration from marine or estuarine areas into freshwater rivers for spawning. This migration usually occurs in the spring; however, the actual time of the spawning migration ranges from early April in Alabama to early June in New Brunswick. On the mid-Atlantic coast spawning occurs mostly in April and May.

THE CONTRIBUTION OF THE HUDSON

The AEC staff conclusion that approximately 80% of the mid-Atlantic stock of mature striped bass is of Hudson origin is based in part on a regression analysis of the relationship between Hudson landings of striped bass and landings of striped bass in the mid-Atlantic region five years later.[3,4] These variates are highly correlated, (with a coefficient of variability of 0.79), but on the basis of a regression analysis one cannot make any valid conclusions with regard to either cause or effect or percent composition. It is invalid to deduce cause and effect from a regression analysis and, although it is correct to say that some 80% of the variability in the mid-Atlantic landings may be explained in terms of Hudson River landings five years earlier, it is not valid to say that 80% of the mid-Atlantic landings consist of Hudson River fish. For example, suppose that fish that originate from the Chesapeake region always contribute a constant figure such as 1,000,000 pounds to the mid-Atlantic catch. If the Hudson River contribution varies from 100 to 10,000 pounds, then 100% of the mid-Atlantic variability could be explained by variations in the Hudson River stock (i.e. the coefficient of variability would be 1.0), yet the contribution of the Hudson would be no more than 1%. This extreme example serves to illustrate the fallacy and danger in interpreting a regression analysis in terms of percent contribution.

Furthermore, it should be noted that landings in the mid-Atlantic are also well correlated with landings in the Chesapeake Bay region (landings in Maryland and Virginia) two years earlier[2] (Figure 1). Schaefer[6] has also found a strong correlation between average 4 year brood production of young-of-the-year striped bass in the Chesapeake Bay and commercial landings of striped bass in New York three to six years later. These correlations have been interpreted as meaning that the Chesapeake Bay is the major contributor to the mid-Atlantic fishery.

On the basis of the divergent views developed from analyzing catch data associated with this region of the Atlantic, it is safe to say that the problem of the relative contribution of the Hudson River to the mid-Atlantic fishery cannot be resolved by more detailed analysis of the existing catch data. Therefore, a resolution of this problem must rely on other means.

There are several methods available which will help to elucidate the makeup of the mid-Atlantic fishery. One of the most powerful of these is analysis of data obtained from the electrophoresis of proteins. Electrophoresis is a method for separating proteins on the basis of size and electrical charge. Identification of genetically controlled proteins offers the use of innate

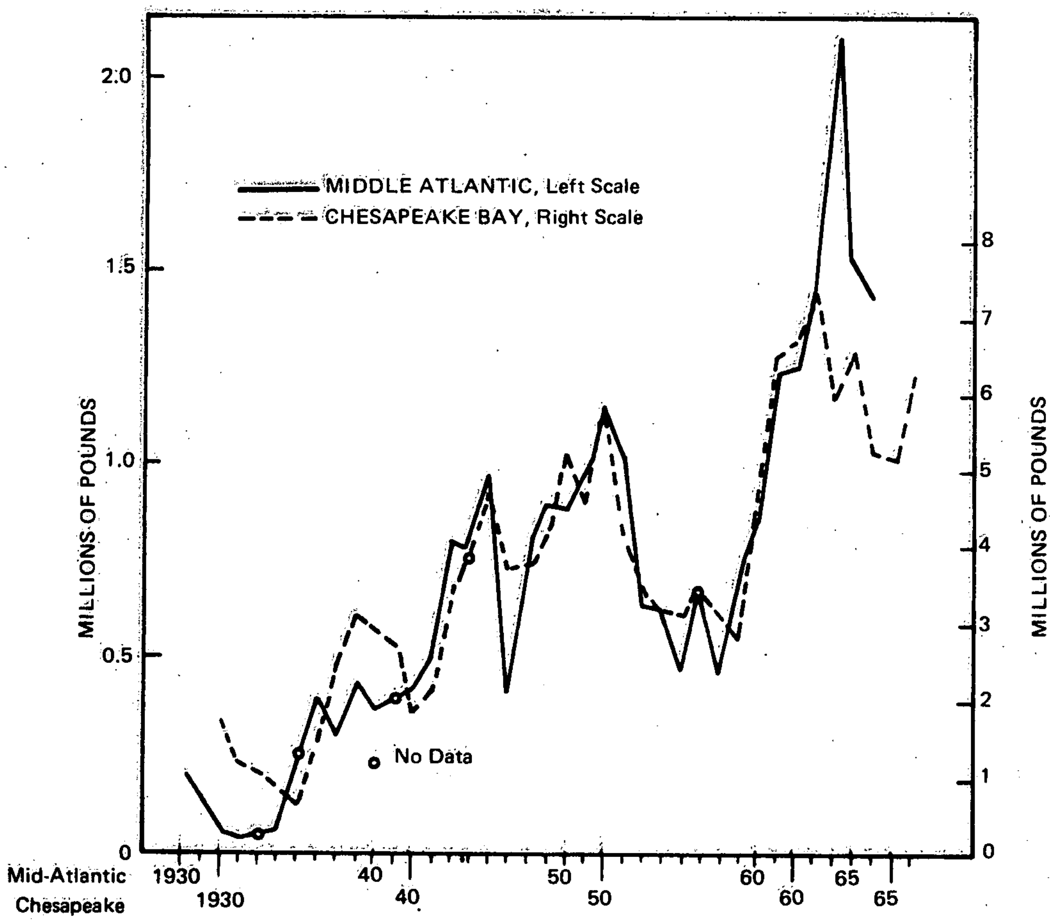

Figure 1. Comparison of striped bass landings of the middle Atlantic and Chesapeake regions (From Koo, 1970).

genetic tags for identification of the source of any particular fish. Electrophoresis has been shown to be a powerful tool in separating racial stocks in fish species such as the striped bass.[7]

A second method of separating stocks is through the analysis of meristic and morphometric information. Meristic characters such as the number of fin rays or the number of scale rows are related to embryonic growth. Genetic differences or environmental differences such as water temperature can regulate embryonic growth, and either of these kinds of regulators unique to a particular geographical area can result in a natural biological tag.

Studies by Raney[8,9] showed that meristic characters can be used to separate 70 to 80 percent of the Hudson River striped bass from Chesapeake Bay bass. Also, preliminary analysis of data collected in a study being conducted by Texas Instruments Incorporated also suggests that it is possible to determine the relative percentage composition of the mid-Atlantic landings with a high degree of reliability on the basis of meristic characters. This type of analysis in concert with an analysis of the ongoing tagging programs of the American Littoral Society, Texas Instruments Incorporated and the cooperative tagging program of the New York State Department of Environmental Conservation and the U.S. Department of Commerce, should assist in answering the question of the origin of the mid-Atlantic striped bass fishery.

Consolidated Edison will conduct an electrophoretic, meristic and morphometric study of striped bass from the major striped bass producing rivers of the Atlantic Coast as well as from the mid-Atlantic commercial fishery. This study is scheduled for completion by December 31, 1975. The study by the New York State Department of Environmental Conservation and the U.S. Department of Commerce is scheduled for completion of phase I by December 31, 1974, and of the entire study by December 31, 1975.

The best information currently available which allows some inference on the relative contribution of the Hudson to the mid-Atlantic striped bass fishery is based on tagging. Several important studies provide the bulk of this information. Raney et al.[9] analyzed tag returns from striped bass tagged along the Atlantic coast from Massachusetts to the Chesapeake Bay. Of fish tagged in the Hudson River in this study none were recovered outside the Hudson. Other data from this study on fish tagged outside of the Hudson River indicate that the Hudson stock of striped bass regularly moves into the western end of Long Island Sound and seldom goes eastward beyond Fairfield, Connecticut, or Northport, Long Island. Others may be found along the southwest shore of Long Island but not often farther east than Jones Beach. In the fall, migration is reversed and striped bass move into the Hudson River. A study by Alperin[10] of returns from striped bass tagged in the Great South Bay from 1956 to 1961 showed 63% of returns were from New York, yet only 2.1% were recovered from the Hudson River. Of the remaining 37%, 11% were from New England and 26% from areas south of New York. It is therefore probable that the Great South Bay population of striped bass is not made up of a large number of fish of Hudson origin, and from an analysis of yearly variations, the Hudson is likely to contribute a substantial proportion (not number) of the Great South Bay population only in years when the population in the Great

South Bay is low. Schaefer[11] conducted tagging operations over a period of 11 years in Westhampton Beach and Great South Beach (Fire Island), both of which are located on the south shore outer barrier of Long Island. Tags were recovered from Virginia to Massachusetts and the timing of these returns indicates a northward movement in the spring from southern wintering areas and an opposite southward movement in fall. Such an annual migratory pattern had previously been documented by other workers along the Atlantic coast.[9,12-16] The major wintering grounds for this contingent of striped bass was probably the Delaware Bay and the area of the ocean from one to five miles off the southern New Jersey coast.[11] This is in marked contrast to the wintering behavior of striped bass tagged in the western quarter of Long Island Sound, the narrows area of New York Bay, and the Southwest shore of Long Island, which apparently overwinter largely in the New York area.[9] Schaefer's[11] results have been interpreted in much the same way as Alperin's,[10] that is, the abundance of striped bass in the south shore surf areas of Long Island is largely dependent on the contribution of southern stocks and the influence of the Hudson is evident only when this contribution is low. Clark's[17] study generally confirmed the findings of Raney et al.[9] and Merriman.[15] Raney[1] has analyzed tag return data of the American Littoral Society and concluded that the Hudson River contributes to the fishery of the New York metropolitan area, but that a large-scale contribution to the Atlantic fishery i.e., the existence of a Hudson-Atlantic contingent in the sense of Clark[17] could neither be proved nor disproved by his study. G. MacMillan[18] of the American Littoral Society stated in a letter to the Long Island Fisherman (1973): "We do not have much to go on with reference to the Hudson River bass going south. It almost appears that they pretty much stay in the Hudson River." A tagging study of large striped bass over 400 mm in total length is currently being conducted in the Hudson River by Texas Instruments Incorporated. During the period from January to June 1973, 149 large striped bass have been captured, tagged and released in the Hudson River areas of Croton Bay and above. As of August 1, 1973, there have been fourteen recoveries. These fish have all been recovered within the Hudson River and the western end of Long Island Sound except for two, one of which was recovered from New Bedford, Mass. and another which was captured at Fire Island inlet (Southern Long Island). The location of recaptures from the TI study is shown pictorially in Figure 2, and additional data is presented in Table 2.

The overall conclusion which can be drawn from the tagging studies conducted to date is that striped bass of Hudson River origin probably contribute relatively little to the mid-Atlantic fishery. The general opinion of most workers, as exemplified by that of Raney,[1] is that the Hudson stock contributes mainly to a fishery in the Hudson itself, the western quarter of Long Island Sound, the southwest shore of Long Island, New York Bay and the northern tip of New Jersey. Further, it is believed that the largest portion of the mid-Atlantic catch is the result of a migratory group which originates in Southern waters, most likely the Chesapeake Bay. The Chesapeake region has had the highest catches of striped bass ever since records have been kept,[2] with catches being about an order of magnitude higher than catches in the mid-Atlantic region and about two orders of magnitude higher than landings in the Hudson. Since the size of the catch in the Hudson is relatively small compared to the size of the catch in the Chesapeake, and aggregations of fish are known to occur in these bodies of water, thereby maximizing probabilities of capture, it is unlikely that the small Hudson stock could contribute significantly to the much larger biomass of the mid-Atlantic fishery.

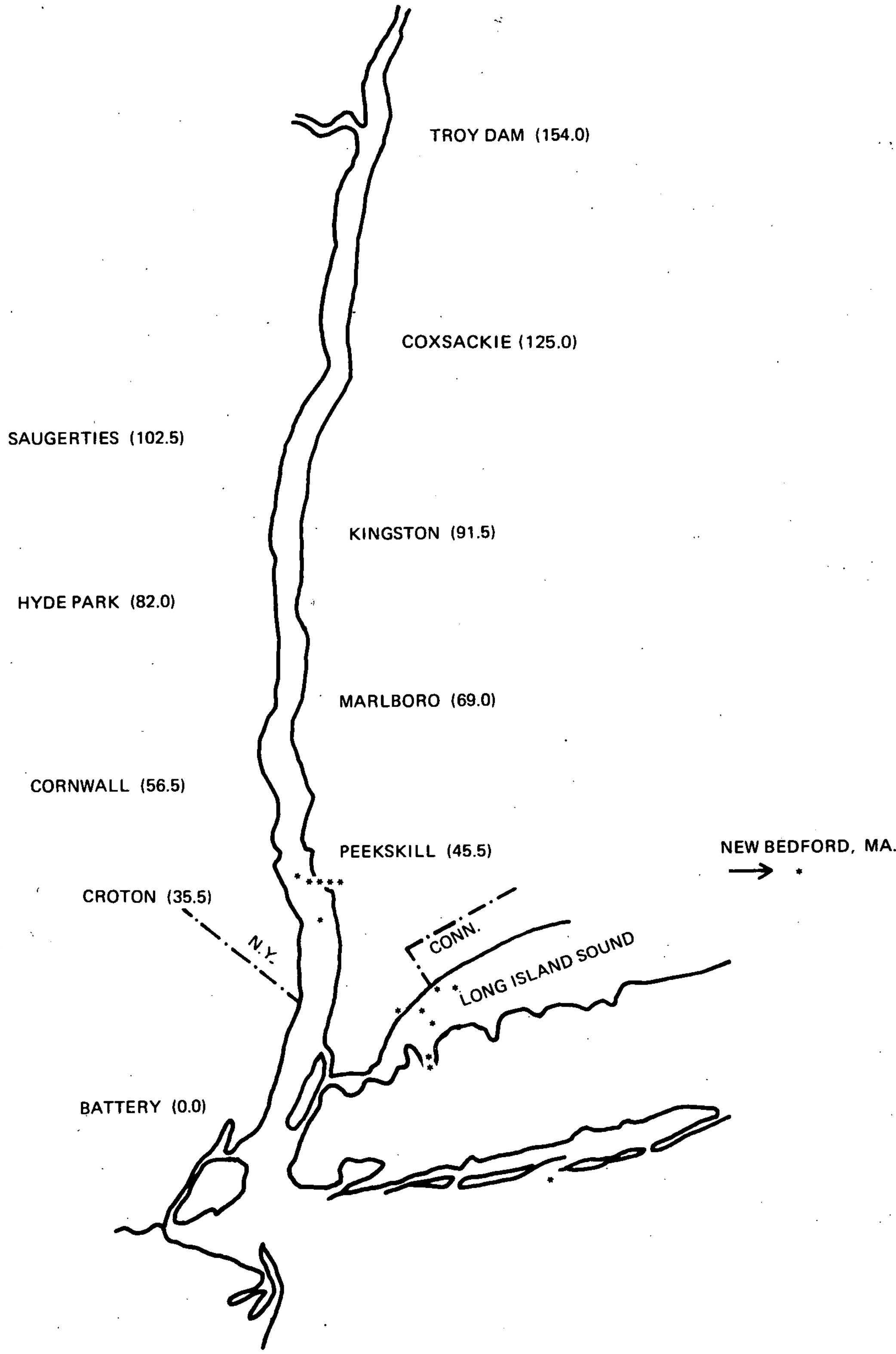

Figure 2. Striped bass recoveries from adult fish tagged in the Hudson, 1973. (River miles in parentheses)

Table 2. Striped bass tag recoveries from the 1973 Texas Instruments Study

	Release		Recapture				
	Location	Date	Location	Date	Days at Large	Total Length	Age
1	Croton Bay	12/28/72	Rye, N.Y.	4/1/73	94	555 mm	
2	Croton Bay	12/28/72	Greenwich, Conn.	5/25/73	148	605	
3	Croton Bay	1/3/73	Croton Bay	5/11/73	128	567	
4	Croton Bay	3/9/73	Croton Bay	4/23/73	45	645	VI
5	Croton Bay	3/9/73	Croton Bay	5/11/73	63	646	
6	Croton Bay	3/9/73	Mamaroneck, N.Y.	7/21/73	134	670	V
7	Ossining	3/13/73	Montrose, N.Y.	5/1/73	49	610	V
8	Ossining	3/13/73	Glen Cove, L.I., N.Y.	6/20/73	99	650	V
9	Ossining	3/13/73	Stamford, Conn.	7/27/73	136	650	V
10	Croton Bay	3/14/73	Croton Bay	3/14/73	0	552	
11	Croton Bay	3/14/73	Little Neck Bay	3/30/73	16	588	
12	Croton Bay	3/26/73	Robert Moses Bridge Fire Island, L.I., N.Y.	6/7/73	73	575	
13	Ossining	4/3/73	Ossining	4/13/73	10	492	IV
14	Cornwall	4/20/73	New Bedford, Mass.	6/19/73	60	975	IX

The records of commercial catches from the Chesapeake and mid-Atlantic regions have been summarized in Table 3. It is apparent that the annual striped bass harvest from the Chesapeake region has been at least 55% of the total Atlantic coast catch since 1930 with the average being 68%, whereas during the same period of time the mid-Atlantic catch has been at most 24% with the average contribution being 13%. Landings in the Hudson have been no more than 2.1% of the total Atlantic catch and have averaged only 0.6%.

Table 3. Percent of Atlantic Coastal Commercial Landings from Selected Regions During the Period from 1930 to 1969

	Chesapeake[1] Region	Mid-Atlantic[2] Region	Hudson[3] River
Maximum	79%	24%	2.1%
Minimum	55%	2.9%	0.04%
Average	68%	13%	0.6%

1. The Chesapeake Region is made up of the states of Maryland and Virginia.

2. The Mid-Atlantic Region is made up of the states of New York, New Jersey and Delaware.

3. All data presented on the Hudson River are from personal communication with Mr. Churchill Smith of the National Marine Fishery Service, NOAA office in Patchogue, Long Island, N.Y.

SUMMARY

From the best assessment that can be made from the existing data, it is likely that the effect of Indian Point Unit 3 on the mid-Atlantic fishery will be small irrespective of the impact on the Hudson River population. Since all available tagging data suggests that the geographical area of the mid-Atlantic region in which the Hudson makes any substantial contribution is small, then any impact on the Hudson would have but a small effect on the mid-Atlantic catch as a whole. Since no reliable numerical estimates of the percent contribution of the Hudson River to the mid-Atlantic fishery are currently available, this is the best assessment of impact which can be made at this time. However, when information from electrophoretic, morphometric and other studies becomes available, estimates of the contribution of the Hudson River to the mid-Atlantic fishery can be incorporated into an overall model of plant effects on the Hudson River striped bass population to yield meaningful predictions of mid-Atlantic impact and allow more accurate analysis of costs and benefits.

In the interim Con Edison is continuing its examination of existing data, particularly the economic impact of the operation of the Indian Point facilities on the contribution of the Hudson River striped bass populations to the mid-Atlantic fishery. An additional assessment of this economic impact will be presented at a later date.

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3) An estimate of the monetized value of the sport and the commerical striped bass fishery in the mid-Atlantic states.

On the basis of an extensive literature review of tagging studies over a 35 year period the applicant maintains that the contribution of the Hudson to the mid-Atlantic fishery is less than 10 percent (4).

Estimates of the percentage reduction in the striped bass population due to the operation of the Indian Point Units 1 and 2 were developed from modeling efforts and were reported in the license hearing for Indian Point Unit 2 (5). Utilizing less conservative, but more realistic model input parameters, which were discussed during the Unit 2 hearings (5, 6, 7, 8), the percentage reduction in striped bass population due to the operation of all units at Indian Point was developed and is listed in Table 1.

Table 1

Percent Reduction in the Hudson River Adult Striped Bass Population due to the operation of Indian Point Units 1, 2 and 3 for 1, 5 and 10 years.

After 1 Year	After 5 Years	After 10 Years
3%	5%	7%

The monetized value of the mid-Atlantic striped bass fishery is a composite of two values; 1) The commercial fishery value and 2) the sport fishery value. An estimate of the approximate value of the annual commercial catch may be developed through an assessment of the average annual catch in pounds and the average retail price per pound for striped bass.

During the period 1961 through 1969 the mid-Atlantic striped bass catch ranged from 1,252,000 to 2,059,000 pounds (the largest catch ever recorded) and averaged 1,660,000 pounds. At the 1971 weighted average retail price of 48¢/lb (9) the average annual commercial catch had an estimated value of $796,800.

Assuming that 1) the operation of Indian Point does result in a striped bass population reduction as identified in Table 1, 2) the Hudson contingent of striped bass does contribute as much as ten percent to the mid-Atlantic fishery, and 3) the percentage reduction in population size due to the operation of Indian Point will result in a comparable percentage reduction in fish catch in the mid-Atlantic, the economic benefits foregone of the commercial fishery will be $2390 the first year and $5578 in the tenth year of plant operation (see Table 2).

Table 2

Economic Benefits Foregone of the Mid-Atlantic Commercial Striped Bass Fishery due to the Operation of Indian Point Units 1, 2 and 3.

After 1 Year	After 5 Years	After 10 Years
$2390	$3984	$5578

To compute the economic value of the mid-Atlantic striped bass sport fishery it is necessary to determine the number and value of the fisherman-days spent pursuing this species. Deuel and Clark (2) reported that out of 1,530,000 salt-water anglers in the North Atlantic Region (including New York and Connecticut), 318,000 or 20.8% reported catching striped bass, and out of 1,375,000 salt-water anglers in the Middle Atlantic Region, 295,000 or 21.5% reported catching striped bass. (9)

For use in computing fisherman-days, these numbers are actually on the high side in view of the fact that some of the respondents reported catches of other salt-water species, so the number of recreation days spent in salt-water angling are not exclusively chargeable to striped bass fishing. To some extent, there is a compensating inexactitude though, in that the 1965 Angling Survey respondents included only those who caught striped bass; self-proclaimed striped bass fishermen who fished for striped bass but caught none during the survey year of 1965 would not have been counted. (9)

In 1970, 74.5% of the national population was 12 years of age or older and 8.0% and 6.9% of these people were reported to be salt-water anglers in the North Atlantic and Mid-Atlantic region, respectively. Combining these percentages with the foregoing estimates of the percentage of salt-water anglers who reported catching striped bass, estimates of the numbers of striped bass fishermen in the Hudson-influenced group of states can be made (see Table 3). (9)

Table 3

Estimated Number of Striped Bass Fishermen in the Mid-Atlantic Region

State	1970 Total Population	Estimated Striped Bass Fishermen
Connecticut	3,031,709	37,600
New York	18,190,740	225,500
New Jersey	7,168,164	79,200
Delaware	548,104	6,100
Total	28,938,717	348,400

The best estimate of the number of fishing-trip days enjoyed by these fishermen is 12.2 days, the average number of days fished by all Atlantic Coast salt-water fishermen in 1970 (10).

Recreation-day values for general and specialized forms of recreation including fishing have been established to assist in developing benefit/cost analyses for federal water projects (11). These values can be used to assess the value of a fisherman-day spent fishing for striped bass.

The general type of outdoor recreation day is defined as one attracting the majority of outdoor recreationists, and which requires the development and maintenance of convenient access and adequate facilities. The range of values for this type of recreation day are $0.75 to $2.25 (11).

A specialized recreation day, however, is defined as one for which opportunities are often limited, intensity of use low, and may involve large personal expense on the part of the user. The values for specialized recreation days range from $3.00 to $9.00 (11).

It is believed striped bass fishing represents a specialized form of sport fishing. However, no precise specialized-day value for this activity is known. Consequently, for the purposes of this discussion both the minimum and maximum values will be presented to provide a range of the annual value for striped bass sport fishing in the mid-Atlantic. Based on a total of 348,400 fishermen spending an average of 12.2 days each year fishing for striped bass at a recreation day value ranging from $3.00 to $9.00 the mid-Atlantic striped bass sport fishery has an annual value ranging from $12,750,000 to $38,254,000.

If a linear reduction in fishing effort results due to the operation of the Indian Point Units 1, 2 and 3,* the economic benefits foregone in the sport fishery will range from a low of $38,253 in the first year of impact at a fishing day value of $3.00 to a high of $267,778 in the tenth year at a fishing day value of $9.00 (see Table 4).

Table 4

Economic Impact of the Operation of Indian Point Units 1, 2 and 3 on the mid-Atlantic Striped Bass Sport Fishery

Fishing Day Value	Years of Operation		
	1	5	10
$3.00	$ 38,253	$ 63,755	$ 89,257
$9.00	$114,762	$191,270	$267,778

Combining the economic assessment of the impact on the commercial fishery (Table 2) with the sport fishery impact assessments (Table 4) the total economic benefits foregone by mid-Atlantic fishermen due to the operation of the Indian Point Units 1, 2 and 3 range from $40,643 in the first year at the $3.00 per recreation-day value to $273,356 on the tenth year at the $9.00 per recreation day value. (See Table 5).

*This is a highly unrealistic assumption because a fisherman would most likely not cease fishing because of a reduction in striped bass. He would probably turn his attention to perhaps bluefish, fluke or some of the other game fishes of the ocean.

Table 5

Combined Striped Bass Commercial and Sport Fishery Economic Benefits Foregone due to Operation of Indian Point Units 1, 2 and 3.

Fishing/-Day Value	Years of Operation		
	1	5	10
$3.00	$ 40,643	$ 67,739	$ 94,835
$9.00	$117,152	$195,254	$273,356

In order to compute a benefit/cost ratio for a closed-cycle cooling system, these economic values of benefits foregone must be compared with the costs of such a system. We will use costs of a single natural-draft wet cooling tower system, but the costs of other feasible systems would not produce substantially different ratios.

The last detailed analysis of the cost of such a system was that presented in the ASLB hearings for Unit No. 2 (12) The cost of such a system for Unit 3 will not be less than that for Unit 2.

The values of the fishery indicated above are most comparable to the average annual cost of the cooling tower system. This is computed by taking the total costs of $488,969,000 divided by the 26-year life of the system to produce an average annual cost of $18,806,000. The average annual cost of such systems at Units 2 and 3 is therefore not less than $37,600,000. The benefit/cost ratios are indicated in Table 6.

The benefit/cost ratios for a single tower at Unit 2 alone would not be substantially different from those indicated in Table 6. The benefits would be approximately half of those indicated in the foregoing analysis (Table 5) and the costs would also be approximately half, producing essentially the same ratio.

Since all the benefit/cost ratios are less than 1, Table 6 indicates that construction of a closed-cycle cooling system cannot be justified on a benefit/cost analysis based on the values established by the Water Resources Council for federal water projects. It should be noted that this analysis does not take into account the adverse scenic impact of natural-draft cooling towers and the potential for other adverse environmental impacts of cooling towers.

Table 6

Benefit/Cost Ratios - Benefits Foregone in Mid-Atlantic Striped Bass Fishery Value: Cost of Closed-Cycle Cooling System

Fishing Day Value	Years of Operation		
	1	5	10
$3.00	.00108	.00180	.00252
$9.00	.00312	.00519	.00727

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A. Biological Impacts

Question 1. Provide a justification for suggesting a loss factor of 5% for the impingement of fish caught at the Unit 3 intake structure, used in Appendix FF of the Environmental Report, p. IV-18. Include in your justification the data and logic used for this loss factor.

Response: In the Indian Point 2 ASLB proceeding, Applicant and Intervenors stipulated that a 25% loss factor for recent counts of impinged fish would be reasonable (Stipulation dated October 30, 1972). Con Edison estimates that the loss factor for Indian Point 3 intake fish counts would be 5% because most of the mechanisms causing losses at Units 1 and 2 have been eliminated in the design of the Unit 3 intake structure and the collecting method employed. These changes are:

1. Fixed screens are not employed at Unit 3. Many of the losses at Units 1 and 2 occur when fixed screens are sprayed and impinged fish are knocked out into the river. At Unit 3 the traveling screens are at the front of the intake structure and fish are removed by simply rotating the screens and lips on the screen lift the fish out of the water to the deck level where they fall into a collecting sluice.

2. The majority of fish losses at Units 1 and 2 occur in the sluice when the collecting screens clog with debris. At Unit 3 the collecting screen is replaced by a screened collection box which can handle a much larger debris load which eliminates this mechanism of fish loss.

Fish impinged at Unit 3 could still be lost due to screen carry-over and in handling after collection. A 5% loss factor has been estimated as reasonable. No tests have yet been conducted because of the very limited operation of the Unit 3 intakes.

Question 2. Provide all information available from the Indian Point site subsequent to that information reported in Appendix BB of the Environmental Report, relating to survival of impinged fish. Include the applicant's efforts and success in determining the survival of the impinged fish returned to the river.

Response: Limited survival tests were carried out in 1972-1973. Short term survival tests were carried out on fish collected on Units 2 and 3 traveling screens. Results of these will be reported in the Indian Point second annual report which is scheduled for June, 1974.

Question 3. Provide data and a regression analysis to evaluate the relationship between the number of white perch impinged (and probability of a white perch being impinged) and water temperature. Compare the number of perch impinged in relation to the population of perch in the river.

Response: Data and regression analysis relating white perch impingement to plant and environmental variables will be discussed extensively in the impingement section of the Indian Point second annual report which is scheduled for June, 1974. Some preliminary discussion of fish populations and the impact of impingement on them is given in the 1973 Indian Point Semi-Annual report, copies of which have been furnished to the AEC and other parties.

Question 4: Provide copies of impingement data for different species of fish collected at Lovett and Danskammer plants from 1971 to the present. Provide similar data available for the Bowline and Roseton plants from the date of startup to the present time. Provide monthly estimates of the number of fish impinged (and species composition) at the Indian Point Units Nos. 1, 2 and 3 and compare the results with those taken at the other plants for comparable time periods. Determine, if possible, the effect of the number of fish impinged on the total fish population.

Response: Presentation and analysis of impingement data for 1971-72 at Danskammer will be provided in a QLM report to Central Hudson Gas and Electric Corporation, scheduled for May, 1974. Impingement data for 1973 at Danskammer will be presented in a similar report scheduled for September, 1974. Upon receipt of these reports from Central Hudson Gas and Electric Corporation, Con Edison will provide copies to the AEC.

Presentation and analysis of impingement data at Bowline and Lovett in 1973 will be provided in a QLM report to Orange & Rockland Utilities, scheduled for July, 1974. Upon receipt of this report from Orange & Rockland Utilities, Con Edison will provide copies to the AEC.

Monthly estimates of the number and species composition of fish impinged based on data at Indian Point Unit 1 through 1972, are given in the Indian Point Unit 3 Environmental Report, Appendix BB. Tabulations of more recent impingement data at all three Indian Point Units are being prepared in response to an HRFA interrogatory. Also, results of 1972-1973 impingement studies by Texas Instruments at Indian Point will be provided in a Texas Instruments report to Con Edison scheduled for June, 1974.

A preliminary estimate of the effect of impingement on total fish populations is given in Texas Instruments Second Semi-Annual Report (November, 1973) on page V-35. This topic will be addressed further in future Annual and Semi-Annual reports.

Question 5.

a) Provide a summary report on the chlorination program carried out at the Unit Nos. 1 and 2 condensers during the summer - fall 1973. Include information relating to total residual chlorine analysis in terms of dates, times and places of sampling, the sampling analyses and results.

b) Any information subsequent to that reported in Appendix Z to the Environmental Report regarding the sensitivity to residual chlorine of fish eggs, larvae and young juveniles in the vicinity of Indian Point should be provided.

Response:

a) No chlorination study program was carried out during the summer-fall of 1973 because Unit No. 1 was out of service and there was only limited operation of Unit No. 2

b) No information has been obtained subsequent to that reported in Appendix Z to the Environmental Report on the sensitivity to residual chlorine of fish eggs, larvae, and young juveniles in the vicinity of Indian Point.

A study is currently under way to determine the effect of cooling tower blowdown (one constituent of which is chlorine) on juvenile fish in the vininity of Indian Point. Results of this study will be presented in two reports on the Effect of Cooling Tower Blowdown at Indian Point - the first scheduled for May, 1974 and the second scheduled for November 1974.

Question 6: Provide monthly densities (with a measure of variation) for microzooplankton (e.g., copepods and cladocerans) and macrozooplankton (e.g., Gammarus and Neomysis) taken in 1972 and 1973. Provide estimates for a best case, worst case, with supporting rationale, of monthly number and weight losses of microzooplankton and macrozooplankton due to entrainment at Indian Point Units Nos. 1, 2 and 3 at full flow.

Response: 1972 density data for macrozooplankton (Gammarus and Neomysis) are presented in Tables 6-1 and 6-2. Further data is available in NYU's Progress Report on 1971–72 entrainment studies at Indian Point, a copy of which has already been provided to the AEC. Best and worst estimates of the numbers of N. americana and Gammarus sp. killed by entrainment at Indian Point Units 1, 2 and 3 are given in Tables 6-3 and 6-4. These estimates were calculated from the density data shown in Table 6-5, the percent mortality data in Tables 6-6a, 6-6b and 6-7, the plant operating data in Table 6-8, and an estimated average weight of 0.8 mg for Gammarus sp. No weight data were available for N. americana. Best and worst estimates reflect variations in intake water temperatures. Minimum and maximum intake temperatures (table 6-9) are the same as those presented by Dr. Lawler as testimony at the Indian Point Unit 2 hearings but expanded to cover the whole year rather than just the striped bass entrainment period. During a portion of this period Unit 1 operated with a surface discharge located close to the intake, which resulted in at least $1^{o}F$ recirculation. With the new submerged discharge located much further from the intakes, we expect a maximum recirculation of $3^{o}F$ and a tidal average recirculation of 2°F. Therefore we assume 2°F recirculation. Day and night density data were averaged on a weighted basis using hours of daylight from Table 6-10.

No definite trend in the monthly abundance of Gammarus sp. could be detected for the period of June to December. Therefore, an annual mean abundance was calculated. A relationship between day and night abundances was calculated for the period of June to August and extrapolated over the entire year for the determination of daylight-weighted abundances. Entrainment mortalities during periods of no chlorination were estimated from observed differences in survival between intake and discharge canal samples and from laboratory temperature tolerance data. Estimates of chlorination mortalities were:

Gammarus sp.	- 33.5% when ambient Temp. $< 20^{\circ}C$
	- 47.5% when ambient Temp. $> 20^{\circ}C$
Neomysis sp.	- 50% at all times

Because of the abundance of these organisms in the estuary, and their continuous generation throughout much of the year, it is very unlikely that the estimates of plant kills shown in Tables 6-3 and 6-4 will have a serious or irreversible impact on their populations in the estuary. Furthermore, those organisms killed by entrainment at the plant are not lost to the food chain in the estuary since they will be either eaten by predators or decomposed by bacteria along with other detritus. Finally, it is quite possible that the increased temperature in the vicinity of the plant will actually stimulate growth and

and increase the length of the growing season for these organisms such that the plant entrainment kills are offset.

1972 density data for microzooplankton (copepods and cladocerans) is given in the attached Table 6-11. Only a few microzooplankton samples were collected in 1973. Thus the most recent complete set of microzooplankton data is that for 1972. Best and worst estimates for number and weight of copepods and cladocerans killed by entrainment at Indian Point Units 1, 2 and 3 are given in Tables 6-12a and 6-12b. These estimates were calculated from the density data shown in Table 6-13, the plant operating data shown in Table 6-8, estimated average weights of 0.33 mg/organism for copepods, and cladocerans, and % mortalities based on analysis of variance for certain ranges of discharge temperature (See NYU Progress Report for 1971-72). Where there was no field data for the projected discharge temperatures, laboratory data were used to estimate % mortality. Thus laboratory data were used to estimate mortality for the maximum discharge temperature conditions expected in the months of July, August, September and October. Best and worst estimates reflect variations in intake water temperatures. Minimum and maximum assumed intake temperatures are given in table 6-9. All estimates are calculated assuming year round full power operation. It should be noted that these calculations reflect full flow of circulator cooling water from April 1 to October 1 and reduced (60%) flow from October 1 to April 1, since this is the anticipated plant operating schedule. Day and night density data were average on a weighted basis using hours of daylight from Table 6-10. Estimates of percent mortality of entrained copepods and cladocerans with and without chlorination as observed during operation of Unit 1 is given in Table 6-14. Table 6-15 shows the projected number of cladocerans and copepods that could be killed due to chlorination at Indian Point Units 1, 2 and 3. An average estimate of chlorination mortalities based on analysis of variance of 1972 microzooplankton field data was used for these calculations. Note that the apparent differences in estimated percent mortality with and without chlorination are not significant at the 95% confidence level; so chlorination effects had no influence on the projected mortality of copepods and cladocerans as indicated by the data in Table 6-12a and 6-12b. As mentioned previously for macrozooplankton, it is very unlikely that these estimates would result in a serious or irreversible impact since the organisms are abundant in the estuary and are reproducing throughout much of the year. Likewise those organisms killed by entrainment are not lost to the food chain since they will either be eaten by predators or decomposed by bacteria. Finally it is quite possible that the increased temperature in the vicinity of the plant will actually stimulate growth and increase the length of the growing season for these organisms.

Table 6-1

Log_{10} (Monthly density of Gammarus sp.) (1972)

Month	Day[1]	Night[1]
January	—	—
February	—	—
March	—	—
April	—	—
May	—	—
June	2.9861 ± 0.3656	4.0655 ± 0.6088
July	2.1987 ± 0.4809	3.7218 ± 0.2857
August	2.6057 ± 0.4393	3.9977 ± 0.2076
September	—	3.2847 ± 0.2841
October	—	3.4838 ± 0.1926
November	—	3.8236 ± 0.1606
December	—	3.1431 ± 0.3338

[1]Units are Log_{10} (Number/1000 m^3) ± 95% Confidence Limit. Results are given in this form because variances were found to be directly correlated with the means, hence log transformations were required to perform valid statistical analysis. The geometric mean abundances can be produced by determining the antilogs of the numbers presented in the table.

Table 6-2

$\log_{10}$ (Monthly density of Neomysis americana) (1972)

Month	Day[1]	Night[1]
January	—	—
February	—	—
March	—	—
April	—	—
May	—	—
June	0	0
July	0.7291 ± 1.2600	3.5055 ± 0.4026[2]
August	0.4491 ± 0.3275	2.6798 ± 0.5055
September	—	3.5300 ± 0.4066
October	—	3.0266 ± 0.4644
November	—	1.3366 ± 1.5529[3]
December	—	0

[1] See note 1 on Table 6-1.

[2] Susceptible to entrainment 23% of July.

[3] Susceptible to entrainment 43% of November.

Table 6-3

Gammarus sp. killed by entrainment at Indian Point

Unit 3 alone

Month	Without chlorination	During chlorination	Total	Total weight Kg
	Number killed x 10^6			
Minimum				
January	7.58	0	7.58	6.07
February	6.32	0	6.32	5.06
March	6.28	0	6.28	5.02
April	9.05	0.07	9.12	7.29
May	8.38	0.14	8.52	6.82
June	24.71	0.19	24.90	19.92
July	26.35	0.30	26.65	21.32
August	29.25	0.30	29.55	23.64
September	31.85	0.29	32.14	25.71
October	22.12	0.12	22.24	17.79
November	7.11	0.08	7.19	5.75
December	7.68	0.04	7.72	6.17
Total	186.7	1.52	188.2	150.5
Maximum				
January	7.58	0	7.58	6.07
February	6.32	0	6.32	5.06
March	6.28	0	6.28	5.02
April	9.05	0.07	9.12	7.29
May	8.38	0.14	8.52	6.82
June	24.71	0.19	24.90	19.92
July	26.35	0.30	26.65	21.32
August	66.51	0.30	66.81	53.45
September	72.42	0.29	72.71	58.17
October	225.4	0.12	225.5	180.4
November	23.24	0.08	23.32	18.6
December	7.68	0.04	7.72	6.17
Total	483.9	1.41	485.4	388.3

Table 6-3 (cont.)

Units 1, 2 and 3

Month	Without chlorination	During chlorination	Total	Total weight Kg
	Number killed x 10^6			
Minimum				
January	17.94	0	17.94	14.35
February	14.95	0	14.95	11.96
March	14.85	0	14.85	11.88
April	21.40	0.48	21.88	17.50
May	19.83	0.99	20.82	16.66
June	58.45	1.27	59.72	47.78
July	62.34	2.11	64.45	51.56
August	69.19	2.11	71.30	57.04
September	75.34	2.04	77.38	61.90
October	52.33	0.84	53.17	42.54
November	16.81	0.58	17.39	13.91
December	18.16	0.30	18.46	14.77
Total	441.6	10.72	452.3	361.84
Maximum				
January	17.94	0	17.94	14.35
February	14.95	0	14.95	11.96
March	14.85	0	14.85	11.88
April	21.40	0.48	21.88	17.50
May	19.83	0.99	20.82	16.66
June	58.45	1.27	59.72	47.78
July	62.34	2.11	64.45	51.56
August	157.3	2.11	159.4	127.52
September	75.34	2.04	77.38	61.90
October	333.3	0.84	334.1	267.28
November	54.98	0.58	55.56	44.45
December	18.16	0.30	18.46	14.77
Total	848.8	10.72	859.5	687.6

Table 6-4

Neomysis americana killed by entrainment at Indian Point

Month	Minimum: Without chlorination	Minimum: During chlorination	Minimum: Total	Maximum: Without chlorination	Maximum: During chlorination	Maximum: Total
			Number killed x 10^6			
July	16.40	0.0037	16.40	41.00	-----	41.00
August	29.84	------	28.84	29.84	-----	29.84
September	46.48	0.0036	46.48	232.4	-----	232.4
October	5.62	0.0015	5.62	51.08	-----	51.08
November	0.05	0.0014	0.05	0.14	0.001	0.14
Total	98.39	0.010	98.40	354.5	0.001	354.5
			Units 1, 2 and 3			
July	19.50	0.026	19.43	96.99	-----	96.99
August	70.59	-----	70.62	70.59	-----	70.59
September	109.94	0.025	109.96	549.7	-----	549.7
October	13.29	0.010	13.30	120.8	-----	120.8
November	0.12	0.010	0.13	0.22	0.010	0.23
Total	213.3	0.071	213.4	838.3	0.010	838.3

Table 6-5

Mean daylight —

weighted monthly abundances of Gammarus sp. and Neomysis americana

Month	Gammarus sp. (Number/1000 m^3)	Neomysis americana (Number/1000 m^3)
January	3582.9	——
February	3304.5	——
March	2966.0	——
April	2649.4	——
May	2376.4	——
June	2212.6	——
July	2283.6	1212.6
August	2534.8	203.0
September	2851.4	1633.2
October	3195.4	579.1
November	3468.3	12.9
December	3626.6	——

Table 6-6a

Minimum estimated percent mortality of entrained Gammarus sp.

		Unit 3 alone		Units 1, 2 & 3	
Month	Intake Temperature °C	Discharge Temperature °C	Percent Mortality	Discharge Temperature	Percent Mortality
January	1.1	16.2	2.4	15.1	2.4
February	1.1	16.2	2.4	15.1	2.4
March	2.2	17.3	2.4	16.2	2.4
April	6.7	15.8	2.4	15.1	2.4
May	12.2	21.3	2.4	20.6	2.4
June	19.4	28.5	7.9	27.8	7.9
July	23.9	33.0	7.9	32.3	7.9
August	25.6	34.7	7.9	34.0	7.9
September	22.8	31.9	7.9	31.2	7.9
October	12.8	27.9	7.9	26.8	7.9
November	11.7	26.8	2.4	25.7	2.4
December	4.4	19.5	2.4	18.4	2.4

Table 6-6b

Maximum estimated percent mortality of entrained Gammarus sp.

Month	Intake Temperature°C	Unit 3 alone: Discharge Temperature°C	Unit 3 alone: Percent Mortality	Units 1, 2 & 3: Discharge Temperature°C	Units 1, 2 & 3: Percent Mortality
January	5.0	20.1	2.4	19.0	2.4
February	3.3	18.4	2.4	17.3	2.4
March	5.0	20.1	2.4	19.0	2.4
April	11.1	20.2	2.4	19.5	2.4
May	16.7	25.8	2.4	25.1	2.4
June	21.1	30.2	7.9	29.5	7.9
July	25.6	34.7	7.9	34.0	7.9
August	27.2	36.3	17.9	35.6	17.9
September	26.1	35.2	17.9	34.5	7.9
October	20.6	35.7	80.0	34.6	50.0
November	14.4	29.5	7.9	28.4	7.9
December	6.7	21.8	2.4	20.7	2.4

Table 6-7

Estimated percent mortality of entrained *Neomysis americana*

	Unit 3 alone				Units 1, 2 &3			
	Minimum		Maximum		Minimum		Maximum	
Month	Discharge temp. (°C)	Percent mortality	Discharge temp. (°C)	Percent mortality	Discharge temp. (°C)	Percent mortality	Discharge temp. (°C)	Percent mortality
July	33.0	40	34.7	100	32.3	20	34.0	100
Aug.	34.7	100	36.3	100	34.0	100	35.6	100
Sept.	31.9	20	35.2	100	31.2	20	34.5	100
Oct.	27.9	11	35.7	100	26.8	11	34.6	100
Nov.	26.8	11	29.5	30	25.7	11	28.4	20

Table 6-8

Flows and Temperature Rises

	Unit 1	Unit	Unit 3
Cond. Flow, gpm (Full Flow)	280,000	840,000	840,000
Cond. Flow, gpm (Red. Flow)	168,000	504,000	504,000
Cond. ΔT, °F (Full Flow)	12.6	14.9	16.3
Cond. ΔT, °F (Red. Flow)	21.0	24.8	27.1
Service Flow, gpm	38,000	30,000	30,000
Service ΔT, °F	7.9	6.7	7.3

Note: All plants will operate at Full flow from April 1 to October 1 and reduced flow from October 1 to April 1.

Transit Times (minutes)

	Single Unit Op.			Simul. 3 Unit Operation		
	1	2	3	1	2	3
Intake to Condenser	1.16	1.52	1.52	1.16	1.52	1.53
Through Condenser	0.08	0.14	0.14	0.08	0.14	0.14
Condenser to River	32.08	13.52	7.05	6.12	7.90	4.25

Estimated Chlorination Schedule at Indian Point

	cycles per week per unit
January 1 - April 15	0
April 16 - June 30	2
July 1 - September 30	3
October 1 - December 15	2
December 16 - December 30	0

Note: One cycle consists of chlorinating one half of each of the main condensers at a unit for one half hour. Total cycle time is therefore one hour. No more than one Unit will be chlorinated at the same time.

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Table 6-9

Estimated Minimum and Maximum Temperatures at Indian Point under various operating conditions

Month	Minimum			Maximum		
		Discharge Temp. °F			Discharge Temp. °F	
	Intake Temp. °F	Unit 3 alone	Units 1,2 & 3	Intake Temp. °F	Unit 3 alone	Units 1,2 & 3
Jan.	34.0	61.2	59.3	41.0	68.2	66.2
Feb.	34.0	61.2	59.2	37.9	65.1	63.1
March	36.0	31.1	61.2	41.0	68.2	66.2
April	44.1	60.4	59.2	52.0	68.4	67.1
May	54.0	70.3	69.1	62.1	78.4	77.2
June	66.9	83.3	82.0	70.0	78.0	85.1
July	75.0	91.4	90.1	78.1	94.5	93.2
August	78.1	94.5	93.2	81.0	97.3	96.1
Sept.	73.0	89.4	88.2	79.0	95.4	94.1
Oct.	55.0	82.2	80.2	69.0	96.3	94.3
Nov.	53.1	80.2	78.3	57.9	85.1	83.1
Dec.	40.0	67.1	65.1	44.1	71.2	69.3

Table 6-10

Average percent of daylight per day (by month)

Month	Percent daylight/day
January	38.7
February	43.8
March	50.0
April	55.8
May	60.8
June	63.8
July	62.5
August	57.9
September	52.1
October	45.8
November	40.8
December	37.9

Table 6-11

Mean Monthly Density of Copepods and Cladocerans at Indian Point (1972)

Month	Day Sampling (Number/Liter)*	Night Sampling (Number/Liter)*
January	-	-
February	-	-
March	-	-
April	-	-
May	21.9 ± 23.5	
June	69.0 ± 29.2	63.9 ± 35.2
July	46.3 ± 26.2	46.3 ± 54.6
August	187.1 ± 71.2	168.0 ± 50.8
September	-	-
October	-	-
November	-	-
December	-	-

* ±95% confidence limits

Table 6-12a

Estimated number and weight of Cladocerans and Copepods lost under minimum temperature conditions

	Units 1, 2 & 3 Operating		Unit 3 alone Operating	
Month	# organisms killed x 10^{10}	Weight lost kg x 10^3	# organisms killed x 10^{10}	Weight Lost kg x 10^3
Jan.	6	1.8	2.6	0.8
Feb.	6	1.8	2.6	0.8
March	120	36.0	52.0	17.2
April	120	36.0	52.0	17.2
May	120	36.0	52.0	17.2
June	234	70.0	68.0	22.4
July	174	52.3	75.0	24.7
August	297	89.3	128.0	42.2
Sept.	147	44.3	63.7	21.0
Oct.	86	25.8	36.8	12.1
Nov.	63	19.0	27.6	9.1
Dec.	6	1.8	2.6	0.8

Table 12b

Estimated number and weight of Cladocerans and Copepods lost under maximum temperature conditions

	Units 1, 2 & 3 operating		Unit 3 alone operating	
Month	# organisms killed x 10^{10}	Weight lost kg x 10^{10}	# organisms killed x 10^{10}	Weight lost kg x 10^{10}
Jan.	6.0	1.8	2.6	.84
Feb.	6.0	1.8	1.7	.5
March	120.0	36.0	52.0	17.2
April	120.0	36.0	52.0	17.2
May	77.4	23.0	33.0	10.9
June	219.0	65.8	68.0	22.4
July	76.4	22.9	32.8	10.8
August	2975.0	892.5	1280.0	422.0
Sept.	64.8	19.4	27.9	9.2
Oct.	40.2	12.1	172.0	5.7
Nov.	63.0	19.0	27.6	9.1
Dec.	6.0	1.8	2.6	0.8

Table 6-13

Mean Monthly Densities
(Day and Night Combined)

Month	Mean Density*
January	1.8 ± .56
February	1.8 ± .56
March	21.9 ± 23.5
April	21.9 ± 23.5
May	21.9 ± 23.5
June	64.1 ± 22.4
July	46.3 ± 18.6
August	180.3 ± 44.2
September	40.5 ± 9.8
October	40.2 ± 6.8
November	31.2 ± 17.3
December	1.8 ± 0.56

* ±95% confidence limits

Table 6-14

Estimated Percent Mortality of Entrained Copepods and Cladocerans at Indian Point Based on Unit 1 Operating Conditions[1]

% Mortality ±95% confidence limits

Month	With Chlorination[2]	Without Chlorination
January	0.0	13.7 ± 6.0
February	0.0	13.7 ± 6.0
March	0.0	0.0 ± 6.4
April	1.8 ± 9.0	0.0 ± 6.4
May	1.8 ± 9.0	0.0 ± 6.4
June	28.2 ± 12.1	7.5 ± 14.0
July	24.8 ± 18.0	9.8 ± 18.0
August	4.9 ± 2.0	0.7 ± 1.6
September	18.2 ± 6.0	0.1 ± 2.0
October	1.1 ± 4.5	0.0 ± 2.6
November	10.6 ± 17.5	10.4 ± 20.0
December	6.2 ± 15.1	13.7 ± 6.0

(1) Note that we have no data based for projecting effects of chlorination at the maximum projected discharge temperatures. The effects could be the same or greater than indicated at Unit 1 operating conditions.

(2) Note that the apparent differences in estimated percent mortality with and without chlorination are not significant at the 95% confidence level, so chlorination effect has no influence on the projected mortality of copepods and cladocerans in Tables 12a and 12b.

Table 6-15

Estimated Numbers of Cladocerans and Copepods Killed Per Month Due to Projected Chlorination Schedules

	Unit 3 Alone
January	0.0*
February	0.0*
March	0.0*
April	3.07×10^9
May	6.14×10^9
June	17.94×10^9
July	19.47×10^9
August	75.81×10^9
September	17.04×10^9
October	6.77×10^9
November	5.23×10^9
December	$.15 \times 10^9$
	Units 1, 2, and 3
January	0.0*
February	0.0*
March	0.0*
April	21.0×10^9
May	43.0×10^9
June	126.0×10^9
July	136.0×10^9
August	531.0×10^9
September	119.0×10^9
October	47.0×10^9
November	37.0×10^9
December	1.1×10^9

*No chlorination

Question 7. Provide copies of all reports (monthly, semiannual, and annual) prepared by Texas Instruments, Inc. for Consolidated Edison subsequent to that already provided on: (a) Hudson River Ecological Study; (b) Cornwall Environmental Study; (c) Indian Point Impingement Study; (d) Ossining Environmental Study; (e) Evaluation of High Frequency Sonar For Fish Stock Evaluation in the Hudson River Estuary (issued in May 1973) (f) Intake-Discharge Structure Report. In reference to the October 1973 report on the 1973 Hudson River Program, p. I-3, provide further data for 1973 that will be available which will include: (a) ichthyoplankton data from April through July on all species; (b) beach seine collection data from March through December; (c) transect ichthyoplankton data for 1973 egg and larvae season; and (d) mark-recapture population estimates for adult white perch and young striped bass and white perch.

Response: The requested reports will be supplied to the AEC as they are published. Please note that there are no monthly reports for Con Edison's studies.

In reference to the request for supplementary data from the 1973 Studies:

a) Ichthyoplankton data for species other than striped bass will be summarized in the soon to be published report "Fisheries Survey of the Hudson River, March-July 1973, Volume III. Copies of this report will be sent to the AEC upon publication. The complete data for other species will be issued as supplements to the reports "1973 Hudson River Program, Fisheries Data Summary, May-July" (hereafter called Volume I) and "1973 Hudson River Program Fisheries Data Summary, July-November," (hereafter called Volume II). These supplements are scheduled to be published in June, 1974.

b) Beach seine collection data for March through November is available in Volume I and II. December data although limited will be available as a supplement to Volume II and will be summarized in the report "Fisheries Survey of the Hudson River, July-December, 1973 - (Volume IV). This report is scheduled for publication in June, 1974.

c) Transect ichthyoplankton data at Cornwall is available in Volume I. The transect data at Indian Point will shortly be available from N.Y.U. Transect data from Bowline, Lovett, Danskammer, Roseton and four upriver transects will soon be available from Orange and Rockland, Central Hudson and P.A.S.N.Y. Copies of these data will be provided to the AEC upon their receipt by Con Edison.

d) Detailed Mark-Recapture population estimates are available in the recently released Indian Point Second Semi-Annual Report, six copies of which have been sent to the AEC. Further estimates and a detailed discussion will appear in the Indian Point Second Annual Report which is scheduled to be published in June, 1974.

Question 8. Provide copies of the New York University 1971, 1972 and 1973 Annual Reports and other reports containing information on the entrainment studies and other ecological studies being conducted by the applicant's consultants at NYU.

Response: The 1971-72 annual report has been published and six copies provided to the AEC. The 1973 NYU Annual Report is scheduled to be published in about June, 1974, at which time copies will be provided to the AEC.

Question 9: In reference to Figure II-2 on page II-8 of the Texas Instruments Annual Report (April 1973), provide tabulation of data for minimum, maximum, and average daily water temperatures for all twelve months, including May, June, and July which have been provided in ER, IP-3, App. FF, pp. IV-28 to IV-30.

Response: Tabulated data for minimum, maximum, and average daily water temperatures in the vicinity of Indian Point are given in Table 9-1. These data were taken from the U.S.G.S. Water Resources Data for New York, Part 2, Water Quality Record for the period October 1959 to February 1969. The source indicates that data collected through September 1966 was taken once daily on the east bank of the Hudson at Charles Point on Lent's Cove. From October 1966 to February 1969 the data was collected near the west bank of the river on the streamward side of the Hudson River Reserve Fleet Administration Barge at Jones Point. The data record for October 1966 to February 1969 list both a maximum and minimum temperature for each day. In the analysis of the data for this latter period, only the daily maxima were considered.

It is likely that these temperatures do not exactly correspond to temperatures which can be expected at the Indian Point intakes. For example, the data for 1959-1966 were recorded on Lent's Cove, where insolation and thermal discharges may lead to higher water temperatures than that of the river water at the plant's intakes. Furthermore, in collecting their data the USGS were not specifically preparing for thermal surveys. This is reflected in the accuracy of their measurements. USGS data were measured to the nearest $^{\circ}F$ with a thermometer (1959-1966) or a thermister (after 1966).

Table 9-1

Hudson River Water Temperature (^{o}F) in the Vicinity of Indian Point
(U.S.G.S. 1959-1969)

	Date	Minimum	Maximum	Mean
January	1	32.0	42.0	35.7
	2	32.0	42.0	35.7
	3	33.0	42.0	35.7
	4	32.0	41.0	35.1
	5	32.0	41.0	34.9
	6	32.0	41.0	34.9
	7	32.0	41.0	34.9
	8	32.0	41.0	34.7
	9	32.0	41.0	34.1
	10	32.0	41.0	34.1
	11	32.0	41.0	34.3
	12	32.0	41.0	34.3
	13	32.0	40.0	33.9
	14	32.0	40.0	33.7
	15	32.0	40.0	33.6
	16	32.0	40.0	33.6
	17	32.0	40.0	33.7
	18	32.0	40.0	33.6
	19	32.0	40.0	33.4
	20	32.0	39.0	33.7
	21	32.0	39.0	33.3
	22	32.0	39.0	33.5
	23	32.0	40.0	33.4
	24	32.0	40.0	33.4
	25	32.0	40.0	33.5
	26	32.0	40.0	33.3
	27	32.0	40.0	33.4
	28	32.0	40.0	33.4
	29	32.0	39.0	33.3
	30	32.0	39.0	33.1
	31	32.0	38.0	33.6

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
February	1	32.0	38.0	33.2
	2	32.0	38.0	33.2
	3	32.0	37.0	33.3
	4	32.0	37.0	32.9
	5	32.0	38.0	33.0
	6	32.0	37.0	33.1
	7	32.0	38.0	33.2
	8	32.0	38.0	33.5
	9	32.0	37.0	33.1
	10	32.0	38.0	33.3
	11	32.0	38.0	33.4
	12	32.0	37.0	33.3
	13	32.0	37.0	33.3
	14	32.0	37.0	33.3
	15	32.0	38.0	33.3
	16	32.0	38.0	33.5
	17	32.0	37.0	33.4
	18	32.0	37.0	33.1
	19	32.0	38.0	33.2
	20	32.0	37.0	33.0
	21	32.0	38.0	33.5
	22	32.0	38.0	33.5
	23	32.0	38.0	33.5
	24	32.0	38.0	33.2
	25	32.0	37.0	32.9
	26	32.0	37.0	33.0
	27	32.0	37.0	33.2
	28	32.0	37.0	33.0
	29	33.0	34.0	33.3

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
March	1	32.0	37.0	33.2
	2	32.0	37.0	33.2
	3	32.0	37.0	33.3
	4	32.0	37.0	33.9
	5	32.0	37.0	33.7
	6	32.0	37.0	33.7
	7	32.0	37.0	33.9
	8	32.0	37.0	34.1
	9	32.0	37.0	33.9
	10	32.0	37.0	34.0
	11	32.0	37.0	34.2
	12	32.0	38.0	33.8
	13	32.0	38.0	34.0
	14	32.0	38.0	33.8
	15	32.0	37.0	33.6
	16	32.0	38.0	34.3
	17	32.0	37.0	34.3
	18	32.0	38.0	34.5
	19	33.0	38.0	35.0
	20	33.0	36.0	34.9
	21	33.0	37.0	35.1
	22	33.0	37.0	35.3
	23	34.0	38.0	35.6
	24	34.0	38.0	35.6
	25	34.0	39.0	36.0
	26	35.0	38.0	36.3
	27	35.0	39.0	36.7
	28	35.0	41.0	37.6
	29	35.0	41.0	38.3
	30	36.0	43.0	39.1
	31	36.0	43.0	39.2

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
April	1	37.0	44.0	40.1
	2	37.0	43.0	39.9
	3	37.0	45.0	40.6
	4	37.0	43.0	40.3
	5	38.0	43.0	40.6
	6	39.0	45.0	41.4
	7	40.0	45.0	41.8
	8	39.0	45.0	41.9
	9	39.0	45.0	42.0
	10	39.0	45.0	42.3
	11	39.0	46.0	42.9
	12	41.0	45.0	42.8
	13	41.0	46.0	43.1
	14	42.0	45.0	43.3
	15	42.0	46.0	43.8
	16	42.0	50.0	44.6
	17	43.0	46.0	44.8
	18	44.0	46.0	44.8
	19	44.0	46.0	45.4
	20	44.0	47.0	45.9
	21	45.0	48.0	46.1
	22	45.0	48.0	46.4
	23	46.0	48.0	46.9
	24	46.0	48.0	47.1
	25	46.0	50.0	47.8
	26	47.0	55.0	49.4
	27	47.0	55.0	49.6
	28	47.0	55.0	49.9
	29	47.0	57.0	50.6
	30	47.0	57.0	51.1

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
May	1	48.0	57.0	51.4
	2	48.0	57.0	52.2
	3	48.0	59.0	52.2
	4	50.0	59.0	52.9
	5	50.0	59.0	53.2
	6	51.0	59.0	53.4
	7	51.0	59.0	54.1
	8	52.0	59.0	54.6
	9	52.0	59.0	54.7
	10	52.0	59.0	55.2
	11	52.0	61.0	55.4
	12	52.0	61.0	55.7
	13	52.0	61.0	55.9
	14	52.0	63.0	56.4
	15	52.0	63.0	56.6
	16	54.0	59.0	56.5
	17	53.0	59.0	56.8
	18	53.0	63.0	58.1
	19	54.0	63.0	58.4
	20	54.0	63.0	58.9
	21	55.0	63.0	59.1
	22	56.0	63.0	59.7
	23	54.0	63.0	59.7
	24	56.0	63.0	60.3
	25	57.0	65.0	61.1
	26	58.0	65.0	61.7
	27	58.0	65.0	61.9
	28	58.0	65.0	62.0
	29	58.0	65.0	61.8
	30	59.0	67.0	62.6
	31	59.0	66.0	62.6

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
June	1	60.0	67.0	63.1
	2	61.0	67.0	63.7
	3	59.0	68.0	63.7
	4	59.0	68.0	64.0
	5	60.0	67.0	64.4
	6	62.0	68.0	64.7
	7	63.0	68.0	65.3
	8	64.0	68.0	65.9
	9	65.0	69.0	66.4
	10	65.0	70.0	67.0
	11	65.0	70.0	67.5
	12	66.0	71.0	67.8
	13	66.0	70.0	68.0
	14	66.0	70.0	68.4
	15	66.0	71.0	68.8
	16	66.0	71.0	68.8
	17	67.0	72.0	68.9
	18	67.0	71.0	69.0
	19	67.0	70.0	68.9
	20	68.0	71.0	69.1
	21	69.0	71.0	69.6
	22	69.0	72.0	70.4
	23	69.0	72.0	70.5
	24	69.0	73.0	71.1
	25	70.0	73.0	71.3
	26	70.0	73.0	71.2
	27	70.0	73.0	71.2
	28	70.0	76.0	72.3
	29	70.0	76.0	72.8
	30	70.0	78.0	73.3

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
July	1	71.0	79.0	74.4
	2	72.0	75.0	74.1
	3	72.0	76.0	74.3
	4	72.0	76.0	74.1
	5	72.0	76.0	74.0
	6	72.0	76.0	73.6
	7	72.0	77.0	74.0
	8	73.0	76.0	74.4
	9	73.0	76.0	74.5
	10	74.0	77.0	75.1
	11	73.0	78.0	75.1
	12	74.0	79.0	75.6
	13	74.0	79.0	75.8
	14	74.0	80.0	75.8
	15	74.0	81.0	75.8
	16	74.0	81.0	76.0
	17	73.0	80.0	76.0
	18	73.0	80.0	76.3
	19	74.0	80.0	76.4
	20	74.0	80.0	76.5
	21	74.0	79.0	76.8
	22	75.0	79.0	76.9
	23	75.0	79.0	77.0
	24	73.0	79.0	77.1
	25	75.0	80.0	77.4
	26	74.0	80.0	77.2
	27	74.0	81.0	77.7
	28	74.0	79.0	77.2
	29	74.0	81.0	77.4
	30	73.0	80.0	77.3
	31	74.0	81.0	77.7

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
August	1	75.0	81.0	77.8
	2	75.0	81.0	78.0
	3	75.0	81.0	78.0
	4	75.0	81.0	77.8
	5	75.0	81.0	77.8
	6	74.0	81.0	77.4
	7	75.0	81.0	77.4
	8	75.0	81.0	77.4
	9	75.0	81.0	77.5
	10	76.0	81.0	77.5
	11	74.0	80.0	77.3
	12	74.0	80.0	77.3
	13	74.0	79.0	76.9
	14	74.0	80.0	77.0
	15	74.0	80.0	76.8
	16	74.0	80.0	76.5
	17	74.0	80.0	76.4
	18	74.0	80.0	76.4
	19	73.0	80.0	76.3
	20	74.0	80.0	76.8
	21	74.0	81.0	76.5
	22	74.0	81.0	76.9
	23	74.0	80.0	76.8
	24	74.0	79.0	76.3
	25	75.0	79.0	76.7
	26	75.0	79.0	76.6
	27	74.0	79.0	76.2
	28	74.0	78.0	76.3
	29	74.0	79.0	76.4
	30	74.0	78.0	76.0
	31	74.0	78.0	76.1

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
September	1	74.0	78.0	76.0
	2	74.0	78.0	75.9
	3	74.0	78.0	75.9
	4	74.0	78.0	75.9
	5	74.0	79.0	75.5
	6	73.0	79.0	75.2
	7	72.0	79.0	74.8
	8	73.0	79.0	74.8
	9	72.0	78.0	74.5
	10	72.0	78.0	74.8
	11	71.0	79.0	74.8
	12	71.0	79.0	74.5
	13	72.0	79.0	74.3
	14	71.0	79.0	73.8
	15	70.0	80.0	73.5
	16	70.0	79.0	73.1
	17	70.0	78.0	72.8
	18	70.0	76.0	72.1
	19	70.0	76.0	72.4
	20	69.0	76.0	71.9
	21	69.0	76.0	71.6
	22	69.0	74.0	70.9
	23	68.0	75.0	71.1
	24	67.0	73.0	70.4
	25	66.0	75.0	70.5
	26	66.0	75.0	70.3
	27	66.0	75.0	69.6
	28	66.0	75.0	69.9
	29	66.0	74.0	69.3
	30	64.0	73.0	68.7

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
October	1	64.0	73.0	69.3
	2	64.0	73.0	68.9
	3	64.0	73.0	68.7
	4	63.0	72.0	67.9
	5	63.0	72.0	67.7
	6	60.0	72.0	66.6
	7	62.0	71.0	66.6
	8	61.0	71.0	66.3
	9	62.0	71.0	66.1
	10	62.0	71.0	65.9
	11	62.0	71.0	65.7
	12	61.0	71.0	65.5
	13	61.0	70.0	65.2
	14	61.0	70.0	65.0
	15	61.0	68.0	64.7
	16	60.0	68.0	64.6
	17	60.0	68.0	64.6
	18	59.0	68.0	64.4
	19	59.0	67.0	63.6
	20	59.0	66.0	63.3
	21	59.0	66.0	62.9
	22	58.0	64.0	62.2
	23	59.0	64.0	62.2
	24	57.0	64.0	61.6
	25	58.0	64.0	61.4
	26	58.0	64.0	60.9
	27	58.0	64.0	60.8
	28	57.0	63.0	60.5
	29	57.0	63.0	60.0
	30	57.0	61.0	59.4
	31	57.0	61.0	59.2

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
November	1	57.0	61.0	58.7
	2	56.0	61.0	58.3
	3	56.0	59.0	57.7
	4	55.0	59.0	57.2
	5	54.0	59.0	57.0
	6	54.0	59.0	56.9
	7	54.0	59.0	56.1
	8	53.0	58.0	55.6
	9	52.0	57.0	55.1
	10	52.0	58.0	54.9
	11	52.0	58.0	54.4
	12	52.0	57.0	54.2
	13	52.0	57.0	54.2
	14	52.0	56.0	54.0
	15	52.0	56.0	53.7
	16	51.0	56.0	52.9
	17	51.0	56.0	52.8
	18	50.0	56.0	52.1
	19	48.0	55.0	51.5
	20	48.0	54.0	50.7
	21	46.0	54.0	50.2
	22	46.0	54.0	50.0
	23	46.0	54.0	49.9
	24	46.0	54.0	49.6
	25	46.0	53.0	49.3
	26	45.0	52.0	48.7
	27	45.0	52.0	48.3
	28	45.0	52.0	48.0
	29	45.0	52.0	47.7
	30	43.0	52.0	47.0

Table 9-1 (Continued)

	Date	Minimum	Maximum	Mean
December	1	43.0	51.0	46.6
	2	42.0	51.0	46.3
	3	40.0	50.0	45.7
	4	40.0	50.0	45.4
	5	40.0	48.0	45.2
	6	40.0	48.0	45.0
	7	40.0	48.0	44.7
	8	40.0	48.0	44.1
	9	39.0	47.0	43.3
	10	39.0	47.0	43.4
	11	39.0	47.0	42.8
	12	37.0	47.0	41.9
	13	37.0	47.0	41.8
	14	37.0	47.0	41.1
	15	36.0	47.0	41.0
	16	36.0	47.0	40.5
	17	35.0	47.0	40.1
	18	35.0	47.0	39.5
	19	35.0	46.0	39.5
	20	35.0	46.0	39.2
	21	34.0	46.0	38.8
	22	34.0	46.0	38.2
	23	34.0	45.0	37.8
	24	35.0	45.0	37.9
	25	34.0	44.0	37.3
	26	34.0	43.0	36.9
	27	34.0	42.0	36.7
	28	33.0	42.0	36.5
	29	33.0	42.0	36.3
	30	32.0	42.0	36.0
	31	32.0	42.0	36.0

Question 10. Provide analysis of the relationship between the water temperatures in the Indian Point vicinity and salt-intrusion length (or lower Hudson River freshwater flow). Report the time of year for the conditions above to apply.

Response: Data and discussions of water temperature in the Indian Point vicinity and salt intrusion length in 1972 are available in the Indian Point First Annual Report (April, 1973). Similar data and discussions for 1973 will be available in the Indian Point Second Annual Report (scheduled for June, 1974).

Question 11. Provide 1972-1973 information relating to: (a) standing crop estimates of eggs, larvae and juvenile striped bass, white perch, and shad; and (b) size and age composition of spawning stock of striped bass, white perch and shad. Provide gear efficiency correction for the collection of data for the standing crop estimates.

Response:

a. Standing crop estimates for 1973 of eggs, larvae and juvenile striped bass, white perch, and shad will be available in Volume IV of the 1973 Hudson River Fisheries Data Summary Report (scheduled for June, 1974). Preliminary estimates of juvenile white perch and striped bass populations in 1972 can be found in the Indian Point First Annual Report and Second Semi-Annual Report. No estimate has been made of 1972 shad populations.

b. The size and age composition of spawning stock of striped bass, white perch, and shad in 1973 will be discussed in the Indian Point Second Annual Report (scheduled for June, 1974) and Volume IV of the Hudson River Fisheries Data Summary Report (scheduled for June, 1974). Gear efficiency will also be discussed; however, correction factors for the standing crop estimates will not be estimated directly.

Similar Data for 1972 is limited. All such data which is presently available for 1972 can be found in the Indian Point First Annual Report (April 1973). Longitudinal data for 1972 is presently lacking although some such data will be available from other studies on the River.

Question 12

Provide the reasoning why there is not more overlap in the epibenthic-sled and Tucker-trawl stations during the sampling process. Supply information as to the importance of simultaneous sampling at the bottom and at a second point in the water column. Select which data were not obtained by simultaneous sampling at the bottom and at one or more points in the water column.

Response:

With the boats and equipment available it was not physically possible to sample simultaneously from one boat with both the Tucker Trawl and Epibenthic Sled. Therefore such simultaneous sampling was not performed during the transect and riverlong surveys. Instead, samples were collected randomly within each strata of the water column for the length of the estuary (RM, i.e. river mile 10-152). This stratified random sampling technique was chosen because it is especially suited for use in the striped bass entrainment models developed by both QLM and the AEC. These models estimate population densities by stratified random techniques - i.e. the river is divided longitudinally into segments and segment average concentrations are calculated from random samples collected in each strata. Thus the stratified random sampling techniques used in collecting the 1973 data is ideal for this type of use, and simultaneous sampling at the bottom (Epibenthic Sled) and a second point in the water column (Tucker Trawl) is not necessary. For reasons mentioned above, none of the transect or river survey samples were collected simultaneously at two points in the water column.

Question 13. Supply the water quality data obtained for Transect 2 (June 28-29, 1973), pp. IIC-5 through IIC-7. Justify the reasons why no water quality data, particularly temperature, were collected for Transect 1 (May 21-22, 1973), pp. IIC-2 through IIC-4. Explain the reasons why water quality data were not collected right at the beginning of the ichthyoplankton survey study. Present a description of plans to carry out further data reduction and data analysis of the transect data.

Response: Water quality data is available for Transect 2. This data is presented on page IIC-7 of the October, 1973 Fisheries Data Summary Report. Due to late delivery by our supplier, water quality equipment was not available for use either in the early riverwide ichthyoplankton collections or when Transect 1 was sampled in May. However, water temperature was measured for transect 1 and was 13°C. Also, salinity in the Cornwall area was known to be zero when this transect was sampled.

Transect data will be analysed in detail to determine variation in the distribution of ichthyoplankton with tides, night and day, east and west side of river and depth using analysis of variance techniques. Species and life stages will be considered. Comparisons of the species composition and size frequency by these factors will also be examined. Length-frequency data and data on other species besides striped bass will be available.

Question 14.

With respect to Figure 2, p. IA-7, what criteria were used in setting up the Tucker trawl stations? In particular, explain why so many surface trawls relative to subsurface trawls were taken.

Response:

This figure describes the five lateral transects at Cornwall. Each transect has a bottom sample and a number of mid-water and surface samples depending upon the depth. This is a standard scientific procedure used to determine egg and larval distribution with depth, and does not reflect any excessive surface and mid-depth sampling, as opposed to bottom sampling.

Question 15. Explain the extent of so large a variability (eg., 1 vs. 1500 M^3) in the volume values reported on pp. II A-3 to II A-27. Provide information as to efforts taken to standardize towing speed and time during collection of the samples.

Response: Towing speeds were standardized at 1 m/sec with sled and 1.5 m/sec with Tucker Trawl. Towing times for both gear were standardized at 2 minutes in high concentrations of eggs and larvae and 5 minutes in other cases. Variability in the measurement of volume sampled arises from two sources:

1) The first of the three nets on the epibenthic sled at times remained open too long because the release bar was not properly dropping. This yields greater than average volumes of water sampled for the first net and less than average volumes of water sampled for the subsequent nets.

2) Difficulties were sometimes encountered with the flowmeters in the nets which resulted in either no measurement or a questionable measurement. In these cases a value of 1 was recorded for the volume sampled.

Question 16. On page II A-3, yolk sac larvae (3.1 to 6.2 mm) were found starting the week of April 30. However, striped bass were not found in the beach seines until the last week of June (p. II A-8) (mean length 16 mm and 23 mm). Was this seven to eight week period in between the April and June weeks longer than expected?

Response: This question suggests a misapplication of the data. In analyzing the data one should be careful not to interpret this to mean the typical growth rate from yolk sac (3-6 mm) to early juvenile stages (16-23 mm) is seven to eight weeks. Reasons for this are: (1) early juveniles (16 to 23 mm) were captured as early as mid-May and more commonly by mid-June in ichthyoplankton gear, (2) yolk-sac larvae were not common until mid-May and thus the probability of capturing juveniles in late June who were yolk-sac larvae before mid-May is remote, and (3) earlier spawned striped bass larvae have a lower growth rate and probably higher mortality than later spawned individuals due to the lower river water temperature during the early part of the larvae season.

Question 17 Describe any plans to extrapolate the beach seine results to depths 3 feet and distances offshore to 100 fee. Include the depths, distances and the reasoning for the extrapolations used on the beach seine results.

Response: The longitudinal river survey is being expanded in 1974 to add extensive sampling of shoal areas with the epibenthic sled.

Question 18. Provide any distinction made between beach areas, shoal areas, and deep water areas in collection of the data reported. Present adequate data to estimate relative abundance of the various stages of striped bass larvae in these three areas.

Response: Shore (beach) areas are defined as the immediate shoreline beach zone sampled by beach seines.

Shoal areas are defined as the extension of shore zone to channel, not including flats which have a mean low tide depth of less than one foot. An arbitrary maximum cutoff point of 20 ft has generally been used. By this definition, very little shoal area exists above river mile 70.

Deepwater areas are defined as the main channel of the river either natural or dredged. An arbitrary standard of water greater than 20 ft has generally been used.

Data which can be used to estimate relative abundance in these areas are provided in the reports:

"1973 Hudson River Program - Fisheries Data Summary"

Volume I	- May-July,	1973	(October, 1973)
Volume II	- July-Nov.,	1973	(December, 1973)
Volume III	- March-July,	1973	(March, 1974*)
Volume IV	- March-Dec.,	1973	(June, 1974*)

*Scheduled Date

Question 19. State criteria used in selecting the primary and alternative transects for conducting the ichthyoplankton survey. State the reasons for carrying out a second transect four weeks after the first transect and for not using the same transect both times.

Response: These transects are the licensed sites for the Cornwall plant intakes. The second transect is located at the alternate licensed site and was added later in the program.

Question 20: In "general indication" No. 1, on p. I-2, it is stated that transport rates of striped bass eggs and larvae are not as great as previously estimated.

a. Provide the decrease in the new estimate of net downstream transport of striped bass eggs and larvae from the previous estimate.

b. Describe any differences in the estimates of the net downstream transport rate for the surface, 1/2 depth and bottom of the river.

c. Provide information as to the size of the larvae found in the revised estimate of transport rates.

Response: a) As noted in general indication 1 of the report "1973 Hudson River Program, Fisheries Data Summary, May-July," transport rates of striped bass eggs and larvae are not as great as previously estimated. Eggs and yolk-sac larvae were found to concentrate in "holes" at the bottom in the deeper sections of the river where they are less subject to downstream transport by the general water currents than if they were more evenly distributed throughout the water column, as had been previously assumed. These concentrations are probably maintained in the "holes" by local currents and eddies strong enough to keep the eggs and larvae suspended off the river bottom, but not strong enough to sweep them downriver. Also, striped bass larvae appear to be migrating to the beaches (rather than being transported downstream) at about 13 mm rather than 25 mm or more as had been previously assumed. This combination of factors reduces both the numbers and exposure times of striped bass eggs and larvae to downstream transport, thus reducing the net downstream transport. The 1973 data, a copy of which has been provided to the AEC, is presently being analyzed by Texas Instruments and Quirk, Lawler and Matusky Engineers. Results of T.I.'s analyses will be available in the report "Fisheries Survey of the Hudson River, March-December, 1973, Volume IV" (scheduled for publication in June, 1974). Results of QLM's analysis in the form of output from their Striped Bass model, will be available at approximately the same time. Results of both of these analyses will be provided to the AEC upon publication.

b) Because the QLM Striped Bass Model, with which Con Edison will estimate plant impact, is one dimensional (river length), Con Edison's consultant's are estimating overall transport rates from river segment to river segment, rather than distinct transport rates for the surface, 1/2 depth, and bottom strata of each segment. The data is of a form, through, that such stratified analysis may be attempted. Con Edison has supplied copies of the data to the AEC.

c) As mentioned in response a above, eggs and yolk-sac larvae have little transport because they concentrate in the deep holes, and older larvae avoid transport by migrating to the shoals. Because of these factors, downstream transport is probably restricted to larvae mostly in the size range 6-13mm. More exact information on the size of transported larvae will be available in the T.I. report "Fisheries Survey of the Hudson River, March-December, 1973, Volume IV", scheduled for publication in June, 1974.

Question 21.

In "general indication" No. 2, p. I-2, it is stated that the striped bass eggs and larvae concentrate near the river bottom:

a. In what sense is this finding that the eggs and larvae concentrate near the river bottom to be a new finding?

b. Describe plans for further data reduction and data analysis of the ichthyoplankton data.

Response:

a) Although the fact that striped bass eggs and larvae seem to concentrate at the bottom has already been demonstrated by past studies, these studies did not provide data for the strata 1-4 feet above the bottom as does the epibenthic sled used in the present study. It is the epibenthic sled findings which show much higher concentrations of eggs and larvae in this lower strata than had been previously assumed which are "new".

b) Further data reduction and analysis will include the following which will be available in Volumes II, III, and IV of the Fisheries Survey of the Hudson River 1973.

Data Reduction:

1. Length-frequency data for ichthyoplankton samples by species.
2. Further ichthyoplankton data summaries will be available for other species besides the striped bass.

Data Analysis:

1. Absolute abundance of eggs and larvae will be estimated based on catch-per-unit volume and river volume.

2. Relative abundance of juveniles based on catch-per-effort weighted as to area of habitat available within river segments will be estimated.

Question 22: In "general indication" No. 3, yolk sac larvae were found to be extended into the extreme lower estuary.

a. Describe the geographic extent of the "extreme lower estuary".

b. Provide the significance of this finding with respect to:

   i. striped bass life cycle and behavior in the Hudson River.

   ii. modification of entrainment models

c. What fraction of the eggs and yolk sac larvae were found below the salt front? Compare these results with those reported in the Carlson-McCann study.

d. Provide information on the comparison of fresh water flow during May-July for 1973 with the flows for 1967 and 1968.

Response:

a) "Extreme lower estuary" means below the Tappan Zee Bridge.

b) i. It means that 1) some spawning must occur in lower estuary where exposure to Indian Point does not occur and 2) the nursery area probably extends below Tappan Zee.

   ii. Allowance should be made in the entrainment models for spawning and development in the lower estuary.

c) Examination of 1973 catch data shows that striped bass eggs were collected as far downriver as mile point 28 and yolk-sac larvae as far as mile point 16. This data is presently being analyzed to determine what fraction of the total eggs and larvae were located below the salt front (which changed rapidly over several river miles during the spawning season). Results of this analysis will be included in the T.I. report "Fisheries Survey of the Hudson River, March–December, 1973, Volume IV", scheduled for publication in June, 1974. A copy of this report will be provided to the AEC upon publication.

The Carlson-McCann Study found that "The spawning of striped bass in the Hudson River was restricted to fresh or slightly brackish water. With two exceptions, striped bass eggs were not collected in salinities greater than 0.3%, and most were collected where salinity measured less than 0.1%.*" Carlson-McCann found striped bass eggs and larvae as far downriver as Croton (mile point 35.5). Because they collected no samples below Croton, there is no data from their study to show if eggs and larvae did actually extend further downriver.

In its 1974 ichthyoplankton survey, Con Edison plans to increase sampling effort in the lower estuary (i.e. down to river mile 10) in order to more accurately define the relationship between the salt front and the distribution of eggs and larvae.

d. Mean, minimum, and maximum freshwater flow data for May-July of 1967, 1968, and 1973, measured at Green Island, New York are given in the attached Table 22-1. Complete listings of daily freshwater flow at Green Island for these and other years are given in "Water Resources Data for New York, Part I, Surface Water Records, U.S. Dept of Interior, Geological Survey".

*Carlson, F. T. and McCann, J. A. "Hudson River Fisheries Investigations 1965–1968, Evaluation of a Proposed Pumped Storage Project at Cornwall, New York in relation to Fish in the Hudson River", Hudson River Policy Committee.

Table 22-1

Hudson River Freshwater Flow data for 1967, 1968, and 1973 from USGS Station, Green Island, New York

Month		Flow (cfs) 1967	1968	1973
May	High	29,200	32,800	62,400
	Mean	17,060	18,490	27,542
	Low	9,700	10,400	11,400
June	High	10,000	46,000	22,600
	Mean	6,197	15,710	13,433
	Low	4,280	5,980	7,290
July	High	8,190	29,800	48,800
	Mean	5,075	9,795	10,200
	Low	2,840	3,800	2,680

Question 23. Describe how the straight lines drawn connecting successive data points in the figures presented in Section II-B should be interpreted.

Response: The straight lines were drawn for visual convenience. We believe they help depict the longitudinal distribution of eggs and larvae. Segment average points incorporating more data points are used in later volumes. The validity of either technique depends on the use made of the data and the actual distribution pattern in the river. More explanation of the sampled distributions will be made in future reports.

Question 24

From the data presented, compare the distribution of white perch eggs and larvae to the distribution of striped bass eggs and larvae.

Response:

A detailed discussion of the distribution of both striped bass and white perch eggs and larvae will be given in the "Texas Instruments Report "Fisheries Survey of the Hudson River, March-July, 1973, Volume III" scheduled for publication in April, 1974. A copy of this report will be provided to the AEC upon publication.

Question 25. Describe any problems in distinguishing between striped bass larvae and white perch larvae. Present the criteria used in the distinction of the two types of post sac larvae at each of the following standard lengths of 7, 9, 11, 13, 15, 17 + millimeters.

Response: Striped bass and white perch from 8-14 mm are difficult to distinguish. In order to distinguish between them we drew upon 1) all of the available literature, 2) reference collections of each species, and 3) the personal experience of our investigators, which we believe to be second to none. A detailed description of techniques and problems in identification prepared jointly by all groups involved on the Hudson, is scheduled for publication in April, 1974.

Question 26. Provide data sheets for the period July to December 1972 and for 1973 comparable to those in the "Hudson River Ecology Study," First Semi-Annual Report Vol I, Appendix D by Texas Instruments.

Response: A copy of the requested data sheets is being sent to the AEC under separate cover.

Question 27. Provide, if possible, actual data for each year for 1962-1973 and predicted estimates for 1974-1981 at each unit at Indian Point, Lovett, Danskammer, Bowline, Roseton and Cornwall power plants for:

a. Average intake flow in cfs.
b. Average heat discharge to the river in Btu/hr.
c. Total amount of sodium hypochlorite or other chlorinating agents used during each month, in pounds as Cl_2.

Response: a. Con Edison does not have data on average intake flow for the Lovett, Danskammer, Bowline and Roseton plants. Reference is made to Table III-1 of the AEC Staff's Final Environmental Statement for Indian Point Unit No. 2 for information on the rated intake flows for the subject power plants other than Indian Point and Cornwall. Data on the Indian Point plants are set forth below. The Indian Point flow rates are the rated capacity of the circulating and service water system, adjusted by 60% recirculation during 6 months of every year since 1971. They have not been adjusted for capacity factors.

With respect to the Cornwall plant, it is not clear what is meant by "average" intake flow since Cornwall will operate in a pumping mode for only a few hours every day. We have computed the estimated average intake since Cornwall will operate in a pumping mode for only a few hours every day. We have computed the estimated average intake flow by looking at the projected schedule for a typical summer week in 1980, a copy of which is annexed. We have computed an average intake flow of approximately 3,000 cfs as follows: The pumping rate for each hour of each day was determined from the graph and the result divided by 24. These daily averages for the week were then added and divided by 7 to produce an average pumping rate (intake flow) for the week. Although there will be changes throughout the year, the annexed schedule is generally representative of pumping rates for the summers of 1980 and 1981.

ANNUAL AVERAGE INTAKE FLOW (CFS)

Year	I.P. Unit 1	I.P. Unit 2	I.P. Unit 3
1962-70	709	---	---
1971-72	567	---	---
1973	O/S	1550	---
1974	567	1550	---
1975-81	567	1550	1550

b. The average heat discharged to the river from the Indian Point plants and (for 1972 and 1973 only) for Bowline No. 1 are presented below. These have been computed for past years by multiplying the maximum heat discharged by the plant capacity factor. For predicted values an 80% plant capacity factor was assumed.

Con Edison does not have the information on average heat discharged to the river from the Lovett, Danskammer, Bowline and Roseton plants except as indicated below. Reference is made to Table III-1 of the AEC Staff's Final Environmental Statement for Indian Point Unit No. 2 for information on the thermal discharges at rated capacity of these plants.

Cor wall will not discharge any measurable heat.

UTILIZATION OF THE CORNWALL PUMPED-STORAGE POWER PLANT
DURING A TYPICAL SUMMER WEEK IN 1980

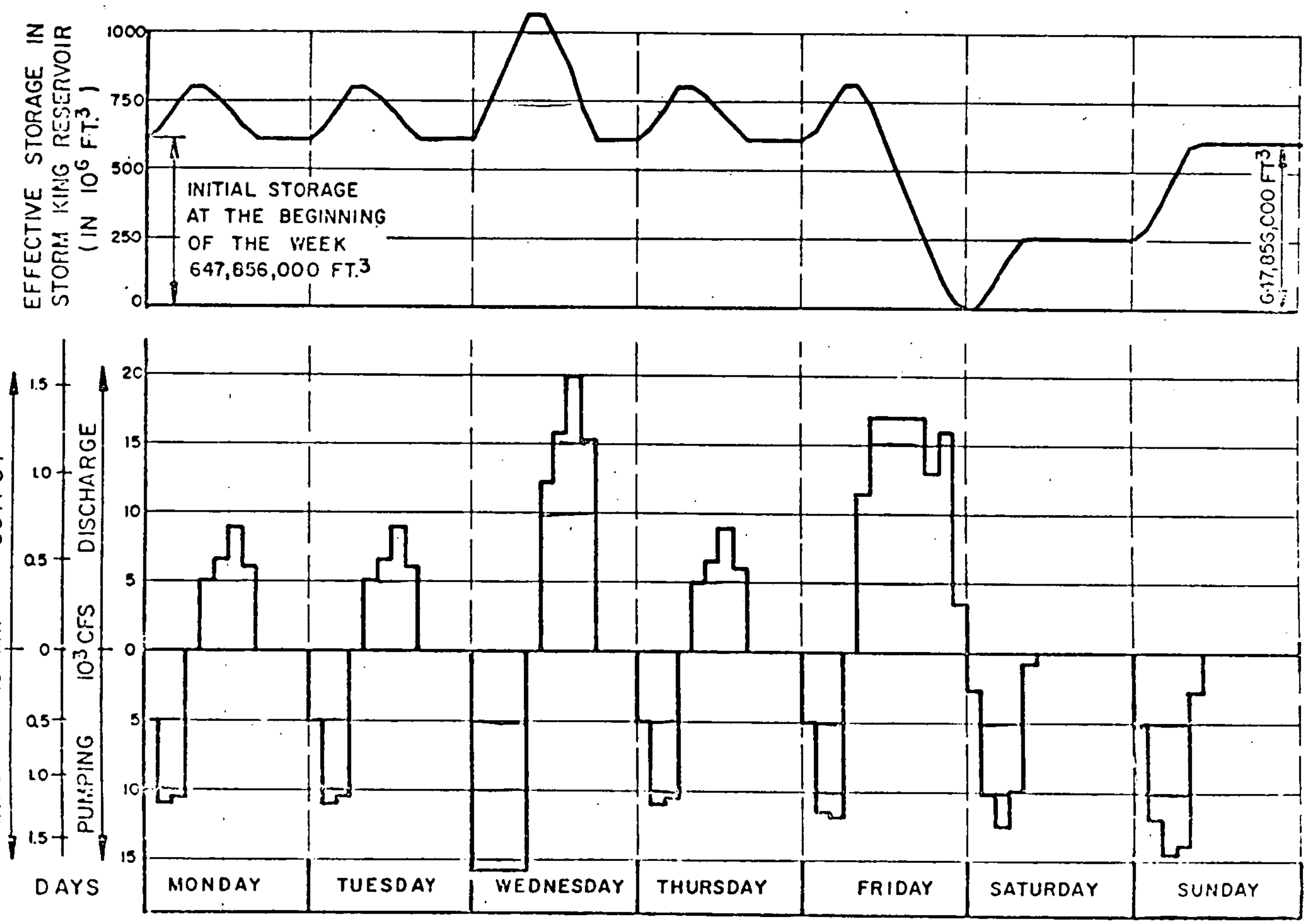

FIGURE 27-1

AVERAGE HEAT DISCHARGE TO THE RIVER (Btu/hr. x 10^9)

Year	I.P. Unit #1	I.P. Unit #2*	I.P. Unit #3	Bowline #1**
1962	.53	---	---	
1963	.73	---	---	
1964	.47	---	---	
1965	.88	---	---	
1966	.96	---	---	
1967	1.34	---	---	
1968	1.24	---	---	
1969	1.38	---	---	
1970	0.27	---	---	
1971	1.01	---	---	
1972	0.93	---	---	1.87
1973	0	1.51	---	1.55
1974	1.34	5.08	---	
1975	.38	5.08	5.56	
1976	0	5.08	5.56	
1977	0.67	5.08	5.56	
1978-81	1.34	5.08	5.56	

Note: Maximum heat discharge (Btu/hr. x 10^9) Indian Point Unit #1 = 1.915; #2 = 6.350; #3 = 6.950

*Unit firm - August 1973
**Unit firm - September 1972

c. The "cooling water data" sheets annexed hereto (October 1966–January 1974) provide actual data on sodium hypochlorite used at Indian Point. Such data for Indian Point prior to October 1966 was not retained and for the other power plants are not in Con Edison's possession. Estimates of future chlorine usage at Indian Point can be predicted from the "Plan of Action" submitted to the AEC Staff on January 1, 1974. In summary this plan initially calls for a reduction in chlorine usage of one-fourth as a test procedure. Results of this test will determine future chlorine usage. Further predictions of future chlorine usage are therefore not possible at this time.

B. Non-Biological Impacts

1. Provide information as to your plans for decomissioning Indian Point Unit No. 1. Identify which structures and facilities will be removed and those retained. Describe any action that will be taken to clear the site area where Unit No. 1 facilities are located. Identify any licensable quantities of radioactive materials that would be stored on site, the term of such storage, and arrangements for custodial care. Estimate the cost of decomissioning on the basis of the present economy. If decisions on these measures have not yet been made, provide information for each alternative that you believe to be practicable.

Response:

Following the completion of operation, Applicant will permanently shut down the facility. The precise nature of the shutdown process is difficult to determine at present, in view of the likelihood of regulatory and technological changes in the coming years. However, the process will probably involve removal of all spent fuel from the facility and shipment offsite; decontamination of the facility through appropriate chemical cleaning and flushing; treatment and disposal of any contaminated water; disposal of resins, filters and miscellaneous radioactive materials; sealing of the containment and adjustments to alarm systems in anticipation of post-shutdown security monitoring; and completion of a final post-shutdown radiation check. During these procedures, security forces at the facility will be maintained at a level to assure proper control. Applicant does not expect that any licensable quantities of radioactive materials would be stored on-site. There are at present no plans to remove any Indian Point Unit No. 1 structures or facilities. Since the Indian Point site is committed to nuclear power generation by the presence of Units 2 and 3, in addition to Unit No. 1, there would be little purpose to clearing the site in connection with decommissioning Unit No. 1. In addition, certain features of the Unit No. 1 facility, as for example, the Health Physics Monitoring Area, are shared with Unit No. 2.

In accordance with the provisions of 10CFR50.82, at such time as Applicant would file for the termination of the facility license in connection with decommissioning Unit No. 1, the Commission will be provided with all necessary information to provide reasonable assurance that decommissioning will be performed so as not to be inimical to the common defense and security or to the health and safety of the public.

Applicant estimates that decommissioning of the facility will require nine months to complete, and will cost approximately $3,000,000 in 1974 dollars, based on 1974 technology.

Following the shutdown process outlined above, Applicant will conduct a security and radiological monitoring program. This will involve a round-the-clock guard to insure against intruders. An alarm system, telephone communications, locked doors and windows, a lighting system, and a perimeter fence will be maintained for this purpose. In addition, regular monitoring of radioactivity in the vicinity of the facility will be performed.

Applicant estimates the annual cost of such a program, in 1974 dollars and using 1974 technology, to be approximately $300,000.

ATTACHMENT 1

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

January , 19 74

COOLING WATER DATA

ate	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %					
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm		Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	-	-	-	-	-	32.2		33.0	-	162.20
	-	-	-	-	-	32.2		33.2	-	111.40
	-	-	-	-	-	32.2		33.5	-	118.60
	-	-	-	-	-	32.5		33.5	-	107.50
	-	-	-	-	-	32.0		33.6	-	104.20
	-	-	-	-	-	32.0		33.7	-	102.50
	-	-	-	-	-	32.0	0.7	34.0	-	103.50
	-	-	-	-	-	32.2		33.6	-	126.50
	-	-	-	-	-	32.0		33.5	-	105.50
10	-	-	-	-	-	31.9		33.5	-	102.50
11	-	-	-	-	-	31.9		33.7	-	102.50
12	-	-	-	-	-	31.7		33.7	-	102.50
13	-	-	-	-	-	31.5		33.4	-	102.50
14	-	-	-	-	-	31.3		33.2	-	103.60
15	-	-	-	-	-	31.5		33.2	-	134.90
16	-	-	-	-	-	31.8	0.7	40.5	-	179.50
17	-	-	-	-	-	31.7		33.2	-	230.00
18	-	-	-	-	-	31.0		38.1	-	240.40
19	-	-	-	-	-	31.2		35.6	-	268.50
20	-	-	-	-	-	31.8		45.0	-	216.20
21	-	-	-	-	-	32.1		48.0	-	196.30
22	-	-	-	-	-	32.4		49.5	-	258.50
23	-	-	-	-	-	32.2		41.3	-	251.50
24	-	-	-	-	-	32.0	0.8	40.5	-	280.80
25	-	-	-	-	-	31.9		40.5	-	473.70
26	-	-	-	-	-	31.8		46.1	-	682.30
27	-	-	-	-	-	32.1		50.2	-	601.90
28	-	-	-	-	-	32.1		45.5	-	452.40
29	-	-	-	-	-	32.1		36.5	-	378.80
30	-	-	-	-	-	32.4		34.1	-	281.90
31	-	-	-	-	-	32.5		33.6	-	331.90

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

December, 19 73

COOLING WATER DATA

te	NaOCl used in Chlorination: UNIT # 1 Gals.	UNIT # 1 Feed Rate gpm	UNIT # 2 Gals.	UNIT # 2 Feed Rate gpm	Conc. %	River: Temp. F	River: Demand	Discharge Canal Effluent: Temp. F	Residual F	Residual T	Daily Average Flow Rate M gpm
	-	-	-	-	-	48.0		49.0	-	-	212.5
	-	-	-	-	-	47.0		48.0	-	-	210.3
	-	-	-	-	-	47.3	1.0	48.0	-	-	212.5
	-	-	-	-	-	47.5		48.0	-	-	212.5
	-	-	-	-	-	47.9		48.0	-	-	212.5
	-	-	-	-	-	48.0		48.5	-	-	212.5
	-	-	-	-	-	46.5		47.2	-	-	212.5
	-	-	-	-	-	46.0		46.5	-	-	212.5
	-	-	-	-	-	46.0		46.5	-	-	231.3
0	-	-	-	-	-	45.9	0.7	46.1	-	-	200.6
1	-	-	-	-	-	45.0		45.1	-	-	227.4
2	-	-	-	-	-	43.6		44.0	-	-	213.4
3	-	-	-	-	-	43.3		43.5	-	-	196.5
4	-	-	-	-	-	42.5		43.0	-	-	196.5
5	-	-	-	-	-	41.5		42.3	-	-	196.5
6	-	-	-	-	-	39.8		41.0	-	-	157.3
7	-	-	-	-	-	37.0		38.0	-	-	102.5
8	-	-	-	-	-	36.5		37.5	-	-	102.5
9	-	-	-	-	-	36.0	0.6	37.3	-	-	54.8
0	-	-	-	-	-	36.3		37.5	-	-	144.7
1	-	-	-	-	-	36.9		38.0	-	-	174.3
2	-	-	-	-	-	35.2		37.0	-	-	100.2
3	-	-	-	-	-	35.0		36.5	-	-	92.0
4	-	-	-	-	-	34.2		35.0	-	-	92.0
5	-	-	-	-	-	32.7		33.5	-	-	112.5
6	-	-	-	-	-	32.9	0.6	33.6	-	-	117.5
7	-	-	-	-	-	32.4		33.5	-	-	101.8
8	-	-	-	-	-	32.3		33.3	-	-	106.0
9	-	-	-	-	-	32.0		33.3	-	-	191.6
30	-	-	-	-	-	32.0		33.3	-	-	153.6
31	-	-	-	-	-	32.4		33.0	-	-	196.5

F = Free, T = Total residual chlorine.

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

November, 19 73

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual*		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
1						59.8		60.0			142.0
2						59.0	1.1	59.5			118.9
3						58.2		59.2			137.0
4						57.0		58.6			142.0
5						56.3		57.2			177.8
6						55.4		56.0			239.0
7						55.2		55.5			221.0
8						54.5		55.0			221.0
9						54.0	1.0	54.6			221.0
10						53.5		52.5			221.0
11						52.5		51.5			268.0
12						52.0		51.0			415.7
13			300	6	9.7	52.0	1.6	51.0	0.3	0.3	457.1
14						52.0		51.7			131.7
15						52.0		51.5			125.0
16						52.0		51.6			140.4
17						51.0		52.0			204.3
18						50.4		51.8			207.5
19						50.4		51.1			207.5
20						50.3		51.0			207.5
21						50.0	1.0	50.8			207.5
22						50.0		50.0			200.6
23						49.9		50.4			201.0
24						49.9		50.3			196.2
25						49.7		50.0			218.0
26						49.6	1.6	50.0			202.5
27						50.0		50.0			186.4
28						50.0		50.3			202.4
29						49.0		50.4			197.5
30						49.0		49.7			212.5
31											

* F and T is free and total residual chlorine

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

October, 19 73

COOLING WATER DATA

ite	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
	---	---				70		75			450.0
	---	---	300	5.0	11.4	70	0.7	71	<.1	<.1	597.0
	---	---				71		79			765.7
	---	---				70		83			534.0
	---	---				70		71			534.0
	---	---				70		80			534.0
	--	---				69		71			579.1
	---	---				69		76			534.0
	---	---				69		80			641.9
0	---	---				69		79			706.0
1	---	---				68		70			534.0
2	---	---				69		83			534.0
3	---	---				68		71			534.0
4	---	---				67		68			534.0
5	---	---				67		67			534.0
6	---	---				66		67			579.2
7	---	---				66		66			600.5
8	--	---				65		65			456.0
9	---	---				64		64			397.6
20	---	---				64		64			112.7
21	---	---				63		65			58.0
22	---	---				63		65			58.0
23	---	---				63		63			361.9
24	---	---				62		62			473.8
25	---	---				62		63			314.1
26	---	---				62		62			346.5
27	---	---				62		62			394.0
28	---	---				61		61			445.7
29	---	---				60		60			394.0
30	---	---				60		60			354.7
31	---	---				60		60			227.3

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

September, 1973

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. °F	Demand	Temp. °F	* Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
1	-	-	-	-		80		92			543.0
2	-	-	-	-		81		92			549.2
3	-	-	-	-		81		93			543.0
4	-	-	-	-		82		93			543.0
5	-	-	-	-		82		93			543.0
6	-	-	175	2.9	3.5	81	1.8	93	<.1	<.1	543.0
7	-	-	-	-		81		89			543.0
8	-	-	-	-		80		80			403.6
9	-	-	-	-		79		79			310.0
10	-	-	-	-		78		78			306.7
11	-	-	-	-		78		78			389.0
12	-	-	-	-		78		78			281.2
13	-	-	-	-		77		78			53.0
14	-	-	-	-		77		78			53.0
15	-	-	-	-		77		78			55.4
16	-	-	-	-		76		76			74.8
17	-	-	-	-		76		77			56.4
18	-	-	-	-		76		76			189.7
19	-	-	-	-		74		76			348.7
20	-	-	280	4.7	2.9	73	1.8	75	<.1	<.1	529.0
21	-	-	-	-		73		79			511.2
22	-	-	-	-		72		87			487.9
23	-	-	-	-		72		82			555.4
24	-	-	-	-		72		82			529.0
25	-	-	-	-		72		80			568.7
26	-	-	-	-		72		78			474.5
27	-	-	305	5.0	14.4	72	1.9	79	<.1	<.1	450.0
28	-	-	-	-		72		79			450.0
29	-	-	-	-		72		77			326.5
30	-	-	-	-		71		71			359.6
31	-	-	-	-							

* Residual chloride is reported as Free (F) and total (T) ppm chlorine

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

August, 1973

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
	–	–	–	–	–	79	–	79	–	–	548
	–	–	–	–	–	79	–	79	–	–	473
	–	–	–	–	–	79	–	79	–	–	491
	–	–	–	–	–	79	–	91	–	–	557
	–	–	–	–	–	79	–	91	–	–	594
	–	–	–	–	–	79	–	91	–	–	562
	–	–	–	–	–	80	–	92	–	–	640
	–	–	–	–	–	80	–	88	–	–	685
	–	–	–	–	–	80	–	93	–	–	562
10	–	–	–	–	–	81	–	92	–	–	562
11	–	–	–	–	–	82	–	83	–	–	419
12	–	–	–	–	–	82	–	93	–	–	454
13	–	–	–	–	–	81	–	88	–	–	562
14	–	–	–	–	–	81	–	92	–	–	562
15	–	–	–	–	–	81	–	89	–	–	562
16	–	–	–	–	–	81	–	91	–	–	562
17	–	–	–	–	–	82	–	90	–	–	562
18	–	–	–	–	–	81	–	92	–	–	562
19	–	–	–	–	–	81	–	91	–	–	581
20	–	–	–	–	–	81	–	91	–	–	562
21	–	–	–	–	–	80	–	89	–	–	643
22	–	–	–	–	–	80	–	92	–	–	626
23	–	–	240	4.0	2.9	80	1.4	91	0.1	0.1	501
24	–	–	–	–	–	80	–	91	–	–	558
25	–	–	–	–	–	80	–	80	–	–	508
26	–	–	–	–	–	79	–	85	–	–	581
27	–	–	–	–	–	80	–	91	–	–	553
28	–	–	–	–	–	80	–	91	–	–	549
29	–	–	225	3.75	2.9	80	1.3	91	0.1	0.1	543
30	–	–	–	–	–	81	–	92	–	–	543
31	–	–	–	–	–	81	–	92	–	–	543

Residual Chloride is reported as Free and Total (ppm Chlorine)

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

July, 1973

COOLING WATER DATA

NaOCl used in Chlorination					River		Discharge Canal Effluent			
UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	* Residual		Daily Average Flow Rate M gpm
Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
–	–	–	–	–	74	–	74	–	–	490
–	–	–	–	–	75	–	77	–	–	483
–	–	–	–	–	76	–	76	–	–	422
–	–	–	–	–	76	–	76	–	–	567
–	–	–	–	–	76	–	76	–	–	310
–	–	–	–	–	76	–	76	–	–	305
–	–	–	–	–	76	–	76	–	–	305
–	–	–	–	–	76	–	77	–	–	138
–	–	–	–	–	77	–	77	–	–	224
–	–	–	–	–	78	–	85	–	–	566
–	–	–	–	–	78	–	79	–	–	443
–	–	–	–	–	78	–	86	–	–	562
–	–	–	–	–	78	–	84	–	–	560
–	–	–	–	–	78	–	78	–	–	562
–	–	250	5.6	5.7	78	1.0	78	<0.1	<0.1	562
–	–	–	–	–	77	–	86	–	–	562
–	–	–	–	–	77	–	83	–	–	642
–	–	–	–	–	78	–	78	–	–	670
–	–	–	–	–	78	–	83	–	–	563
–	–	–	–	–	78	–	86	–	–	562
–	–	–	–	–	78	–	80	–	–	562
–	–	–	–	–	78	–	79	–	–	562
–	–	–	–	–	78	–	79	–	–	562
–	–	–	–	–	78	–	78	–	–	582
–	–	–	–	–	78	–	80	–	–	433
–	–	–	–	–	79	–	81	–	–	532
–	–	–	–	–	78	–	88	–	–	562
–	–	–	–	–	78	–	78	–	–	562
–	–	–	–	–	79	–	79	–	–	527
–	–	–	–	–	79	–	79	–	–	473
–	–	–	–	–	79	–	79	–	–	544

* Residual Chlorine is reported as Free and Total (ppm Chlorine)

.olidated Edison Co. of N.Y., Inc.

Indian Point Station

June , 1973

COOLING WATER DATA

.e	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
	–	–	–	–	–	59	–	59	–	565
	–	–	–	–	–	60	–	60	–	565
	–	–	–	–	–	60	–	60	–	565
	–	–	–	–	–	60	–	60	–	565
	–	–	–	–	–	61	–	61	–	473
	–	–	–	–	–	62	–	62	–	473
	–	–	–	–	–	62	–	62	–	489
	–	–	–	–	–	62	–	62	–	468
	–	–	–	–	–	62	–	62	–	557
	–	–	–	–	–	62	–	62	–	557
	–	–	–	–	–	63	–	63	–	554
	–	–	–	–	–	65	–	65	–	196
	–	–	–	–	–	66	–	66	–	279
	–	–	–	–	–	67	–	67	–	221
	–	–	–	–	–	68	–	68	–	221
	–	–	–	–	–	68	–	68	–	221
	–	–	–	–	–	70	–	70	–	221
	–	–	–	–	–	69	–	69	–	221
	–	–	–	–	–	69	–	69	–	221
	–	–	–	–	–	70	–	70	–	301
	–	–	–	–	–	71	–	71	–	221
	–	–	–	–	–	71	–	71	–	178
	–	–	–	–	–	71	–	71	–	221
	–	–	–	–	–	72	–	72	–	221
	–	–	–	–	–	72	–	72	–	280
	–	–	–	–	–	72	–	74	–	634
	–	–	–	–	–	72	–	75	–	557
	–	–	–	–	–	73	–	80	–	489
	–	–	–	–	–	73	–	77	–	365
	–	–	–	–	–	73	–	73	–	523

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

May, 19 73

COOLING WATER DATA

e	NaOCl used in Chlorination: UNIT # 1 Gals.	UNIT # 1 Feed Rate gpm	UNIT # 2 Gals.	UNIT # 2 Feed Rate gpm	Conc. %	River Temp. F	River Demand	Discharge Canal Effluent Temp. F	Residual F	Residual T	Daily Average Flow Rate M gpm
	-	-	-	-	-	53	-	53	-	-	310
	-	-	-	-	-	53	-	54	-	-	224
	-	-	-	-	-	54	-	54	-	-	142
	-	-	-	-	-	55	-	55	-	-	132
	-	-	-	-	-	55	-	55	-	-	71
	-	-	-	-	-	55	-	55	-	-	114
	-	-	-	-	-	56	-	56	-	-	209
	-	-	-	-	-	56	-	56	-	-	339
	-	-	-	-	-	57	-	57	-	-	230
	-	-	-	-	-	58	-	58	-	-	192
	-	-	-	-	-	58	-	58	-	-	262
	-	-	-	-	-	58	-	58	-	-	262
	-	-	-	-	-	59	-	59	-	-	262
	-	-	-	-	-	59	-	59	-	-	262
	-	-	-	-	-	60	-	60	-	-	262
	-	-	-	-	-	60	-	60	-	-	202
	-	-	-	-	-	60	-	60	-	-	267
	-	-	-	-	-	60	-	60	-	-	342
	-	-	-	-	-	60	-	60	-	-	372
	-	-	-	-	-	60	-	61	-	-	308
	-	-	-	-	-	60	-	61	-	-	313
	-	-	-	-	-	59	-	59	-	-	318
	-	-	-	-	-	58	-	59	-	-	213
	-	-	-	-	-	60	-	60	-	-	260
	-	-	-	-	-	59	-	59	-	-	303
	-	-	-	-	-	59	-	59	-	-	303
	-	-	-	-	-	59	-	59	-	-	303
	-	-	-	-	-	58	-	58	-	-	481
	-	-	-	-	-	60	-	60	-	-	481
	160	2.7	-	-	6.5	60	0.4	60	0.1	0.2	481
	-	-	-	-	-	60	-	60	-	-	481

Residual Chlorine is reported as Free and Total (ppm Chlorine)

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

April , 19 73

COOLING WATER DATA

NaOCl used in Chlorination					River		Discharge Canal Effluent		
UNIT # 1		UNIT # 2							
Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
–	–	–	–	–	43	–	43	–	333
–	–	–	–	–	42	–	42	–	403
–	–	–	–	–	42	–	43	–	442
–	–	–	–	–	42	–	42	–	392
–	–	–	–	–	44	–	44	–	219
–	–	–	–	–	45	–	45	–	102
	–	–	–	–	46	–	47	–	225
–	–	–	–	–	46	–	46	–	225
–	–	–	–	–	47	–	47	–	225
–	–	–	–	–	47	–	47	–	303
–	–	–	–	–	46	–	46	–	395
–	–	–	–	–	46	–	46	–	361
–	–	–	–	–	46	–	46	–	361
–	–	–	–	–	45	–	45	–	181
–	–	–	–	–	46	–	47	–	147
–	–	–	–	–	44	–	45	–	202
–	–	–	–	–	44	–	44	–	184
–	–	–	–	–	46	–	46	–	87
–	–	–	–	–	48	–	48	–	84
–	–	–	–	–	49	–	49	–	141
–	–	–	–	–	49	–	49	–	137
–	–	–	–	–	49	–	49	–	87
–	–	–	–	–	50	–	50	–	53
–	–	–	–	–	48	–	48	–	227
–	–	–	–	–	47	–	47	–	448
–	–	–	–	–	49	–	49	–	607
–	–	–	–	–	51	–	51	–	327
–	–	–	–	–	52	–	52	–	179
–	–	–	–	–	52	–	52	–	142
–	–	–	–	–	52	–	52	–	232

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

March, 1973

COOLING WATER DATA

NaOCl used in Chlorination					River		Discharge Canal Effluent		
UNIT # 1		UNIT # 2		Conc.					
Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	%	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
--	---	---	---	--	34	---	34	---	323
--	---	---	---	--	34	---	35	---	323
---	---	---	---	--	34	---	34	---	323
---	---	---	---	--	34	---	34	---	323
---	---	---	---	--	34	---	35	---	259
---	---	---	---	--	34	---	34	---	210
---	---	---	---	--	34	---	34	---	328
---	---	---	---	--	34	---	34	---	292
---	---	---	---	--	35	---	35	---	124
---	---	---	---	--	36	---	36	---	323
---	---	---	---	--	37	---	37	---	323
---	---	---	---	--	38	---	38	---	308
---	---	---	---	--	39	---	39	---	320
---	---	---	---	--	38	---	38	---	323
---	---	---	---	--	38	---	38	---	401
---	---	---	---	--	39	---	39	---	372
---	---	---	---	--	40	---	40	---	332
---	---	---	---	--	40	---	40	---	334
---	---	---	---	--	41	---	41	---	404
---	---	---	---	--	41	---	41	---	738
---	---	---	---	--	40	---	41	---	894
---	---	---	---	--	41	---	41	---	823
---	---	---	---	--	41	---	41	---	616
---	---	---	---	--	41	---	41	---	456
---	---	---	---	--	42	---	42	---	331
---	---	---	---	--	42	---	42	---	235
---	---	---	---	--	42	---	42	---	336
---	---	---	---	--	43	---	43	---	176
---	---	---	---	--	43	---	43	---	220
---	---	---	---	--	42	---	42	---	338
---	---	---	---	--	43	---	43	---	338

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

February, 19 73

COOLING WATER DATA

	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc.					
ce	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	%	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	-	-	-	-	-	33	-	34	-	91
	-	-	-	-	-	34	-	36	-	43
	-	-	-	-	-	34	-	35	-	43
	-	-	-	-	-	35	-	36	-	43
	-	-	-	-	-	35	-	37	-	43
	-	-	-	-	-	34	-	36	-	43
	-	-	-	-	-	34	-	36	-	43
	-	-	-	-	-	33	-	34	-	77
	-	-	-	-	-	33	-	34	-	74
	-	-	-	-	-	33	-	34	-	43
	-	-	-	-	-	32	-	34	-	43
		-	-	-	-	32	-	35	-	43
	-	-	-	-	-	32	-	33	-	81
	-	-	-	-	-	32	-	34	-	211
	-	-	-	-	-	32	-	33	-	123
	-	-	-	-	-	32	-	33	-	211
	-	-	-	-	-	32	-	33	-	211
	-	-	-	-	-	32	-	33	-	211
	-	-	-	-	-	33	-	33	-	211
	-	-	-	-	-	33	-	34	-	113
	-	-	-	-	-	33	-	35	-	43
2	-	-	-	-	-	33	-	33	-	194
3	-	-	-	-	-	33	-	33	-	231
4	-	-	-	-	-	33	-	35	-	43
5	-	-	-	-	-	34	-	36	-	43
6	-	-	-	-	-	34	-	35	-	127
7	-	-	-	-	-	34	-	35	-	186
8	-	-	-	-	-	34	-	35	-	129
9										
0										
1										

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

January, 19 73

COOLING WATER DATA

ce	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1 Gals.	UNIT # 1 Feed Rate gpm	UNIT # 2 Gals.	UNIT # 2 Feed Rate gpm	Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	–	–	–	–	–	34	–	34	–	102
	–	–	–	–	–	34	–	34	–	99
	–	–	–	–	–	34	–	35	–	99
	–	–	–	–	–	34	–	35	–	99
	–	–	–	–	–	34	–	34	–	98
	–	–	–	–	–	34	–	34	–	99
	–	–	–	–	–	33	–	34	–	99
	–	–	–	–	–	33	–	34	–	74
	–	–	–	–	–	33	–	35	–	27
	–	–	–	–	–	34	–	35	–	27
	–	–	–	–	–	34	–	35	–	27
	–	–	–	–	–	34	–	34	–	27
	–	–	–	–	–	34	–	35	–	27
	–	–	–	–	–	33	–	34	–	27
	–	–	–	–	–	33	–	33	–	27
	–	–	–	–	–	34	–	34	–	27
	–	–	–	–	–	34	–	34	–	27
	–	–	–	–	–	35	–	35	–	27
	–	–	–	–	–	34	–	35	–	43
	–	–	–	–	–	34	–	35	–	43
	–	–	–	–	–	35	–	35	–	43
2	–	–	–	–	–	35	–	35	–	43
3	–	–	–	–	–	34	–	35	–	43
	–	–	–	–	–	33	–	34	–	43
5	–	–	–	–	–	33	–	33	–	43
	–	–	–	–	–	32	–	33	–	43
	–	–	–	–	–	32	–	33	–	43
	–	–	–	–	–	32	–	33	–	43
9	–	–	–	–	–	32	–	33	–	91
	–	–	–	–	–	32	–	32	–	102
1	–	–	–	–	–	32	–	32	–	211

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

December, 1972

COOLING WATER DATA

te	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc.				* Residual		Daily Average Flow Rate
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	%	Temp. F	Demand	Temp. F	F	T	M gpm
	-	-	-	-	-	38	-	64	-	-	187
	-	-	-	-	-	38	-	64	-	-	187
	-	-	-	-	-	38	-	64	-	-	187
	-	-	-	-	-	40	-	66	-	-	187
	75	1.3	-	-	15.0	39	0.6	54	<0.1	0.1	182
		-	-	-	-	40	-	55	-	-	171
	-	-	-	-	-	41	-	64	-	-	180
	-	-	-	-	-	37	-	63	-	-	200
	-	-	-	-	-	37	-	61	-	-	200
]	-	-	-	-	-	36	-	61	-	-	200
1	-	-	-	-	-	37	-	62	-	-	200
2	50	0.8	-	-	14.8	36	0.6	61	<0.1	<0.1	200
3	-	-	-	-	-	36	-	46	-	-	179
4	-	-	-	-	-	36	-	36	-	-	140
5	-	-	-	-	-	35	-	35	-	-	115
6	-	-	-	-	-	34	-	34	-	-	115
7		-	-	-	-	33	-	33	-	-	115
8	-	-	-	-	-	32	-	32	-	-	169
9	75	1.3	-	-	14.5	33	0.6	33	<0.1	<0.1	171
0	-	-	-	-	-	34	-	54	-	-	171
1	-	-	-	-	-	34	-	56	-	-	171
2	-	-	-	-	-	35	-	56	-	-	171
3	-	-	-	-	-	35	-	57	-	-	171
4	-	-	-	-	-	34	-	56	-	-	171
5	-	-	-	-	-	34	-	56	-	-	171
6	50	0.8	-	-	14.2	35	0.6	54	<0.1	<0.1	171
7	-	-	-	-	-	34	-	54	-	-	171
8	-	-	-	-	-	33	-	54	-	-	171
9	-	-	-	-	-	32	-	46	-	-	171
0	-	-	-	-	-	33	-	34	-	-	171
1	-	-	-	-	-	34	-	34	-	-	171

Residual Chlorine is reported as Free and Total (ppm Chlorine)

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

November , 19 72

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual*		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
						46		61			226
						46		61			226
	100	2.0	-	-	15.9	46	0.8	60	0.2	0.2	220
						45		46			176
						46		46			176
						47		47			173
						48		48			5
						49		49			149
						50		50			159
0						51		51			187
1						51		51			187
2						50		50			187
3						49		61			187
4	50	0.8	-	-	15.5	48	0.8	60	0.1	0.1	187
5						47		59			187
6						46		59			187
7						46		65			187
8						46		64			150
9						45		63			162
0						45		65			187
1	50	0.8	-	-	15.3	44	0.8	65	0.1	0.1	192
2						44		66			187
3						44		66			187
4						43		65			187
5						43		65			187
6						43		66			187
7						41		64			187
8	75	1.3	-	-	15.1	40	0.9	63	0.1	0.1	187
9						40		63			187
0						39		62			187
1						38		61			187

* Residual Chlorine is reported as Free and Total [redacted]

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

OCTOBER, 19 72

COOLING WATER DATA

ce	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	* Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
						65		71			491
						64		70			491
	200	3.5			11.8	64	0.9	70	<0.1	<0.1	470
						64		71			450
						65		72			428
	0	3.25			11.6	65	0.8	73	<0.1	<0.1	340
						64		69			391
						65		70			352
						63		68			393
)	150	2.0			11.3	60	0.8	69	<0.1	<0.1	392
-						59		71			293
:						58		69			293
:	125	2.25			11.1	57	0.7	68	<0.1	<0.1	293
-						56		67			293
5						55		66			293
6						53		64			293
7	50	3.0			10.8	52	0.8	63	<0.1	<0.1	293
8						53		64			293
9						52		63			293
0	150	2.5			10.6	51	0.8	62	0.1	0.15	293
1						51		62			293
2						50		60			312
3						49		58			324
4	150	2.5			10.3	49	0.8	55	<0.1	0.1	293
5						49		59			293
6						49		58			314
7	150	2.5			10.1	48	0.7	55	<0.1	0.1	242
8						47		55			226
9						47		55			226
0						47		55			226
1	200	3.25			9.9	47	0.7	55	0.1	0.15	226

* Residual Chlorine is reported as Free and Total [redacted]

September , 19 72

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	* Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
	--	--	--	--	--	75	--	81	--	--	622
	--	--	--	--	--	75	--	82	--	--	560
	--	--	--	--	--	73	--	80	--	--	560
	--	--	--	--	--	73	--	80	--	--	560
	150	2.5	--	--	13.7	72	0.9	80	<0.1	<0.1	474
	--	--	--	--	--	72	--	80	--	--	478
	--	--	--	--	--	73	--	79	--	--	560
	--	--	--	--	--	72	--	76	--	--	503
	--	--	--	--	--	74	--	80	--	--	420
10	--	--	--	--	--	74	--	80	--	--	420
11	--	--	--	---	--	71	--	76	--	--	435
12	150	2.3	--	--	13.3	72	0.8	80	0.15	0.15	457
13	--	--	--	--	--	70	--	78	--	--	256
14	--	--	--	--	--	70	--	82	--	--	315
15	150	2.3	--	--	13.1	68	0.9	76	<0.1	<0.1	526
16	--	--	--	--	--	70	--	76	--	--	595
17	--	--	--	--	--	69	--	76	--	--	595
18	--	--	--	--	--	69	--	76	--	--	595
19	200	3.1	--	--	12.8	73	0.9	79	<0.1	<0.1	494
20	--	--	--	--	--	68	--	75	--	--	277
21	--	--	--	--	--	70	--	74	--	--	605
22	100	2.9	--	--	12.7	69	0.9	74	<0.1	<0.1	517
23	--	--	--	--	--	70	--	70	--	--	465
24	--	--	--	--	--	70	--	70	--	--	465
25	--	--	--	--	--	74	--	78	--	--	460
26	100	2.9	--	--	12.3	74	0.9	80	0.15	0.15	373
27	--	--	--	--	--	75	--	80	--	--	423
28	--	--	--	--	--	71	--	72	--	--	544
29	200	3.1			12.0	66	0.8	71	<0.1	<0.1	600
30	--	--	--	--	--	65	--	71	--	--	600
31											

*Residual Chlorine is reported as free and total (ppm Cl_2)

Consolidated Edison Co. of N.Y., Inc. | Indian Point Station

AUGUST , 1972

COOLING WATER DATA

ate	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	* Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
1	200	3.3	--	--	7.7	78	0.7	90	<0.1	<0.1	325
2	--	--	--	--	--	78	--	90			325
3	225	3.8	--	--	7.7	79	0.7	91	0.1	0.1	325
4	--	--	--	--	--	79	--	90			325
5	--	--	--	--	--	78	--	90			325
6	--	--	--	--	--	77	--	89			325
7	--	--	--	--	--	77	--	87			325
8	225	3.8	--	--	7.6	77	0.7	86	<0.1	<0.1	325
9	--	--	--	--	--	77	--	88			325
10	225	3.8	--	--	7.5	76	0.7	86	<0.1	<0.1	325
11	--	--	--	--	--	77	--	89			325
12	--	--	--	--	--	77	--	89			325
13	--	--	--	--	--	77	--	89			335
14	--	--	--	--	--	77	--	89			335
15	225	3.8	--	--	7.5	78	0.7	89	<0.1	<0.1	330
16	--	--	--	--	--	77	--	88			330
17	225	3.8	--	--	7.5	76	0.8	88	0.1	0.1	330
18	--	--	--	--	--	76	--	83			577
19	--	--	--	--	--	76	--	81			577
20	--	--	--	--	--	76	--	82			577
21	--	--	--	--	--	76	--	84			493
22	180	3.0	--	--	14.5	77	0.8	85	0.1	0.2	471
23	--	--	--	--	--	77	--	85			471
24	175	2.9	--	--	14.4	77	0.9	85	<0.1	0.1	498
25	--	--	--	--	--	76	--	84			498
26	--	--	--	--	--	76	--	81			325
27	--	--	--	--	--	76	--	77			532
28	--	--	--	--	--	76	---	80			577
29	175	2.9	--	--	14.1	76	0.8	82	<0.1	<0.1	577
30	--	--	--	--	--	77	--	84			577
31	100	3.0	--	--	14.1	77	0.8	84	<0.1	<0.1	577

*Residual Chlorine will be reported as free and total [redacted]

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

July, 1972

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	* Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
1	--	--	--	--	--	69	--	69	--	--	399.5
2	--	--	--	--	--	69	--	70	--	--	399.5
3	--	--	--	--	--	70	--	70	--	--	399.5
4	--	--	--	--	--	69	--	70	--	--	399.5
5	--	--	--	--	--	69	--	70	--	--	170.5
6	125	1.8	--	--	10.3	69	0.7	69	0.1	0.25	343.5
7	--	--	--	--	--	70	--	70	--	--	343.5
8	--	--	--	--	--	70	--	70	--	--	343.5
9	--	--	--	--	--	71	--	71	--	--	343.5
10	--	--	--	--	--	71	--	71	--	--	343.5
11	100	1.7	--	--	10.1	71	0.7	71	0.1	0.2	175.5
12	--	--	--	--	--	70	--	71	--	--	175.5
13	100	1.7	--	--	9.8	70	0.7	72	<0.1	0.1	325.5
14	--	--	--	--	--	72	--	78	--	--	325.5
15	--	--	--	--	--	73	--	73	--	--	330.5
16	--	--	--	--	--	74	--	78	--	--	330.5
17	--	--	--	--	--	74	--	84	--	--	330.5
18	100	1.7	--	--	9.1	75	0.8	86	<0.1	0.1	330.5
19	--	--	--	--	--	75	--	86	--	--	330.5
20	150	1.9	--	--	8.8	75	0.8	84	<0.1	0.1	280.5
21	--	--	--	--	--	76	--	81	--	--	280.5
22	--	--	--	--	--	76	--	87	--	--	330.5
23	--	--	--	--	--	77	--	88	--	--	330.5
24	--	--	--	--	--	77	--	88	--	--	330.5
25	200	3.3	--	--	8.0	77	0.8	88	0.1	0.15	330.5
26	--	--	--	--	--	77	--	88	--	--	330.5
27	200	2.5	--	--	7.8	77	0.8	88	0.1	0.1	330.5
28	--	--	--	--	--	77	--	88	--	--	330.5
29	--	--	--	--	--	77	--	86	--	--	280.5
30	--	--	--	--	--	78	--	89	--	--	330.5
31	--	--	--	--	--	78	--	89	--	--	330.5

* Residual Chlorine reported as free and total ([redacted]).

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

June, 1972

COOLING WATER DATA

e	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	* Residual		Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm					F	T	
1	—	—	—	—	—	63	—	69	—	—	180.5
2	200	2.5	—	—	5.7	63	0.7	73	0.1	0.15	325.5
3	—	—	—	—	—	64	—	76	—	—	325.5
4	—	—	—	—	—	65	—	76	—	—	325.5
5	200	2.5	—	—	5.6	66	0.7	78	<0.1	0.1	325.5
6	200	2.5	—	—	5.6	67	0.7	79	0.15	0.2	325.5
7	—	—	—	—	—	67	—	80	—	—	325.5
8	200	2.5	—	—	5.5	68	0.7	81	0.1	0.15	325.5
9	—	—	—	—	—	67	—	80	—	—	325.5
10	—	—	—	—		68	—	81	—	—	325.5
11	—	—	—	—	—	68	—	80	—	—	325.5
12	—	—	—	—	—	68	—	80	—	—	325.5
13	200	3.3	—	—	5.3	68	0.7	80	0.1	0.15	325.5
14	—	—	—	—	—	67	—	80	—	—	325.5
15	100	1.25	—	—	13.0	67	0.7	80	<0.1	0.1	325.5
16	—	—	—	—	—	67	—	75	—	—	549.5
17	—	—	—	—	—	66	—	77	—	—	399.5
18	—	—	—	—	—	66	—	67	—	—	399.5
19	—	—	—	—	—	66	—	67	—	—	399.5
20	100	2.2	—	—	12.5	67	0.7	67	<0.1	<0.1	311.5
21	—	—	—	—	—	68	—	68	—	—	343.5
22	70	1.5	—	—	12.3	69	0.7	69	<0.1	<0.1	343.5
23	—	—	—	—	—	69	—	69	—	—	343.5
24	—	—	—	—	—	69	—	70	—	—	443.5
25	—	—	—	—	—	68	—	69	—	—	353.5
26	—	—	—	—	—	68		68	—	—	343.5
27	150	2 5	—	—	11.7	68	0.7	68	<0.1	<0.1	509.5
28	—	—	—	—	—	68		68	—	—	509.5
29	175	2.2	—	—	11.5	69	0.7	69	0.1	0.1	559.5
30	—	—	—	—	—	69	—	69	—	—	459.5
31	—	—	—	—	—	—	—	—	—	—	—

* Residual Chlorine - will be reported as free and total ( )

May , 19 72

COOLING WATER DATA

ate	NaOCl used in Chlorination					River		Discharge Canal Effluent			
	UNIT # 1		UNIT # 2		Conc.				* Residual		Daily Average
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	%	Temp. F	Demand	Temp. F	F	T	Flow Rate M gpm
	-	-	-	-	-	48	-	61	-	-	185.5
	-	-	-	-	-	48	-	61	-	-	190.5
	-	-	-	-	-	49	-	62	-	-	190.5
	-	-	-	-	-	48	-	62	-	-	190.5
	-	-	-	-	-	48	-	62	-	-	185.5
	-	-	-	-	-	49	-	62	-	-	185.5
	-	-	-	-	-	49	-	62	-	-	180.5
	-	-	-	-	-	50	-	63	-	-	175.5
	-	-	-	-	-	49	-	63	-	-	180.5
	-	-	-	-	-	50	-	63	-	-	180.5
	-	-	-	-	-	50	-	63	-	-	180.5
	-	-	-	-	-	51	-	64	-	-	180.5
	-	-	-	-	-	51	-	66	-	-	155.5
	-	-	-	-	-	52	-	65	-	-	180.5
	-	-	-	-	-	52	-	65	-	-	180.5
	-	-	-	-	-	53	-	66	-	-	180.5
	-	-	-	-	-	53	-	66	-	-	180.5
	-	-	-	-	-	54	-	67	-	-	180.5
	-	-	-	-	-	54	-	66	-	-	180.5
	-	-	-	-	-	55	-	68	-	-	180.5
	-	-	-	-	-	55	-	68	-	-	180.5
	-	-	-	-	-	56	-	69	-	-	180.5
	-	-	-	-	-	57	-	70	-	-	180.5
	160	2.0	-	-	5.8	58	0.8	70	0.1	0.3	180.5
	-	-	-	-	-	59	-	68	-	-	280.5
	-	-	-	-	-	59	-	67	-	-	330.5
	-	-	-	-	-	61	-	68	-	-	330.5
	-	-	-	-	-	62	-	69	-	-	330.5
	-	-	-	-	-	63	-	70	-	-	330.5
	150	1.5	-	-	5.8	63	0.8	70	0.15	0.15	330.5
	-	-	-	-	-	64	-	70	-	-	330.5

*Residual Chlorine - will be reported as free and total onsolidated Edison Co. of N.Y., Inc.

Indian Point Station

April, 19 72

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	-	-	-	-	-	38	-	38	-	185.5
2	-	-	-	-	-	39	-	39	-	185.5
3	-	-	-	-	-	39	-	39	-	185.5
4	-	-	-	-	-	39	-	40	-	185.5
5	-	-	-	-	-	39	-	40	-	185.5
6	-	-	-	-	-	39	-	39	-	185.5
7	-	-	-	-	-	40	-	40	-	185.5
8	-	-	-	-	-	39	-	40	-	185.5
9	-	-	-	-	-	40	-	40	-	185.5
10	-	-	-	-	-	40	-	40	-	185.5
11	-	-	-	-	-	40	-	41	-	185.5
12	-	-	-	-	-	40	-	41	-	185.5
13	-	-	-	-	-	41	-	41	-	185.5
14	-	-	-	-	-	41	-	41	-	185.5
15	-	-	-	-	-	42	-	42	-	185.5
16	-	-	-	-	-	42	-	42	-	185.5
17	-	-	-	-	-	43	-	43	-	185.5
18	-	-	-	-	-	43	-	43	-	185.5
19	-	-	-	-	-	43	-	44	-	185.5
20	-	-	-	-	-	43	-	44	-	185.5
21	-	-	-	-	-	44	-	45	-	190.5
22	-	-	-	-	-	44	-	44	-	190.5
23	-	-	-	-	-	44	-	44	-	190.5
24	-	-	-	-	-	45	-	45	-	190.5
25	-	-	-	-	-	45	-	45	-	115.5
26	-	-	-	-	-	45	-	46	-	165.5
27	-	-	-	-	-	46	-	47	-	190.5
28	-	-	-	-	-	45	-	45	-	190.5
29	-	-	-	-	-	46	-	53	-	190.5
30	-	-	-	-	-	47	-	58	-	190.5
31										

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

March, 19 72

COOLING WATER DATA

NaOCl used in Chlorination					River		Discharge Canal Effluent		
UNIT # 1		UNIT # 2		Conc.					
Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	%	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
-	-	-	-	-	33	-	55	-	180.5
-	-	-	-	-	33	-	52	-	180.5
-	-	-	-	-	33	-	50	-	230.5
-	-	-	-	-	34	-	52	-	125.5
-	-	-	-	-	33	-	47	-	175.5
-	-	-	-	-	34	-	57	-	175.5
-	-	-	-	-	34	-	57	-	180.5
-	-	-	-	-	35	-	57	-	180.5
-	-	-	-	-	34	-	57	-	175.5
-	-	-	-	-	34	-	55	-	180.5
-	-	-	-	-	35	-	49	-	175.5
-	-	-	-	-	35	-	48	-	175.5
-	-	-	-	-	36	-	53	-	175.5
-	-	-	-	-	36	-	54	-	175.5
-	-	-	-	-	37	-	55	-	175.5
-	-	-	-	-	36	-	54	-	175.5
-	-	-	-	-	36	-	54	-	175.5
-	-	-	-	-	37	-	51	-	175.5
-	-	-	-	-	37	-	51	-	150.5
-	-	-	-	-	38	-	53	-	175.5
-	-	-	-	-	38	-	52	-	175.5
-	-	-	-	-	37	-	50	-	175.5
-	-	-	-	-	38	-	40	-	25.5
-	-	-	-	-	39	-	40	-	105.5
-	-	-	-	-	38	-	40	-	25.0
-	-	-	-	-	39	-	41	-	25.0
-	-	-	-	-	39	-	41	-	25.0
-	-	-	-	-	39	-	41	-	25.5
-	-	-	-	-	39	-	40	-	105.5
-	-	-	-	-	39	-	39	-	175.5
-	-	-	-	-	39	-	39	-	175.5

ated Edison Co. of N.Y., Inc.

Indian Point Station

February, 19 72

COOLING WATER DATA

	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc.					
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	%	Temp. F	Demand	Temp. F	Residual	Daily Avera Flow Rate M gpm
	–	–	–	–	–	32	–	34	–	240.5
	–	–	–	–	–	32	–	33	–	545.5
	–	–	–	–	–	32	–	33	–	500.5
	–	–	–	–	–	32	–	33	–	460.5
	–	–	–	–	–	32	–	33	–	320.5
	–	–	–	–	–	32	–	34	–	245.5
	–	–	–	–	–	32	–	34	–	245.5
	–	–	–	–	–	31	–	33	–	245.5
	–	–	–	–	–	31	–	33	–	245.5
0	–	–	–	–	–	32	–	34	–	245.5
1	–	–	–	–	–	32	–	33	–	245.5
2	–	–	–	–	–	33	–	34	–	245.5
3	–	–	–	–	–	32	–	33	–	245.5
4	–	–	–	–	–	32	–	35	–	245.5
5	–	–	–	–	–	32	–	35	–	270.5
6	–	–	–	–	–	32	–	41	–	320.5
7	–	–	–	–	–	32	–	42	–	325.5
8	–	–	–	–	–	32	–	41	–	325.5
9	–	–	–	–	–	32	–	39	–	325.5
0	–	–	–	–	–	31	–	38	–	325.5
1	–	–	–	–	–	32	–	39	–	325.5
2	–	–	–	–	–	32	–	41	–	325.5
3	–	–	–	–	–	32	–	42	–	325.5
4	–	–	–	–	–	32	–	45	–	325.5
5	–	–	–	–	–	32	–	43	–	320.5
6	–	–	–	–	–	32	–	33	–	320.5
7	–	–	–	–	–	31	–	32	–	320.5
8	–	–	–	–	–	32	–	45	–	320.5
9	–	–	–	–	–	32	–	53	–	180.5
0										
1										

onsolidated Edison Co. of N.Y., Inc.

Indian Point Station

January , 19 72

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	-	-	-	-	-	38	-	47	-	175.5
2	-	-	-	-	-	38	-	49	-	175.5
3	-	-	-	-	-	38	-	53	-	175.5
4	100	1.5	-	-	14.7	38	0.7	53	0.1	175.5
5	-	-	-	-	-	39	-	54	-	175.5
6	-	-	-	-	-	37	-	52	-	175.5
7	-	-	-	-	-	38	-	53	-	175.5
8	-	-	-	-	-	37	-	52	-	175.5
9	-	-	-	-	-	38	-	49	-	175.5
10	-	-	-	-	-	39	-	53	-	175.5
11	100	1.5	-	-	14.5	38	0.7	53	0.1	175.5
12	-	-	-	-	-	38	-	52	-	175.5
13	-	-	-	-	-	38	-	52	-	175.5
14	-	-	-	-	-	37	-	44	-	325.5
15	-	-	-	-	-	37	-	46	-	175.5
16	-	-	-	-	-	35	-	45	-	175.5
17	-	-	-	-	-	35	-	49	-	175.5
18	-	-	-	-	-	36	-	50	-	175.5
19	-	-	-	-	-	36	-	37	-	111.5
20	-	-	-	-	-	35	-	36	-	111.5
21	-	-	-	-	-	36	-	37	-	111.5
22	-	-	-	-	-	35	-	36	-	111.5
23	-	-	-	-	-	36	-	37	-	111.5
24	-	-	-	-	-	36	-	37	-	111.5
25	-	-	-	-	-	36	-	37	-	111.5
26	-	-	-	-	-	35	-	36	-	111.5
27	-	-	-	-	-	34	-	35	-	111.5
28	-	-	-	-	-	35	-	36	-	111.5
[illegible]	-	-	-	-	-	33	-	34	-	111.5
30	-	-	-	-	-	33	-	34	-	111.5
31	-	-	-	-	-	32	-	34	-	111.5

DEC. 1971

Da[illegible]	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	* Demand	Temp. F	* Residual	Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	75	1.25	-	-	15.2	49	0.8	67	<0.1	175.5
2	-	-	-	-	-	48	-	66	-	175.5
3	75	1.15	-	-	15.2	46	0.8	57	<0.1	175.5
4	-	-	-	-	-	46	-	64	-	175.5
5	-	-	-	-	-	45	-	62	-	175.5
6	75	1.65	-	-	15.1	45	0.8	62	<0.1	175.5
7	-	-	-	-	-	45	-	63	-	175.5
8	100	1.55	-	-	15.1	46	0.8	63	<0.1	175.5
9	-	-	-	-	-	45	-	62	-	175.5
10	-	-	-	-	-	44	-	62	-	175.5
11	-	-	-	-	-	44	-	62	-	175.5
12	-	-	-	-	-	42	-	43	-	175.5
13	75	1.15	-	-	15.0	41	0.8	42	<0.1	175.5
14	-	-	-	-	-	40	-	58	-	175.5
15	100	1.65	-	-	15.0	42	0.8	60	<0.1	175.5
[illegible]	-	-	-	-	-	41	-	59	-	175.5
17	100	1.55	-	-	15.0	41	0.8	59	<0.1	175.5
18	-	-	-	-	-	38	-	56	-	175.5
19	-	-	-	-	-	37	-	55	-	175.5
20	100	1.55	-	-	15.0	39	0.8	57	<0.1	175.5
21	-	-	-	-	-	39	-	50	-	175.5
22	100	1.55	-	-	14.9	38	0.8	52	<0.1	175.5
23	-	-	-	-	-	37	-	51	-	175.5
24	-	-	-	-	-	37	-	52	-	175.5
25	-	-	-	-	-	38	-	48	-	175.5
26	-	-	-	-	-	39	-	50	-	175.5
27	-	-	-	-	-	39	-	50	-	175.5
28	100	1.55	-	-	14.9	40	0.8	55	<0.1	175.5
29	-	-	-	-	-	41	-	56	-	175.5
30	-	-	-	-	-	41	-	56	-	175.5
31	-	-	-	-	-	40	-	55	-	175.5

*Chlorine (ppm)

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

Nov. , 19 71

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1 Gals.	UNIT # 1 Feed Rate gpm	UNIT # 2 Gals.	UNIT # 2 Feed Rate gpm	Conc. %	Temp. F	* Demand	Temp. F	* Residual	Daily Average Flow Rate M gpm
1	-	-	-	-	-	65	-	65	-	330.5
2	-	-	-	-	-	65	-	65	-	330.5
3	75	1.2	-	-	9.2	65	0.8	65	<0.1	330.5
4	-	-	-	-	-	64	-	70	-	330.5
5	75	1.1	-	-	9.2	63	0.8	75	< 0.1	330.5
6	-	-	-	-	-	62	-	74	-	330.5
	-	-	-	-	-	60	-	62	-	330.5
8	100	1.5	-	-	9.1	58	0.8	65	< 0.1	750.5
9	-	-	-	-	-	58	-	64	-	750.5
10	100	1.5	-	-	9.1	59	0.8	65	< 0.1	605.5
11	-	-	-	-	-	59	-	65	-	605.5
12	125	1.9	-	-	9.1	59	0.8	66	< 0.1	605.5
13	-	-	-	-	-	58	-	65	-	745.5
14	-	-	-	-	-	57	-	64	-	745.5
15	75	1.2	-	-	15.6	56	0.8	63	<0.1	745.5
16	-	-	-	-	-	55	-	62	-	745.5
17	50	0.75	-	-	-	55	-	62	-	745.5
18	-	-	-	-	-	54	-	60	-	745.5
19	50	0.75	-	-	15.5	54	0.8	61	<0.1	745.5
20	-	-	-	-	-	53	-	56	-	745.5
21	-	-	-	-	-	52	-	56	-	745.5
22	50	0.75	-	-	15.4	50	0.8	54	<0.1	745.5
23	-	-	-	-	-	50	-	53	-	325.5
24	50	1.0	-	-	15.4	49	0.8	60	<0.1	175.5
25	-	-	-	-	-	50	-	61	-	175.5
26	50	0.75	-	-	15.3	50	0.8	61	<0.1	175.5
27	-	-	-	-	-	50	-	61	-	175.5
28	-	-	-	-	-	49	-	50	-	175.5
29	50	0.75	-	-	15.3	49	0.8	67	<0.1	175.5
30	-	-	-	-	-	50	-	67	-	175.5
31										

* Chlorine (ppm)

12.3 x 10^9 gal

DEC - 7.6 x 10^9 gal

October , 1971

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	100	1.5	-	-	10.7	70	0.7	76	0.1	320.5
2	-	-	-	-	-	71	-	76	-	320.5
3	-	-	-	-	-	71	-	76	-	320.5
4	100	1.5	-	-	10.5	70	0.7	76	0.1	320.5
5	-	-	-	-	-	70	-	76	-	320.5
6	100	1.7	-	-	10.4	70	0.7	78	0.1	245.5
7	-	-	-	-	-	69	-	79	-	170.5
	100	1.5	-	-	10.4	68	0.7	78	0.1	170.5
9	-	-	-	-	-	68	-	78	-	170.5
10	-	-	-	-	-	68	-	78	-	170.5
11	100	1.5	-	-	10.2	68	0.7	77	0.1	170.5
12	-	-	-	-	-	67	-	77	-	170.5
13	100	1.5	-	-	10.1	66	0.7	76	0.1	170.5
14	-	-	-	-	-	66	-	76	-	182.0
15	100	1.5	-	-	10.0	67	0.7	68	0.1	205.5
16	-	-	-	-	-	68	-	68	-	188.0
17	-	-	-	-	-	68	-	68	-	188.0
18	0	0	-	-	9.8	67	0.7	67	0.1	188.0
19	-	-	-	-	-	67	-	67	-	170.5
20	100	1.5	-	-	9.7	66	0.7	67	0.1	245.5
21	-	-	-	-	-	66	-	66	-	320.5
22	-	-	-	-	-	66	-	66	-	320.5
23	-	-	-	-	-	65	-	66	-	320.5
24	-	-	-	-	-	65	-	65	-	320.5
25	-	-	-	-	-	65	-	65	-	320.5
26	-	-	-	-	-	65	-	65	-	320.5
27	-	-	-	-	-	65	-	65	-	320.5
28	-	-	-	-	-	66	-	66	-	320.5
29	-	-	-	-	-	65	-	65	-	320.5
30	-	-	-	-	-	65	-	65	-	320.5
31	-	-	-	-	-	65	-	65	-	320.5

5.28×10^9 gal

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

September, 1971

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	250	3.9	-	-	10.7	75	0.9	86	<0.1	205.0
2	-	-	-	-	-	75	-	84	-	307.5
3	250	3.9	-	-	10.5	75	0.8	86	<0.1	213.0
4	-	-	-	-	-	75	-	86	-	213.0
5	-	-	-	-	-	76	-	87	-	213.0
6	-	-	-	-	-	77	-	88	-	213.0
7	250	3.9	-	-	10.1	77	0.8	88	<0.1	213.0
8	-	-	-	-	-	76	-	83	-	325.5
9	-	-	-	-	-	76	-	82	-	325.5
10	100	2.5	-	-	15.0	76	0.8	77	<0.1	325.5
11	-	-	-	-	-	76	-	77	-	186.5
12	-	-	-	-	-	76	-	76	-	186.5
13	-	-	-	-	-	77	-	77	-	186.5
14	-	-	-	-	-	76	-	82	-	325.5
15	175	2.7	-	-	14.5	76	0.8	82	<0.1	325.5
16	-	-	-	-	-	76	-	82	-	325.5
17	-	-	-	-	-	75	-	81	-	325.5
18	-	-	-	-	-	74	-	80	-	325.5
19	-	-	-	-	-	74	-	80	-	325.5
20	175	2.7	-	-	13.0	74	0.7	80	<0.1	325.5
21	-	-	-	-	-	74	-	80	-	325.5
22	175	2.7	-	-	12.8	72	0.7	78	<0.1	325.5
23	-	-	-	-	-	72	-	78	-	325.5
24	175	2.7	-	-	12.6	71	0.7	77	<0.1	325.5
25	-	-	-	-	-	71	-	77	-	325.5
26	-	-	-	-	-	71	-	77	-	325.5
27	325	2.7	-	-	12.3	70	0.7	76	<0.1	325.5
28	300	2.3	-	-	12.2	70	0.7	76	0.3	325.5
29	125	1.9	-	-	12.1	70	0.7	76	<0.1	325.5
30	-	-	-	-	-	71	-	77		325.5
31										

12.28 x10^9

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

August , 19 71

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1 Gals.	UNIT # 1 Feed Rate gpm	UNIT # 2 Gals.	UNIT # 2 Feed Rate gpm	Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
1	-	-	-	-	-	77	-	78	-	182.5
2	-	-	-	-	-	77	-	77	-	182.5
3	-	-	-	-	-	77	-	78	-	182.5
4	-	-	-	-	-	78	-	78	-	182.5
5	-	-	-	-	-	78	-	78	-	182.5
6	-	-	-	-	-	78	-	78	-	182.5
7	-	-	-	-	-	77	-	78	-	177.5
8	-	-	-	-	-	77	-	77	-	177.5
9	-	-	-	-	-	77	-	77	-	25.5
10	-	-	-	-	-	77	-	78	-	112.0
11	-	-	-	-	-	77	-	77	-	313.5
12	-	-	-	-	-	77	-	77	-	92.25
13	-	-	-	-	-	77	-	77	-	177.5
14	-	-	-	-	-	77	-	77	-	177.5
15	-	-	-	-	-	77	-	77	-	177.5
16	150	2.5	-	-	11.5	77	0.7	78	<0.1	177.5
17	-	-	-	-	-	77	-	85	-	325.5
18	-	-	-	-	-	77	-	85	-	325.5
19	-	-	-	-	-	77	-	85	-	325.5
20	150	2.5	-	-	11.3	78	0.7	86	<0.1	325.5
21	-	-	-	-	-	78	-	85	-	325.5
22	-	-	-	-	-	78	-	85	-	325.5
23	100	1.7	-	-	11.2	78	0.7	85	<0.1	325.5
24	-	-	-	-	-	76	-	84	-	325.5
25	100	1.55	-	-	11.1	76	0.7	83	<0.1	325.5
26	-	-	-	-	-	76	-	81	-	325.5
27	150	2.3	-	-	10.9	76	0.7	84	<0.1	173.5
28	-	-	-	-	-	76	-	85	-	173.5
29	-	-	-	-	-	75	-	83	-	177.5
30	-	-	-	-	-	75	-	83	-	196.0
31	75	2.15	-	-	10.8	75	0.7	83	<0.1	196.0

9.14×10^9 gal.

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

July, 1971

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc.					
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm	%	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
1	-	-	-	-	-	73	-	83	-	330.5
2	100	1.8	-	-	13.3	74	0.9	84	0.1	330.5
3	-	-	-	-	-	73	-	74	-	330.5
4	-	-	-	-	-	72	-	73	-	330.5
5	125	1.9	-	-	12.8	74	1.0	80	0.1	330.5
[illegible]	-	-	-	-	-	73	-	83	-	330.5
7	125	1.9	-	-	12.7	73	1.0	83	0.1	330.5
8	-	-	-	-	-	73	-	84	-	330.5
9	150	2.3	-	-	12.4	74	1.0	80	0.1	335.5
10	-	-	-	-	-	74	-	79	-	335.5
11	-	-	-	-	-	74	-	80	-	335.5
1[illegible]	100	1.6	-	-	15.0	74	1.0	80	0.1	335.5
13	-	-	-	-	-	74	-	75	-	335.5
14	-	-	-	-	-	74	-	75	-	335.5
15	-	-	-	-	-	74	-	75	-	255.5
16	-	-	-	-	-	74	-	76	-	182.5
17	-	-	-	-	-	76	-	77	-	182.5
18	-	-	-	-	-	76	-	77	-	182.5
19	-	-	-	-	-	76	-	77	-	176.5
20	-	-	-	-	-	76	-	77	-	176.5
21	-	-	-	-	-	76	-	76	-	176.5
22	-	-	-	-	-	76	-	76	-	30.5
23	-	-	-	-	-	77	-	77	-	30.5
24	-	-	-	-	-	77	-	77	-	30.5
25	-	-	-	-	-	77	-	77	-	30.5
26	-	-	-	-	-	77	-	78	-	30.5
27	-	-	-	-	-	77	-	77	-	32.0
28	-	-	-	-	-	77	-	77	-	32.0
[illegible]	-	-	-	-	-	78	-	78	-	32.0
30	-	-	-	-	-	78	-	78	-	32.0
31	-	-	-	-	-	77	-	78	-	32.0

8.59×10^9 gal.

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

June, 19 71

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Aver Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	50	1.65	-	-	14.9	59	1.0	59	<0.1	170.5
2	-	-	-	-	-	60	-	60	-	170.5
3	-	-	-	-	-	60	-	60	-	170.5
4	-	-	-	-	-	61	-	61	-	30.5
5	-	-	-	-	-	61	-	61	-	170.5
6	-	-	-	-	-	62	-	62	-	330.5
7	100	1.55	-	-	14.7	63	1.0	71	<0.1	347.5
8	-	-	-	-	-	63	-	71	-	424.0
9	75	1.15	-	-	14.6	63	1.0	73	<0.1	377.25
10	-	-	-	-	-	64	-	75	-	330.5
11	100	1.55	-	-	14.5	64	1.0	75	<0.1	330.5
12	-	-	-	-	-	65	-	76	-	330.5
13	-	-	-	-	-	65	-	76	-	330.5
14	100	1.55	-	-	14.3	66	1.0	72	<0.1	330.5
15	-	-	-	-	-	66	-	71	-	330.5
16	100	1.55	-	-	14.3	66	1.0	72	<0.1	330.5
17	-	-	-	-	-	67	-	73	-	330.5
18	100	1.55	-	-	14.1	67	1.0	78	<0.1	330.5
19	-	-	-	-	-	68	-	77	-	330.5
20	-	-	-	-	-	69	-	79	-	330.5
21	100	1.55	-	-	14.0	70	1.0	80	<0.1	330.5
22	-	-	-	-	-	71	-	79	-	424.0
23	100	1.55	-	-	13.9	70	0.9	80	<0.1	330.5
24	-	-	-	-	-	71	-	81	-	330.5
25	100	1.55	-	-	13.7	71	0.9	81	<0.1	330.5
26	-	-	-	-	-	71	-	82	-	330.5
27	-	-	-	-	-	71	-	81	-	330.5
28	100	1.55	-	-	13.6	72	0.8	82	<0.1	330.5
29	-	-	-	-	-	72	-	82	-	335.5
30	100	2.2	-	-	13.5	73	0.9	83	<0.1	335.5
31										

12.48×10^9 gal.

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

May , 1971

COOLING WATER DATA

ate	NaOCl used in Chlorination					River		Discharge Canal Effluent		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Average Flow Rate M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
	-	-	-	-	-	46	-	58	-	330.5
	-	-	-	-	-	46	-	58	-	330.5
	50	1.0	-	-	11.1	46	0.8	54	<0.1	570.5
	-	-	-	-	-	47	-	58	-	379.75
	50	1.0	-	-	11.1	47	0.8	57	<0.1	406.5
	-	-	-	-	-	48	-	58	-	402.5
	50	1.1	-	-	11.0	47	0.8	57	<0.1	406.5
	-	-	-	-	-	48	-	54	-	544.0
	-	-	-	-	-	49	-	58	-	448.5
10	50	0.9	-	-	11.0	49	0.8	57	<0.1	482.0
11	-	-	-	-	-	50	-	59	-	458.5
12	50	0.9	-	-	11.0	51	0.8	57	<0.1	566.0
13	-	-	-	-	-	52	-	57	-	570.5
14	50	0.9	-	-	10.9	52	0.8	58	<0.1	570.5
15	-	-	-	-	-	53	-	58	-	570.5
16	-	-	-	-	-	53	-	59	-	570.5
17	75	1.3	-	-	10.9	54	0.8	60	<0.1	570.5
	-	-	-	-	-	56	-	61	-	570.5
19	75	1.2	-	-	10.8	55	0.8	61	<0.1	570.5
20	-	-	-	-	-	56	-	62	-	570.5
21	75	1.2	-	-	10.8	56	0.8	62	<0.1	570.5
22	-	-	-	-	-	57	-	63	-	570.5
23	-	-	-	-	-	57	-	63	-	570.5
24	75	1.2	-	-	10.7	57	0.8	63	<0.1	570.5
25	-	-	-	-	-	58	-	61	-	570.5
26	-	-	-	-	-	58	-	62	-	489.25
27	50	1.1	-	-	10.6	58	1.0	63	<0.1	422.5
28	50	1.3	-	-	15.0	59	1.0	64	<0.1	390.5
29	-	-	-	-	-	59	-	59	-	330.5
30	-	-	-	-	-	59	-	59	-	330.5
31	-	-	-	-	-	59	-	59	-	330.5

12.3 x 10^9 gal.

April ,

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Efflu		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily A Flow R M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	-	-	-	-	-	38	-	59	-	210.25
2	75	1.25	-	-	13.8	41	0.9	61	<0.1	208.75
3	-	-	-	-	-	42	-	62	-	207.50
4	-	-	-	-	-	42	-	62	-	207.25
5	75	1.25	-	-	13.5	43	1.0	63	< 0.1	205.75
6	-	-	-	-	-	44	-	64	-	191.00
7	50	0.85	-	-	13.3	41	1.0	61	< 0.1	208.00
8	-	-	-	-	-	40	-	61	-	184.50
9	50	0.85	-	-	13.1	39	0.9	62	< 0.1	180.25
10	-	-	-	-	-	39	-	52	-	177.50
11	-	-	-	-	-	41	-	53	-	175.50
12	50	0.85	-	-	12.9	41	0.9	64	< 0.1	170.50
13	-	-	-	-	-	42	-	65	-	168.00
14	50	0.85	-	-	12.7	43	0.8	63	< 0.1	212.75
15	-	-	-	-	-	42	-	63	-	218.25
16	50	0.85	-	-	12.5	43	0.8	63	<0.1	224.75
17	-	-	-	-	-	43	-	64	-	200.25
18	-	-	-	-	-	44	-	66	-	193.50
19	-	-	-	-	-	45	-	67	-	182.00
20	-	-	-	-	-	45	-	59	-	285.00
21	50	0.85	-	-	12.0	45	0.8	59	<0.1	295.00
22	-	-	-	-	-	47	-	59	-	325.50
23	50	0.85	-	-	11.8	47	0.7	60	<0.1	325.50
24	-	-	-	-	-	47	-	59	-	325.50
25	-	-	-	-	-	46	-	58	-	325.50
26	50	0.85	-	-	11.6	47	0.7	58	<0.1	325.50
27	-	-	-	-	-	47	-	58	-	325.50
28	50	0.85	-	-	11.3	46	0.8	57	<0.1	325.50
29	-	-	-	-	-	46	-	57	-	325.50
30	50	0.85	-	-	11.1	46	0.8	57	<0.1	325.50
31										

10.16 x 10^9 gal.

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

March , 197

COOLING WATER DATA

Date	NaOCl used in Chlorination					River		Discharge Canal Efflu		
	UNIT # 1 Gals.	UNIT # 1 Feed Rate gpm	UNIT # 2 Gals.	UNIT # 2 Feed Rate gpm	Conc. %	Temp. F	Demand	Temp. F	Residual	Daily A Flow R M gpm
1	-	-	-	-	-	33	-	53	-	179.0
2	100	1.2	-	-	14.3	33	0.8	54	<0.1	182.2
3	-	-	-	-	-	33	-	53	-	207.0
4	75	1.1	-	-	14.3	33	0.8	52	<0.1	230.5
5	-	-	-	-	-	33	-	44	-	597.5
6	-	-	-	-	-	34	-	54	-	243.0
7	-	-	-	-	-	34	-	46	-	566.5
8	50	1.0	-	-	14.2	33	0.9	55	<0.1	209.5
9	-	-	-	-	-	33	-	56	-	217.0
10	50	0.9	-	-	14.2	33	0.9	50	<0.1	440.75
11	-	-	-	-	-	34	-	51	-	482.0
12	50	0.9	-	-	14.2	34	0.9	56	<0.1	228.0
13	-	-	-	-	-	33	-	55	-	231.5
14	-	-	-	-	-	34	-	55	-	236.5
15	75	1.25	-	-	14.1	33	0.9	56	<0.1	241.5
16	-	-	-	-	-	34	-	54	-	207.0
17	50	0.9	-	-	14.1	34	0.9	51	<0.1	420.5
18	-	-	-	-	-	34	-	52	-	423.0
19	50	0.9	-	-	14.0	35	0.9	52	<0.1	419.5
20	-	-	-	-	-	35	-	51	-	420.5
21	-	-	-	-	-	34	-	52	-	422.0
22	75	1.25	-	-	14.0	34	0.9	51	<0.1	424.0
23	-	-	-	-	-	35	-	50	-	405.0
24	50	0.9	-	-	14.0	36	0.9	50	<0.1	374.5
25	-	-	-	-	-	36	-	59	-	184.0
26	75	1.15	-	-	13.9	38	1.0	60	<0.1	180.5
27	-	-	-	-	-	35	-	58	-	176.5
28	-	-	-	-	-	36	-	59	-	172.5
29	75	1.25	-	-	13.9	36	1.0	60	<0.1	169.5
30	-	-	-	-	-	37	-	60	-	171.0
31	75	1.25	-	-	13.9	37	1.0	61	<0.1	167.2

7.05×10^9 gal

Feb., 1971

COOLING WATER DATA

ate	NaOCl used in Chlorination					River		Discharge Canal Efflu[illegible]		
	UNIT # 1		UNIT # 2		Conc. %	Temp. F	Demand	Temp. F	Residual	Daily Ave Flow Ra[illegible] M gpm
	Gals.	Feed Rate gpm	Gals.	Feed Rate gpm						
1	-	-	-	-	-	33	-	33	-	51.5
2	-	-	-	-	-	33	-	33	-	30.5
3	-	-	-	-	-	33	-	33	-	122.5
4	-	-	-	-	-	33	-	33	-	411.5
5	-	-	-	-	-	33	-	33	-	447.5
6	-	-	-	-	-	33	-	33	-	475.5
7	100	1.5	-	-	6.1	33	0.6	33	0.1	531.5
8	-	-	-	-	-	32	-	39	-	531.5
9	-	-	-	-	-	32	-	45	-	549.0
10	125	2.1	53	0.8	6.1	32	0.6	48	0.1	429.5
11	-	-	-	-	-	33	-	58	-	181.5
12	-	-	-	-	-	33	-	57	-	181.[illegible]
13	-	-	-	-	-	33	-	58	-	176.[illegible]
14	-	-	-	-	-	33	-	58	-	176.
15	-	-	-	-	-	33	-	58	-	176.
16	-	-	-	-	-	32	-	57	-	180.
17	-	-	-	-	-	33	-	57	-	219.
18	50	2.0	-	-	6.0	32	0.7	54	0.1	185.
19	-	-	-	-	-	32	-	57	-	185.
20	150	2.5	-	-	14.4	32	0.7	57	0.1	185.
21	-	-	-	-	-	33	-	57	-	185
22	-	-	-	-	-	33	-	58	-	185
23	150	1.7	-	-	14.4	33	0.8	49	0.1	443
24	125	1.4			14.4	33	0.8	52	0.1	322
25	-	-	-	-	-	33	-	50	-	433
26	-	-	-	-	-	33	-	46	-	535
27	125	1.6	-	-	14.3	33	0.8	48	0.1	477
28	-	-	-	-	-	33	-	57	-	18[illegible]
29										
30										
31										

5.81 × 10⁸ gal

Consolidated Edison Co. of N.Y., Inc.

Unit No. 1

Jan. 197[illegible]

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp.
	Residual	Demand	Feed Rate GPM	Gals.	* % (conc.)		In
1	-	-	-	-	-	65.1	34
2	-	-	-	-	-	82.5	34
3	-	-	-	-	-	82.5	33
4	0.1	0.9	0.70	25	6.4	82.5	33
5	-	-	-	-	-	131.5	33
6	0.1	0.9	0.75	25	6.4	130.3	33
7	-	-	-	-	-	104.5	33
8	-	-	-	-	-	104.5	33
9	-	-	-	-	-	104.5	33
10	-	-	-	-	-	104.5	33
11	-	-	-	-	-	104.5	32
12	-	-	-	-	-	104.5	32
13	-	-	-	-	-	151.0	32
14	-	-	-	-	-	140.5	32
15	-	-	-	-	-	104.5	32
16	-	-	-	-	-	104.5	32
17	-	-	-	-	-	104.5	32
18	-	-	-	-	-	70.5	32
19	-	-	-	-	-	20.5	32
20	-	-	-	-	-	69.5	32
21	-	-	-	-	-	128.0	32
22	-	-	-	-	-	166.5	32
23	-	-	-	-	-	166.5	32
24	-	-	-	-	-	166.5	32
25	0.1	0.7	1.25	50	6.[illegible]	166.5	32
26	-	-	-	-	-	166.5	32
27	-	-	-	-	-	166.5	32
28	-	-	-	-	-	166.5	32
29	-	-	-	-	-	148.4	32
30	-	-	-	-	-	104.5	32
31	-	-	-	-	-	104.5	32
	5.2×10^8 gal					3617.8	

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Dec

Indian Point No. 1

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm
	Residual	Demand	Feed Rate gpm	Gals.	* %(conc.)	
1	-	-	-	-	-	320.5
2	<0.1	1.0	1.5	100	7.5	320.5
3	-	-	-	-	-	320.5
4	-	-	-	-	-	168.5
5	-	-	-	-	-	157.5
6	-	-	-	-	-	172.5
7	-	-	-	-	-	170.5
8	-	-	-	-	-	213.0
9	-	-	-	-	-	288.5
10	-	-	-	-	-	166.5
11	-	-	-	-	-	166.5
12	-	-	-	-	-	166.5
13	-	-	-	-	-	220.0
14	-	-	-	-	-	320.5
15	-	-	-	-	-	296.5
16	-	-	-	-	-	306.0
17	-	-	-	-	-	256.5
18	-	-	-	-	-	230.5
19	-	-	-	-	-	230.5
20	-	-	-	-	-	230.5
21	-	-	-	-	-	320.5
22	<0.1	1.1	1.2	75	6.5	320.5
23	-	-	-	-	-	320.5
24	-	-	-	-	-	320.5
25	-	-	-	-	-	320.5
26	-	-	-	-	-	308.0
27	-	-	-	-	-	289.5
28	-	-	-	-	-	320.5
29	-	-	-	-	-	233.0
30	-	-	-	-	-	20.5
31	-	-	-	-	-	156.0

* Calculated

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

Nov. , 1970

Indian Point No. 2

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp.
	Residual	Demand	Feed Rate gpm	Gals.	* %(conc.)		In
1	-	-	-	-	-	5.0	60
2	-	-	-	-	-	5.0	59
3	-	-	-	-	-	5.0	59
4	-	-	-	-	-	5.0	58
5	-	-	-	-	-	5.0	57
6	-	-	-	-	-	5.0	56
7	-	-	-	-	-	5.0	57
8	-	-	-	-	-	5.0	56
9	-	-	-	-	-	5.0	56
10	-	-	-	-	-	5.0	56
11	-	-	-	-	-	5.0	56
12	-	-	-	-	-	5.0	56
13	<0.1	1.1	0.3	1.5	9.1	5.0	56
14	-	-	-	-	-	5.0	55
15	-	-	-	-	-	5.0	54
16	-	-	-	-	-	5.0	54
17	-	-	-	-	-	5.0	53
18	-	-	-	-	-	5.0	53
19	-	-	-	-	-	5.0	53
20	-	-	-	-	-	5.0	53
21	-	-	-	-	-	5.0	53
22	-	-	-	-	-	5.0	53
23	-	-	-	-	-	5.0	52
24	-	-	-	-	-	5.0	52
25	<0.1	1.1	0.3	1.5	7.5	5.0	51
26	-	-	-	-	-	5.0	51
27	-	-	-	-	-	5.0	51
28	-	-	-	-	-	5.0	50
29	-	-	-	-	-	5.0	50
30	-	-	-	-	-	5.0	49
31	-	-	-	-	-		

* Calculated

Consolidated Edison Co. of N.Y., Inc.

November, 19 [illegible]

Indian Point No. 1

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (	
	Residual	Demand	Feed Rate gpm	Gals.	* % (conc.)		In	Out
1	-	-	-	-	-	320.5	60	
2	-	-	-	-	-	320.5	50	
3	-	-	-	-	-	320.5	[illegible]	
4	-	-	-	-	-	201.75	[illegible]	
5	-	-	-	-	-	20.5	[illegible]	
6	-	-	-	-	-	180.25	[illegible]	
7	-	-	-	-	-	114.25	57	
8	-	-	-	-	-	20.5	[illegible]	
9	-	-	-	-	-	20.5	[illegible]	
10	-	-	-	-	-	245.5	[illegible]	
11	-	-	-	-	-	320.5	[illegible]	
12	-	-	-	-	-	320.5	[illegible]	
13	-	-	-	-	-	320.5	[illegible]	
14	-	-	-	-	-	320.5	[illegible]	
15	-	-	-	-	-	320.5	54	
16	-	-	-	-	-	320.5	54	
17	-	-	-	-	-	320.5	53	
18	-	-	-	-	-	320.5	53	
19	-	-	-	-	-	270.5	53	
20	-	-	-	-	-	20.5	53	
21	-	-	-	-	-	20.5	53	
22	-	-	-	-	-	20.5	53	
23	-	-	-	-	-	20.5	52	
24	-	-	-	-	-	20.5	52	
25	-	-	-	-	-	20.5	51	
26	-	-	-	-	-	20.5	51	
27	-	-	-	-	-	20.5	51	
28	-	-	-	-	-	20.5	50	
29	-	-	-	-	-	320.5	50	
30	-	-	-	-	-	320.5	49	
31								

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

Oct , 1970

Unit No. 2

COOLING WATER DATA

ay of onth	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp.	
	Residual	Demand	Feed Rate gpm	Gals.	* %(conc.)		In	O
1	—	—	—	—	—	5.0	70	70
2	—	—	—	—	—	5.0	70	70
3	—	—	—	—	—	5.0	70	70
4	—	—	—	—	—	5.0	69	69
[illegible]	—	—	—	—	—	5.0	69	69
[illegible]	-----	—	—	—	—	5.0	69	69
[illegible]	—	—	—	—	—	5.0	69	69
[illegible]	—	—	—	—	—	5.0	68	[illegible]
[illegible]	—	—	—	—	—	5.0	68	[illegible]
10	—	—	—	—	—	5.0	68	[illegible]
11	—	—	—	—	—	5.0	67	67
12	—	—	—	—	—	5.0	66	66
13	—	—	—	—	—	5.0	65	65
14	—	—	—	—	—	5.0	65	65
15	—	—	—	—	—	5.0	65	[illegible]
16	—	—	—	—	—	31.7	65	[illegible]
17	—	—	—	—	—	5.0	64	[illegible]
18	--	—	—	—	—	5.0	64	[illegible]
19	<0.1	1.2	1.7	50	11.9	59.2	64	[illegible]
20	—	—	—	—	—	5.0	64	[illegible]
21	—	—	—	—	—	5.0	64	[illegible]
22	—	—	—	—	—	5.0	64	[illegible]
23	—	—	—	—	—	5.0	64	[illegible]
24	—	—	—	—	—	5.0	64	[illegible]
[illegible]	—	—	—	—	—	5.0	64	[illegible]
[illegible]	—	—	—	—	—	5.0	63	[illegible]
[illegible]	—	—	—	—	—	5.0	62	[illegible]
[illegible]	—	—	—	—	—	5.0	62	[illegible]
[illegible]	—	—	—	—	—	5.0	62	
30	<0.1	1.3	0.2	1	11.1	5.0	62	[illegible]
31	—	—	—	—	—	5.0	61	

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
Sept., 1970

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate gpm	Gals.	* %(conc.)		In	Out
1	–	–	–	–	–	20.5	76	[illegible]
2	–	–	–	–	–	20.5	77	77
3	–	–	–	–	–	20.5	76	76
4	–	–	–	–	–	20.5	77	77
5	–	–	–	–	–	20.5	77	77
6	–	–	–	–	–	20.5	77	77
7	–	–	–	–	–	20.5	76	76
8	–	–	–	–	–	20.5	76	76
9	–	–	–	–	–	20.5	76	76
10	–	–	–	–	–	20.5	75	76
11	–	–	–	–	–	20.5	74	75
12	–	–	–	–	–	20.5	74	75
13	–	–	–	–	–	20.5	74	75
14	–	–	–	–	–	20.5	73	74
15	–	–	–	–	–	20.5	73	74
16	–	–	–	–	–	20.5	73	74
17	–	–	–	–	–	20.5	73	74
18	–	–	–	–	–	20.5	73	73
19	–	–	–	–	–	20.5	72	73
20	–	–	–	–	–	20.5	72	73
21	–	–	–	–	–	20.5	72	73
22	–	–	–	–	–	20.5	73	74
23	–	–	–	–	–	20.5	74	75
24	–	–	–	–	–	20.5	75	75
25	–	–	–	–	–	20.5	74	75
26	–	–	–	–	–	20.5	75	75
27	–	–	–	–	–	20.5	74	74
28	–	–	–	–	–	20.5	72	73
29	–	–	–	–	–	20.5	72	72
30	–	–	–	–	–	20.5	72	72
31	N.A.							

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

August , 19 70

COOLING WATER DATA

y of nth	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate ppm	Gals.	* % (conc.)		In	Out
1	–	–	–	–	–	20.5	78	79
2	–	–	–	–	–	20.5	79	80
3	–	–	–	–	–	19.0	79	80
4	–	–	–	–	–	19.0	79	80
5	–	–	–	–	–	75.25	79	80
6	–	–	–	–	–	319	79	80
7	–	–	–	–	–	319	79	79
8	–	–	–	–	–	319	79	79
9	–	–	–	–	–	319	79	79
10	<0.1	1.8	2.0	550	4.0	319	79	79
11	<0.1	1.8	2.2	700	4.0	319	78	78
12	–	–	–	–	–	319	78	79
13	–	–	–	–	–	319	78	79
14	–	–	–	–	–	319	78	79
15	–	–	–	–	–	319	78	79
16	–	–	–	–	–	319	79	80
17	<0.1	1.7	1.9	125	14.9	144	79	80
18	–	–	–	–	–	20.5	79	80
19	–	–	–	–	–	20.5	81	83
20	–	–	–	–	–	20.5	81	82
21	–	–	–	–	–	19.0	79	80
22	–	–	–	–	–	19.0	79	80
23	–	–	–	–	–	19.0	79	80
24	–	–	–	–	–	19.0	78	79
25	–	–	–	–	–	20.5	78	79
26	–	–	–	–	–	20.5	77	78
27	–	–	–	–	–	20.5	79	79
28	–	–	–	–	–	20.5	79	79
29	–	–	–	–	–	20.5	78	78
30	–	–	–	–	–	20.5	78	78
31	–	–	–	–	–	20.5	77	77

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

July, 1970

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate GPM	Gals.	* %(conc.)		In	Out
1	-	-	-	-	-	20.5	71	72
2	-	-	-	-	-	20.5	69	70
3	-	-	-	-	-	20.5	71	73
4	-	-	-	-	-	67.2	72	74
5	-	-	-	-	-	29.3	72	73
[illegible]	-	-	-	-	-	20.5	72	73
7	-	-	-	-	-	20.5	72	74
8	-	-	-	-	-	83.9	72	73
9	-	-	-	-	-	20.5	73	75
10	-	-	-	-	-	53.7	73	75
11	-	-	-	-	-	145.0	72	74
12	-	-	-	-	-	145.0	72	73
13	-	-	-	-	-	190.8	73	74
14	-	-	-	-	-	168.5	73	75
15	-	-	-	-	-	168.5	74	75
16	-	-	-	-	-	168.5	74	75
17	-	-	-	-	-	168.5	74	75
18	-	-	-	-	-	168.5	73	75
19	-	-	-	-	-	168.5	75	[illegible]
20	-	-	-	-	-	168.5	75	76
21	-	-	-	-	-	168.5	75	77
22	-	-	-	-	-	168.5	75	77
23	-	-	-	-	-	20.5	75	77
24	-	-	-	-	-	20.5	75	77
25	-	-	-	-	-	20.5	77	78
26	-	-	-	-	-	20.5	78	79
27	-	-	-	-	-	20.5	78	79
28	-	-	-	-	-	20.5	79	80
29	-	-	-	-	-	20.5	80	81
30	-	-	-	-	-	20.5	[illegible]	[illegible]
31	-	-	-	-	-	20.5	79	80

* Calculated

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

June, 19 70

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm) Residual	Demand	NaOCl Used Feed rate GPM	Gals.	* %(conc.)	Volume Treated (10^6 Gals)	Temp. (°F) In	Out
1	-	-	-	-	-	135	63	65
2	-	-	-	-	-	110.5	64	66
3	<0.1	1.2	1.25	50	9.0	110.5	66	67
4	-	-	-	-	-	110.5	66	67
5	-	-	-	-	-	110.5	66	67
[illegible]	-	-	-	-	-	110.5	66	67
[illegible]	-	-	-	-	-	110.5	66	67
[illegible]	-	-	-	-	-	110.5	66	67
9	-	-	-	-	-	110.5	67	68
10	-	-	-	-	-	110.5	68	69
11	-	-	-	-	-	300	68	69
12	-	-	-	-	-	300	69	70
13	-	-	-	-	-	300	68	69
14	-	-	-	-	-	300	68	69
15	<0.1	1.6	1.15	75	8.5	300	68	69
16	-	-	-	-	-	160	68	69
17	-	-	-	-	-	160	68	69
[illegible]	-	-	-	-	-	160	69	70
19	-	-	-	-	-	20.5	69	70
20	-	-	-	-	-	20.5	69	70
21	-	-	-	-	-	20.5	69	70
22	-	-	-	-	-	20.5	70	71
23	-	-	-	-	-	20.5	70	71
24	-	-	-	-	-	20.5	70	72
25	-	-	-	-	-	20.5	71	72
26	-	-	-	-	-	20.5	70	71
27	-	-	-	-	-	20.5	69	70
28	-	-	-	-	-	20.5	70	71
29	-	-	-	-	-	20.5	70	71
30	-	-	-	-	-	20.5	71	72
31								

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

May , 19 70

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm) Residual	Maximum Chlorine (ppm) Demand	NaOCl Used Feed Rate gpm	NaOCl Used Gals.	NaOCl Used * %(conc.)	Average Discharge Flow Rate M gpm	Temp. (°F) In	Temp. (°F) Out
1	-	-	-	-	-	19	52	54
2	-	-	-	-	-	19	53	54
3	-	-	-	-	-	19	53	54
4	-	-	-	-	-	19	53	54
5	-	-	-	-	-	19	53	55
6	-	-	-	-	-	19	53	55
7	-	-	-	-	-	19	54	55
8	-	-	-	-	-	19	55	56
9	-	-	-	-	-	19	55	56
10	-	-	-	-	-	19	56	57
11	-	-	-	-	-	19	57	58
12	-	-	-	-	-	19	58	60
13	-	-	-	-	-	19	58	59
14	-	-	-	-	-	19	57	58
15	-	-	-	-	-	19	57	58
16	-	-	-	-	-	19	57	58
17	-	-	-	-	-	19	57	58
18	-	-	-	-	-	19	58	59
19	-	-	-	-	-	300	59	60
20	-	-	-	-	-	256	61	? 82
21	-	-	-	-	-	166	61	? 69
22	-	-	-	-	-	162	62	? 75
23	-	-	-	-	-	112	60	61
24	-	-	-	-	-	112	61	62
25	-	-	-	-	-	112	63	64
26	-	-	-	-	-	200	61	62
27	-	-	-	-	-	112	60	61
28	-	-	-	-	-	110	62	63
29	-	-	-	-	-	135	62	64
30	-	-	-	-	-	135	62	[illegible]
31	-	-	-	-	-	135	62	63

* Calculated

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

April, 1970

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate gpm	Gals.	* %(conc.)		In	Out
1	-	-	-	-	-	150	37	38
2	-	-	-	-	-	280	37	38
3	-	-	-	-	-	19	38	39
4	-	-	-	-	-	300	40	41
5	-	-	-	-	-	150	40	41
6	-	-	-	-	-	225	40	40
[illegible]	-	-	-	-	-	300	40	41
8	-	-	-	-	-	300	41	41
9	-	-	-	-	-	266	41	41
10	-	-	-	-	-	250	42	42
11	-	-	-	-	-	250	43	43
12	-	-	-	-	-	250	44	44
13	-	-	-	-	-	270	44	44
14	-	-	-	-	-	300	44	44
15	-	-	-	-	-	300	45	45
16	-	-	-	-	-	260	45	45
17	-	-	-	-	-	120	45	45
[illegible]	-	-	-	-	-	120	46	46
19	-	-	-	-	-	120	46	46
20	-	-	-	-	-	300	47	47
21	-	-	-	-	-	280	48	48
22	-	-	-	-	-	295	49	49
23	-	-	-	-	-	257	49	49
24	-	-	-	-	-	220	50	50
25	-	-	-	-	-	190	50	50
26	-	-	-	-	-	173	50	50
27	-	-	-	-	-	180	50	50
28	-	-	-	-	-	19	51	51
29	-	-	-	-	-	19	51	51
30	-	-	-	-	-	19	52	52
31								

* Calculated **The unit was shutdown for refueling.

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
March 19[illegible]

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M GPM	Temp.	
	Residual	Demand	Feed Rate GPM	Gals.	* %(conc.)		In	Out
1	-	-	-	-	-	139	[illegible]	[illegible]
2	<0.1	1.0	1.25	75	12.7	300	[illegible]	[illegible]
[illegible]	-	-	-	-	-	300	[illegible]	[illegible]
4	<0.1	0.9	1.25	75	12.5	300	[illegible]	[illegible]
[illegible]	-	-	-	-	-	300	[illegible]	[illegible]
[illegible]	<0.1	0.9	1.15	75	12.3	300	[illegible]	[illegible]
[illegible]	-	-	-	-	-	300	[illegible]	[illegible]
[illegible]	-	-	-	-	-	300	[illegible]	[illegible]
9	-	-	-	-	-	300	[illegible]	[illegible]
10	-	-	-	-	-	300	[illegible]	[illegible]
[illegible]	<0.1	0.8	1.25	75	11.7	300	[illegible]	[illegible]
[illegible]	-	-	-	-	-	300	[illegible]	[illegible]
[illegible]	<0.1	0.8	1.25	75	11.5	[illegible]	[illegible]	[illegible]
[illegible]	-	-	-	-	-	300	[illegible]	[illegible]
[illegible]	-	-	-	-	-	225	[illegible]	40
[illegible]	<0.1	0.8	1.15	75	11.1	300	35	45
[illegible]	-	-	-	-	-	159	35	45
[illegible]	<0.1	0.8	0.7	25	10.9	159	35	37
[illegible]	-	-	-	-	-	300	[illegible]	[illegible]
20	<0.1	0.8	1.25	75	10.7	300	[illegible]	[illegible]
21	-	-	-	-	-	200	[illegible]	37
22	-	-	-	-	-	300	35	[illegible]
[illegible]	-	-	-	-	-	19	35	[illegible]
24	-	-	-	-	-	78	35	35
[illegible]	-	-	-	-	-	80	35	35
[illegible]	-	-	-	-	-	78	[illegible]	[illegible]
[illegible]	-	-	-	-	-	19	[illegible]	[illegible]
[illegible]	-	-	-	-	-	19	[illegible]	[illegible]
[illegible]	-	-	-	-	-	80	35	[illegible]
30	-	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	-	-	-	-	-	200	[illegible]	37

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
February, 1970

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm) Residual	Maximum Chlorine (ppm) Demand	NaOCl Used Feed Rate gpm	NaOCl Used Gals.	NaOCl Used * % (conc.)	Average Discharge Flow Rate M gpm	Temp. (°F) In	Temp. (°F) Out
1	<0.1	0.8	1.65	100	10.6	300	33	43
2	<0.1	0.9	1.65	100	10.5	225	33	43
3	-	-	-	-	-	275	33	43
4	<0.1	0.9	1.65	100	10.3	275	33	43
5	-	-	-	-	-	300	33	43
6	<0.1	0.9	1.25	75	15.3	300	33	43
7	-	-	-	-	-	300	33	43
8	-	-	-	-	-	300	33	43
9	<0.1	1.0	0.85	50	15.0	300	34	44
10	-	-	-	-	-	300	34	44
11	<0.1	1.0	1.25	75	14.8	300	34	44
12	-	-	-	-	-	300	34	44
13	<0.1	1.0	1.65	100	14.5	300	33	43
14	-	-	-	-	-	275	33	43
15	-	-	-	-	-	275	33	43
16	<0.1	1.0	1.65	100	14.2	300	33	43
17	-	-	-	-	-	173	33	34
18	-	-	-	-	-	300	33	43
19	<0.1	1.0	1.65	100	13.9	275	33	43
20	<0.1	1.0	1.65	100	13.8	300	33	43
21	-	-	-	-	-	300	33	43
22	-	-	-	-	-	300	33	43
23	-	-	-	-	-	300	33	43
24	<0.1	1.0	1.65	100	13.3	300	33	43
25	<0.1	1.0	1.65	100	13.2	300	33	43
26	-	-	-	-	-	194	33	38
27	<0.1	1.0	1.65	100	13.0	300	33	43
28	-	-	-	-	-	39	33	34
29								
30								
31								

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

January , 1970

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate	Gals.	* %(conc.)		In	Out
1	-	-	-	-	15.5	300	34	44
2	<0.1	0.9	1.55	100	13.4	300	34	44
[illegible]	-	-	-	-	13.3	300	33	43
4	-	-	-	-	13.2	300	33	43
[illegible]	<0.1	0.9	1.25	75	13.1	300	32	42
[illegible]	-	-	-	-	12.9	300	32	42
[illegible]	<0.1	0.9	1.25	75	12.8	250	32	[illegible]
[illegible]	-	-	-	-	12.8	250	32	43
[illegible]	<0.1	0.9	1.25	75	12.7	250	32	[illegible]
10	-	-	-	-	12.6	250	32	[illegible]
11	-	-	-	-	12.5	250	32	[illegible]
[illegible]	<0.1	0.9	0.75	50	12.4	250	32	[illegible]
[illegible]	-	-	-	-	12.3	250	32	[illegible]
14	<0.1	0.9	0.75	50	12.2	250	32	[illegible]
[illegible]	-	-	-	-	12.1	250	32	[illegible]
[illegible]	<0.1	0.9	1.25	75	12.0	250	32	[illegible]
[illegible]	-	-	-	-	11.9	250	32	[illegible]
[illegible]	-	-	-	-	11.9	250	32	[illegible]
[illegible]	<0.1	0.8	0.85	50	11.[illegible]	250	32	[illegible]
[illegible]	-	-	-	-	11.7	19	32	[illegible]
[illegible]	-	-	-	-	11.6	19	32	[illegible]
[illegible]	<0.1	0.8	0.79	25	11.5	159	32	44
[illegible]	<0.1	0.8	0.85	50	11.4	250	32	45
[illegible]	-	-	-	-	11.3	250	32	[illegible]
[illegible]	-	-	-	-	11.2	250	33	[illegible]
[illegible]	<0.1	0.8	1.0	75	11.1	250	33	[illegible]
[illegible]	-	-	-	-	11.0	250	32	[illegible]
[illegible]	<0.1	0.8	1.0	75	11.0	275	[illegible]	[illegible]
[illegible]	-	-	-	-	10.[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]
31	-	-	-	-	10.7	275	32	[illegible]

* Calculated

Consolidated Edison Co. of N.Y., Inc. — Indian Point Station

December, 1969

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate gpm	Gals.	* %(conc.)		In	Out
1	<0.1	0.8	2.1	125	10.2	300	44	54
2	-	-	-	-	-	300	44	54
3	<0.1	0.8	2.5	150	10.2	300	44	54
4	-	-	-	-	-	300	44	54
5	<0.1	0.9	2.3	150	10.1	300	43	53
6	-	-	-	-	-	300	43	53
7	-	-	-	-	-	300	43	53
8	<0.1	0.8	2.5	150	10.0	300	42	52
9	-	-	-	-	-	300	42	52
10	<0.1	0.8	2.5	150	10.0	300	42	52
11	-	-	-	-	-	300	42	52
12	<0.1	0.9	1.25	75	15.9	300	43	53
13	-	-	-	-	-	300	43	53
14	-	-	-	-	-	300	42	52
15	<0.1	0.9	1.25	75	15.5	300	42	52
16	-	-	-	-	-	300	41	51
17	<0.1	0.9	1.25	75	15.2	300	40	50
18	-	-	-	-	-	300	40	50
19	<0.1	0.9	1.25	75	15.0	300	39	49
20	-	-	-	-	-	300	39	49
21	-	-	-	-	-	300	38	48
22	<0.1	0.9	1.25	75	14.6	300	38	48
23	-	-	-	-	-	300	37	47
24	<0.1	1.0	1.25	75	14.4	300	36	46
25	-	-	-	-	-	300	36	46
26	<0.1	1.0	1.25	75	14.1	300	35	45
27	-	-	-	-	-	300	35	45
28	-	-	-	-	-	300	34	44
29	<0.1	1.0	1.25	75	13.7	300	33	42
30	-	-	-	-	-	300	33	43
31	<0.1	1.0	1.25	75	13.5	300	33	43

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

Nov. , 1969

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate gpm	Gals.	* %(conc.)		In	Out
1	-	-	-	-	-	300	59	69
2	-	-	-	-	-	300	59	69
3	<0.1	1.0	1.9	125	11.4	300	58	68
4	-	-	-	-	-	300	57	67
5	<0.1	1.0	2.1	125	11.2	300	57	67
6	-	-	-	-	-	300	56	66
	<0.1	0.9	2.1	125	11.0	300	56	66
8	-	-	-	-	-	300	56	66
9	-	-	-	-	-	300	55	65
10	<0.1	0.9	2.1	125	10.8	300	55	65
11	-	-	-	-	-	300	55	65
12	<0.1	0.9	2.1	125	10.1	300	56	67
13	-	-	-	-	-	300	54	64
14	<0.1	0.9	2.1	125	10.7	300	53	63
15	-	-	-	-	-	300	53	63
16	-	-	-	-	-	300	53	63
17	<0.1	0.8	2.1	125	10.6	300	54	66
	-	-	-	-	-	300	52	62
19	<0.1	0.8	2.1	125	10.6	300	51	61
20	-	-	-	-	-	300	51	61
21	<0.1	0.8	1.7	100	10.5	300	51	61
22	-	-	-	-	-	300	50	60
23	-	-	-	-	-	300	50	60
24	<0.1	0.8	2.1	125	10.5	300	49	59
25	-	-	-	-	-	300	48	58
26	<0.1	0.8	2.1	125	10.4	300	47	57
27	-	-	-	-	-	300	47	57
28	<0.1	0.8	2.1	125	10.4	300	46	56
29	-	-	-	-	-	300	46	56
30	-	-	-	-	-	300	46	[illegible]
31								

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
October, 1969

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Feed rate GPM	Gals.	* %(conc.)		In	Out
1	<0.1	1.0	2.3	150	13.3	300	67	77
2	-	-	-	-	-	300	67	77
3	<0.1	1.0	2.3	150	13.1	300	67	77
4	-	-	-	-	-	300	67	77
5	-	-	-	-	-	300	68	78
[illegible]	<0.1	1.0	2.3	150	12.9	300	68	78
[illegible]	-	-	-	-	-	300	68	78
[illegible]	<0.1	1.0	2.3	150	12.7	300	68	78
[illegible]	-	-	-	-	-	300	68	78
[illegible]	<0.1	1.0	1.5	100	15.6	300	68	78
[illegible]	-	-	-	-	-	300	68	78
[illegible]	-	-	-	-	-	300	68	78
[illegible]	<0.1	1.0	1.2	75	15.0	300	68	78
[illegible]	-	-	-	-	-	300	68	78
[illegible]	-	-	-	-	-	300	67	78
[illegible]	-	-	-	-	-	22	67	67
[illegible]	-	-	-	-	-	22	66	[illegible]
[illegible]	-	-	-	-	-	22	66	[illegible]
[illegible]	-	-	-	-	-	300	65	75
[illegible]	<0.1	1.0	1.2	75	13.6	300	65	75
[illegible]	-	-	-	-	-	300	65	75
[illegible]	<0.1	1.0	1.5	100	13.2	300	65	75
[illegible]	-	-	-	-	-	300	65	75
[illegible]	<0.1	1.0	1.9	125	12.8	300	64	74
[illegible]	-	-	-	-	-	300	63	73
[illegible]	-	-	-	-	-	300	62	72
[illegible]	<0.1	1.0	1.9	125	12.2	300	60	70
[illegible]	-	-	-	-	-	300	60	70
[illegible]	<0.1	1.0	1.9	125	12.0	300	59	69
[illegible]	-	-	-	-	-	300	60	70
31	<0.1	1.0	2.3	150	11.6	300	60	70

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

Sept., 1969

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Volume Treated (10^6 Gals)	Temp. (^{o}F)	
	Residual	Demand	Feed rate GPM	Gals.	* %(conc.)		In	Out
1	<0.1	0.9	2.3	150	11.4	300	78	[illegible]
2	-	-	-	-	-	300	78	88
3	<0.1	0.9	2.3	150	11.2	300	78	88
4	-	-	-	-	-	300	79	89
5	<0.1	0.9	2.3	150	11.0	300	79	89
[illegible]	-	-	-	-	-	300	79	89
[illegible]	-	-	-	-	-	300	78	88
[illegible]	<0.1	0.9	2.3	150	11.8	300	78	88
[illegible]	-	-	-	-	-	300	78	88
10	<0.1	0.9	1.9	125	11.7	300	79	89
11	-	-	-	-	-	300	79	89
[illegible]	<0.1	0.9	2.3	150	11.5	300	79	89
13	-	-	-	-	-	300	79	89
[illegible]	-	-	-	-	-	300	78	88
[illegible]	<0.1	0.9	1.4	100	15.7	300	78	89
[illegible]	-	-	-	-	-	300	77	87
[illegible]	<0.1	0.9	1.5	100	15.6	300	76	86
[illegible]	-	-	-	-	-	300	76	86
[illegible]	-	-	-	-	-	300	75	85
[illegible]	-	-	-	-	-	300	75	85
[illegible]	<0.1	0.9	1.9	125	15.1	300	74	84
[illegible]	<0.1	1.0	2.3	150	15.0	300	73	83
[illegible]	-	-	-	-	-	300	74	84
[illegible]	<0.1	1.0	2.3	150	14.8	300	74	84
[illegible]	-	-	-	-	-	300	73	83
[illegible]	<0.1	1.0	2.3	150	14.5	300	73	83
[illegible]	-	-	-	-	-	300	72	82
[illegible]	-	-	-	-	-	300	71	81
[illegible]	-	-	-	-	-	300	71	81
30	-	-	-	-	-	300	70	80
31	-	-	-	-	-	300	[illegible]	[illegible]

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
August, 1969

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm) Residual	Maximum Chlorine (ppm) Demand	NaOCl Used Feed rate GPM	NaOCl Used Gals.	NaOCl Used * %(conc.)	Volume Treated (10^6 Gals)	Temp. (°[illegible] In	Temp. Out
1	<0.1	1.0	4.6	300	6.1	300	76	[illegible]
2	-	-	-	None	-	300	76	[illegible]
3	-	-	-	None	-	300	77	[illegible]
4	<0.1	1.0	4.6	300	5.7	300	77	85
5	-	-	-	None	-	300	77	[illegible]
[illegible]	<0.1	0.9	4.6	300	5.4	300	77	86
7	-	-	-	None	-	300	77	87
	<0.1	0.9	4.6	300	5.1	300	77	[illegible]
[illegible]	-	-	-	None	-	300	77	[illegible]
10	-	-	-	None	-	300	78	79
11	<0.1	0.9	1.5	100	14.7	300	78	[illegible]
12	-	-	-	None	-	300	77	[illegible]
13	<0.1	0.9	1.5	100	14.5	300	78	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
[illegible]	<0.1	0.9	1.5	100	14.2	300	78	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
17	-	-	-	None	-	300	77	[illegible]
[illegible]	<0.1	0.9	1.5	100	13.8	300	77	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
[illegible]	<0.1	0.9	1.9	125	13.5	300	78	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
[illegible]	<0.1	0.9	1.9	125	13.2	300	78	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
[illegible]	<0.1	0.9	1.9	125	12.5	300	78	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
[illegible]	<0.1	0.9	2.0	130	12.2	300	78	[illegible]
[illegible]	-	-	-	None	-	300	78	[illegible]
[illegible]	<0.1	0.9	2.1	135	11.8	300	78	[illegible]
[illegible]	-	-	-	None	-	300	[illegible]	[illegible]
31	-	-	-	None	-	300	78	[illegible]

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
July, 1969

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate gph	Gals.	* % (conc.)		In	Out
1	-	-	-	None	-	300	74	[illegible]
2	-	-	-	None	-	300	74	[illegible]
3	-	-	-	None	-	300	74	[illegible]
4	-	-	-	None	-	300	74	[illegible]
5	-	-	-	None	-	300	74	[illegible]
[illegible]	-	-	-	None	-	300	75	85
[illegible]	<0.1	1.0	0.8	200	9.3	300	75	[illegible]
[illegible]	-	-	-	None	-	300	74	[illegible]
[illegible]	<0.1	1.0	0.5	50	9.1	300	74	[illegible]
10	<0.1	1.0	1.0	125	9.0	300	74	[illegible]
[illegible]	-	-	-	None	-	300	75	[illegible]
[illegible]	<0.1	1.0	2.3	150	8.8	300	75	[illegible]
13	-	-	-	None	-	300	75	[illegible]
[illegible]	-	-	-	None	-	300	75	[illegible]
[illegible]	<0.1	1.1	2.7	175	8.5	300	75	[illegible]
[illegible]	-	-	-	None	-	300	76	[illegible]
[illegible]	<0.1	1.1	3.1	200	8.2	300	75	[illegible]
[illegible]	<0.1	1.1	3.1	200	8.0	300	75	[illegible]
[illegible]	-	-	-	None	-	300	75	[illegible]
[illegible]	-	-	-	None	-	300	75	[illegible]
[illegible]	<0.1	1.1	3.1	200	7.6	300	74	84
[illegible]	-	-	-	None	-	300	75	[illegible]
[illegible]	<0.1	1.0	3.1	125	7.3	300	75	[illegible]
[illegible]	-	-	-	None	-	19	75	[illegible]
[illegible]	-	-	-	None	-	19	75	[illegible]
[illegible]	-	-	-	None	-	19	75	[illegible]
[illegible]	-	-	-	None	-	19	76	[illegible]
[illegible]	-	-	-	None	-	19	76	[illegible]
[illegible]	-	-	-	[illegible]	-	300	76	[illegible]
[illegible]	<0.1	1.0	4.6	300	6.4	300	76	[illegible]
31	-	-	-	None	-	300	76	[illegible]

* Calculated

COOLING WATER DATA JUNE

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. °F	
	Residual	Demand	Feed Rate gph	Gals.	*%(conc.)		In	Out
1	-	-	-	None	-	300	65	76
2	< 0.1	0.9	1.55	100	10.1	300	65	76
3	-	-	-	None	-	300	65	76
4	< 0.1	0.9	1.55	100	9.9	300	65	76
5	-	-	-	None	-	300	66	77
6	< 0.1	0.9	1.9	125	9.6	300	67	78
7	-	-	-	None	-	300	67	78
8	-	-	-	None	-	300	68	79
9	< 0.1	0.9	2.3	150	9.2	300	69	80
10	-	-	-	None	-	300	69	80
11	< 0.1	1.0	2.3	150	8.9	300	69	80
12	-	-	-	None	-	300	69	80
13	< 0.1	1.0	3.1	200	8.6	300	70	81
14	-	-	-	None	-	300	70	81
15	-	-	-	None	-	300	70	81
16	< 0.1	1.0	3.1	200	8.2	300	70	81
17	-	-	-	None	-	300	70	80
18	< 0.1	1.0	1.9	125	15.6	300	70	81
19	-	-	-	None	-	300	71	81
20	< 0.1	1.0	1.9	125	15.4	300	71	81
21	-	-	-	None	-	300	72	80
22	-	-	-	None	-	300	72	79
23	< 0.1	0.9	1.9	125	15.0	300	71	81
24	-	-	-	None	-	300	71	81
25	< 0.1	0.9	1.9	125	14.7	300	71	81
26	-	-	-	None	-	300	71	81
27	< 0.1	1.0	1.9	125	14.5	300	72	82
28	-	-	-	None	-	300	73	83
29	-	-	-	None	-	300	74	84
30	< 0.1	1.0	2.3	150	10.0	300	74	84
31								

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

May, 19 69

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (°F)	
	Residual	Demand	Feed Rate GPM	Gals.	* %(conc.)		In	Out
1	<0.1	0.9	1.15	75	13.8	300	51	61
2	<0.1	1.1	1.15	75	13.7	300	52	60
3	-	-	-	None	-	300	52	60
4	-	-	-	None	-	300	52	62
5	<0.1	0.8	1.15	75	13.3	300	52	60
6	-	-	-	None	-	300	52	60
[illegible]	<0.1	0.9	1.15	75	13.1	300	52	60
8	-	-	-	None	-	300	53	63
9	<0.1	1.0	1.55	100	13.0	300	55	65
10	-	-	-	None	-	300	55	65
11	-	-	-	None	-	300	55	65
12	<0.1	1.0	1.55	100	12.6	300	55	65
13	-	-	-	None	-	300	56	66
14	<0.1	1.1	1.35	100	12.4	300	56	66
15	-	-	-	None	-	300	56	66
16	<0.1	1.0	1.55	100	12.2	300	57	67
17	-	-	-		-	20	57	57
18	-	-	-		-	20	58	58
19	-	-	-		-	20	58	58
20	-	-	-		-	19	60	60
21	-	-	-		-	19	60	60
22	-	-	-		-	21	59	59
23	-	-	-		-	19	59	59
24	-	-	-		-	19	59	59
25	-	-	-		-	19	59	59
26	<0.1	1.0	1.55	100	11.0	300	59	67
27	-	-	-	None	-	300	60	63
28	<0.1	0.9	1.55	100	10.8	300	61	72
[illegible]	-	-	-	None	-	300	62	73
30	-	-	-	[illegible]	-	300	[illegible]	[illegible]
31	-	-	-	None	-	300	65	76

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

April, 1969

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate M gpm	Temp. (	
	Residual	Demand	Feed Rate GPM	Gals.	* % (conc.)		In	Out
1	<0.1	1.0	2.5	75	8.9	300	41	51
2	<0.1	1.0	1.0	25	8.9	300	41	52
3	<0.1	1.0	1.0	25	8.9	300	40	49
4	<0.1	0.9	1.5	100	8.8	300	41	51
5	-	-	-	None	-	300	42	53
6	-	-	-	None	-	300	42	52
7	<0.1	0.9	1.5	100	8.8	300	42	53
8	-	-	-	None	-	300	42	53
9	<0.1	0.9	1.2	75	16.4	300	42	53
10	-	-	-	None	-	300	42	52
11	<0.1	0.9	1.5	100	16.2	300	43	55
12	-	-	-	None	-	300	44	56
13	-	-	-	None	-	300	45	55
14	<0.1	1.0	1.5	100	15.8	300	45	56
15	-	-	-	None	-	300	46	56
16	<0.1	1.1	1.9	125	15.6	300	47	57
17	-	-	-	None	-	300	47	57
18	<0.1	1.0	1.5	100	15.4	300	47	57
19	-	-	-	None	-	300	48	58
20	-	-	-	None	-	300	48	59
21	<0.1	0.9	1.4	90	15.0	300	49	59
22	-	-	-	None	-	300	49	59
23	<0.1	0.9	1.4	90	14.8	300	49	5[illegible]
24	-	-	-	None	-	300	49	59
25	<0.1	0.9	1.4	90	14.6	300	49	59
26	-	-	-	None	-	300	50	60
27	-	-	-	None	-	300	51	61
28	<0.1	0.9	1.2	80	14.2	300	51	61
29	-	-	-	None	-	300	51	61
30	-		-	None	-	300	52	6[illegible]
31								

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

March, 19 69

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used			Average Discharge Flow Rate % gpm	Temp. [illegible]	
	Residual	Demand	Feed Rate gpm	Gals.	(Conc.)		In	[illegible]
1	-	-	-	None	-	16	33	**
2	-	-	-	"	-	16	33	**
3	-	-	-	"	-	16	34	**
4	-	-	-	"	-	16	34	**
5	-	-	-	"	-	16	34	**
6	-	-	-	"	-	16	34	**
7	-	-	-	"	-	16	34	**
8	-	-	-	"	-	16	34	**
9	-	-	-	"	-	16	34	**
10	-	-	-	"	-	16	34	**
11	-	-	-	"	-	16	34	**
12	-	-	-	"	-	16	35	**
13	-	-	-	"	-	16	35	**
14	-	-	-	"	-	16	35	**
15	-	-	-	"	-	16	[illegible]	**
16	-	-	-	"	-	16	35	**
17	-	-	-	"	-	16	35	**
18	-	-	-	"	-	35	37	**
19	-	-	-	"	-	35	37	**
20	-	-	-	"	-	155	37	37
21	-	-	-	"	-	165	37	37
22	-	-	-	"	-	165	[illegible]	[illegible]
23	-	-	-	"	-	165	37	37
24	-	-	-	"	-	165	37	37
[illegible]	-	-	-	"	-	150	[illegible]	[illegible]
[illegible]	-	-	-	"	-	150	39	39
[illegible]	-	-	-	"	-	300	39	41
[illegible]	-	-	-	"	-	300	40	42
[illegible]	-	-	-	"	-	300	41	52
[illegible]	-	-	-	"	-	300	41	[illegible]
[illegible]	-	-	-	"	-	300	42	52

* Calculated

** Main circulators shut down

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
February , 19 69

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm) Residual	Maximum Chlorine (ppm) Demand	NaOCl Used Gals.	NaOCl Used ** % (conc.)	Volume Treated (10^6 Gals)	Temp. (°F) In	Temp. (°F) Out
1	<0.1	0.6	100	10.9	19.5	[illegible]	[illegible]
2	<0.1	0.6	100	10.9	19.5	41	[illegible]
3	<0.1	0.6	100	10.8	19.5	[illegible]	[illegible]
4	-	-	-	-	None	36	53
5	<0.1	0.5	95	10.7	19.5	35	40
6	-	-	-	-	None	38	[illegible]
7	<0.1	0.5	90	10.6	19.5	36	40
8	-	-	-	-	None	39	52
9	-	-	-	-	None	35	51
10	<0.1	0.5	90	10.5	19.5	34	47
11	-	-	-	-	None	34	47
12	0.4	0.3	40	10.4	[illegible]	[illegible]	24
13	-	-	-	-	None	33	*
14	-	-	-	-	None	33	*
15	-	-	-	-	None	33	*
16	-	-	-	-	None	33	*
17	-	-	-	-	None	33	*
18	-	-	-	-	None	33	*
19	-	-	-	-	None	33	*
20	-	-	-	-	None	33	*
21	-	-	-	-	None	33	*
22	-	-	-	-	None	33	*
23	-	-	-	-	None	33	*
24	-	-	-	-	None	33	*
25	-	-	-	-	None	33	*
26	-	-	-	-	None	33	*
27	-	-	-	-	None	34	*
28	-	-	-	-	None	34	*
29	-	-	-	-	None	34	*
30							
31	* Main Circulator Shut Down						

** Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

January , 19 69

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* % (conc.)		In	Out
1	0.2	0.3	75	12.3	19.5	[illegible]	47
2	-	-	-	12.3	None	33	43
3	-	-	-	12.2	None	33	43
4	0.1	0.4	75	12.2	19.5	34	44
5	-	-	-	12.1	None	34	44
6	<0.1	0.3	75	12.1	19.5	34	44
7	-	-	-	12.0	None	34	45
8	<0.1	0.5	75	12.0	19.5	37	48
9	-	-	-	12.0	None	35	49
10	<0.1	0.4	50	11.9	16.5	39	50
11	-	-	-	11.9	None	34	45
12	-	-	-	11.8	None	34	45
13	<0.1	0.5	75	11.8	19.5	[illegible]	[illegible]
14	-	-	-	11.7	None	34	45
15	<0.1	0.5	75	11.7	19.5	34	45
16	-	-	-	11.6	None	35	46
17	<0.1	0.4	65	11.6	19.5	[illegible]	[illegible]
18	-	-	-	11.6	None	34	44
19	-	-	-	11.5	None	34	44
20	<0.1	0.4	65	11.5	19.5	[illegible]	47
21	-	-	-	11.4	None	34	44
22	<0.1	0.4	70	11.4	19.5	40	52
23	-	-	-	11.3	None	40	52
24	<0.1	0.4	65	11.3	19.5	37	51
25	-	-	-	11.2	None	34	50
26	-	-	-	11.2	None	33	49
27	0.1	0.3	65	11.1	18.0	[illegible]	51
28	<0.1	0.3	65	11.1	22.5	34	50
29	<0.1	0.3	55	11.0	19.5	35	51
30	<0.1	0.3	60	11.0	10.5	34	[illegible]
31	<0.1	0.4	65	10.9	18.0	35	51

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

December, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	%(conc.)		In	Out
1	-	-	-	14.2	None	44	52
2	0.1	0.8	125	14.1	19.5	44	44
3	-	-	-	14.1	None	44	52
4	0.1	0.8	125	14.0	19.5	44	52
5	-	-	-	13.9	None	44	52
6	0.1	0.8	125	13.9	19.5	44	52
7	-	-	-	13.8	None	43	51
8	-	-	-	13.8	None	41	50
9	<0.1	0.5	70	13.7	19.5	41	50
10	-	-	-	13.6	None	39	47
11	<0.1	0.2	40	13.6	19.5	37	46
12	-	-	-	13.5	None	39	46
13	0.1	0.3	60	13.4	19.5	41	50
14	-	-	-	13.4	None	37	47
15	-	-	-	13.3	None	37	45
16	<0.1	0.4	55	13.3	19.5	35	44
17	-	-	-	13.2	-	37	46
18	-	-	-	13.1	-	38	47
19	-	-	-	13.1	-	36	45
20	-	-	-	13.0	-	37	46
21	-	-	-	12.9	-	37	47
22	-	-	-	12.9	-	37	46
23	0.3	0.9	125	12.8	13.5	39	48
24	-	-	-	12.8	-	37	47
25	0.2	0.5	100	12.7	19.5	36	47
26	-	-	-	12.6	-	35	44
27	0.3	0.4	100	12.6	19.5	34	44
28	-	-	-	12.5	-	35	45
29	-	-	-	12.4	-	36	45
30	0.3	0.4	100	12.4	19.5	[illegible]	44
31	-	-	-	12.3	-	[illegible]	44

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
November, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp.	
	Residual	Demand	Gals.	*%(conc.)		In	Out
1	<0.1	0.5	75	12.0	19.5	60	67
2	-	-	-	11.9	None	60	67
3	-	-	-	11.8	None	60	67
4	<0.1	0.5	75	11.7	19.5	56	64
5	-	-	-	11.6	None	56	63
6	<0.1		75	11.5	19.5	56	64
7	-	-	-	11.4	None	56	64
8	0.1	0.4	75	11.3	19.5	57	64
9	-	-	-	11.2	None	56	64
10	-	-	-	11.1	None	51	51
11	<0.1	0.4	50	11.0	19.5	51	51
12	-	-	-	10.9	None	51	51
13	0.1	0.4	75	10.8	19.5	51	51
14	-	-	-	10.7	None	51	51
15	-	-	-	10.6	None	51	51
16	-	-	-	10.5	None	51	51
17	-	-	-	10.4	None	51	51
18	-	-	-	10.3	None	51	51
19	-	-	-	10.2	None	51	51
20	-	-	-	10.1	None	51	51
21	-	-	-	10.0	None	[illegible]	[illegible]
22	-	-	-	9.9	None	[illegible]	[illegible]
23	-	-	-	9.8	None	[illegible]	[illegible]
24	-	-	-	9.7	None	51	51
25	-	-	-	9.6	None	[illegible]	[illegible]
26	-	-	-	9.5	None	[illegible]	[illegible]
27	-	-	-	9.4	None	[illegible]	[illegible]
28	-	-	-	9.3	None	47	[illegible]
29	-	-	-	9.2	None	47	47
30	-	-	-	9.1	None	[illegible]	[illegible]
31	-	-	-	9.0	None	[illegible]	[illegible]

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
October, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	—	—	15.1	–	NONE	72	73
2	<0.1	1.0	15.0	175	25.5	72	79
3	—	—	14.9		NONE	72	79
4	<0.1	0.9	14.8	115	19.5	71	78
5	—	—	14.7	–	NONE	69	76
6	—	—	14.6	–	NONE	68	76
7	0.2	0.8	14.5	135	19.5	68	76
8	—	—	14.4	–	NONE	68	76
9	0.1	0.7	14.3	100	19.5	68	76
10	—	—	14.2	–	NONE	68	76
11	0.1	0.7	14.1	100	19.5	68	76
12	—	—	14.0	–	NONE	68	76
13	—	—	13.9	–	NONE	67	75
14	0.1	0.7	13.8	100	19.5	67	75
15	—	—	13.7	–	NONE	67	75
16	<0.1	0.7	13.6	100	19.5	66	73
17	—	—	13.5	–	NONE	66	73
18	—	—	13.4	–	NONE	66	73
19	—	—	13.3	–	NONE	66	73
20	—	—	13.2	–	NONE	66	74
21	<0.1	0.7	12.1	105	19.5	65	73
22	—	—	13.0	–	NONE	64	71
23	<0.1	0.8	12.9	125	19.5	65	72
24	—	—	12.8	–	NONE	65	72
25	<0.1	0.7	12.7	75	13.5	65	72
26	—	—	12.6	–	NONE	64	71
27	—	—	12.5	–	NONE	64	71
28	<0.1	0.7	12.4	100	19.5	63	70
29	—	—	12.3	–	NONE	62	69
30	<0.1	0.6	12.2	100	19.5	61	68
31	—	—	12.1	–	NONE	60	67

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
SEPTEMBER, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	—	—	—	14.3	NONE	76	86
2	<0.1	1.1	150	14.2	19.5	76	86
3	—	—	—	14.1	NONE	75	85
4	<0.1	1.2	575	15.2	70.5	76	86
5	—	—	—	15.1	NONE	76	86
6	<0.1	1.3	75	15.0	9.0	76	86
7	—	—	—	14.9	NONE	76	86
8	—	—	—	14.8	NONE	76	86
9	—	—	—	14.7	NONE	76	86
10	—	—	—	14.6	NONE	76	86
11	<0.1	1.5	175	14.5	16.5	75	86
12	—	—	—	14.4	NONE	75	85
13	—	—	—	14.3	NONE	74	84
14	—	—	—	14.2	NONE	74	74
15	—	—	—	14.1	NONE	75	75
16	—	—	—	14.0	NONE	75	86
17	—	—	—	13.9	NONE	73	83
18	<0.1	1.0	275	13.8	25.5	73	83
19	—	—	—	13.7	NONE	72	82
20	0.1	1.1	625	13.6	73.5	72	82
21	—	—	—	13.5	NONE	72	82
22	—	—	—	13.4	NONE	72	82
23	0.1	1.1	[illegible]	13.3	37.5	73	83
24	—	—	—	13.2	NONE	72°	82°
25	—	—	—	13.1	NONE	72°	82°
26	—	—	—	15.5	NONE	72°	82°
27	<0.1	1.2	150	15.4	19.5	71	81
28	—	—	—	15.3	NONE	70	81
29	—	—	—	15.2	NONE	70	80
30	<0.1	1.1	245	15.1	34.5	68	78
31							

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
AUGUST, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	—	—	—	14.9	NONE	78	88
2	<0.1	0.8	375	14.8	57.0	78	88
3	—	—	—	14.7	NONE	78	88
4	—	—	—	14.6	NONE	78	88
5	<0.1	0.7	375	14.5	79.5	78	89
6	—	—	—	15.8	NONE	78	88
7	—	—	—	15.7	None	78	88
8	—	—		15.6	NONE	78	88
9	<0.1	1.0	120	15.5	19.5	78	88
10	—	—	—	15.4	NONE	78	88
11	—	—	—	15.3	None	77	88
12	0.1	0.9	130	15.2	19.5	77	88
13	—	—	—	15.1	NONE	79	89
14	<0.1	1.1	600	15.0	78.0	78	88
15				14.9	NONE	79	89
16	<0.1	1.1	800	14.8	105.0	78	88
17	—	—		14.7	NONE	78	88
18	—	—	—	14.6	None	78	88
19	<0.1	1.0	600	14.5	85.5	78	88
20	—	—	—	14.4	NONE	78	88
21	<0.1	0.9	125	14.3	19.5	79	89
22	—	—	—	14.2	NONE	78	88
23	0.1	0.9	365	15.2	55.5	78	88
24	—	—	—	15.1	NONE	78	88
25	—	—	—	15.0	NONE	79	89
26	<0.1	1.2	655	14.9	79.5	78	88
27	—	—	—	14.8	NONE	78	88
28	<0.1	1.1	155	14.7	19.5	78	88
29	—	—	—	14.6	NONE	78	88
30	<0.1	1.1	625	14.5	780	77	87
31	—	—	—	14.4	NONE	76	86

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
July, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	0.2	0.5	105	12.7	19.5	71	82
2	0.1	0.7	400	12.6	60.0	72	83
3	<0.1	0.8	275	12.5	42.9	73	84
4	–	–	–	15.6	NONE	73	84
5	<0.1	0.8	100	15.5	18.0	73	84
6	–	–	–	15.4	NONE	71	82
7	–	–	–	15.3	NONE	74	84
8	<0.1	1.0	475	15.2	73.5	74	85
9	–	–	–	15.1	NONE	74	
10	<0.1	0.8	100	15.0	19.5	74	85
11	–	–	–	14.9	NONE	74	85
12	<0.1	0.7	275	14.8	48.0	74	85
13	–	–	–	14.7	NONE	74	85
14	–	–	–	14.6	NONE	74	84
15	<0.1	0.9	425	14.5	67.5	75	86
16	–	–	–	14.4	NONE	77	88
17	0.1	0.8	125	14.3	19.5	77	88
18	–	–	–	14.2	NONE	77	88
19	<0.1	0.8	400	14.1	69.0	78	89
20	–	–	–	14.0	NONE	77	88
21	–	–	–	13.9	NONE	77	88
22	0.1	0.9	490	13.8	73.5	78	89
23	–	–	–	15.8	NONE	79	90
24	<0.1	0.9	130	15.7	19.5	78	89
25	–	–	–	15.6	NONE	79	90
26	0.1	0.9	440	15.5	67.5	79	90
27	–	–	–	15.4	NONE	79	90
28	–	–	–	15.3	NONE	79	89
29	0.1	1.1	675	15.2	79.5	77	87
30	–	–	–	15.1	NONE	78	87
31	0.1	1.0	140	15.0	19.5	79	89

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
JUNE, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	—	—	—	11.7	NONE	65	65
2	—	—	—	11.6	NONE	68	68
3	0.2	0.4	100	16.5	19.5	64	74
4	—	—	—	16.4	NONE	65	75
5	0.1	0.5	100	16.3	19.5	65	75
6	—	—	—	11.2	NONE	66	76
7	0.1	0.7	330	11.1	44.4	67	77
8	—	—	—	11.0	NONE	68	78
9	—	—	—	10.9	NONE	68	78
10	0.2	0.5	125	10.8	19.5	68	79
11	—	—	—	10.7	NONE	68	79
12	0.1	0.7	150	10.6	19.5	68	80
13	—	—	—	14.5	NONE	68	79
14	0.2	1.0	450	14.4	560	68	78
15	—	—	—	14.3	NONE	67	78
16	—	—	—	14.2	NONE	68	79
17	0.2	0.7	125	14.1	19.5	68	80
18	<0.1	1.2	300	14.0	34.5	68	80
19	<0.1	0.7	100	13.9	19.5	68	80
20	—	—	—	13.8	NONE	68	79
21	0.1	0.6	100	13.7	19.5	68	78
22				13.6	NONE	68	80
23				13.5	NONE	67	78
24	0.4	0.6	330	13.4	43.5	69	79
25				13.3	NONE	68	80
26	0.9	0.4	580	13.2	61.5	68	80
27				13.1	NONE	65	75
28	0.2	0.5	390	13.0	720	69	81
29				12.9	NONE	70	82
30				12.8	NONE	70	71
31							

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

MAY, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	—	—	—	14.8	NONE	54°	54°
2	—	—	—	14.7	NONE	57°	57°
3	—	—	—	14.6	"	57°	57°
4	—	—	—	14.5	"	55°	55°
5	—	—	—	14.4	"	55	55
6	0.3	0.4	100	14.3	19.5	54	64
7	—	—	—	14.2	NONE	58	66
8	0.1	0.5	80	14.1	19.5	57	66
9	—	—	—	14.0	NONE	55	65
10	<0.1	0.6	100	13.9	19.5	58	68
11	—	—	—	13.8	NONE	59	68
12	—	—	—	13.7	NONE	57	66
13	<0.1	0.5	80	13.6	19.5	60	69
14	—	—	—	12.5	NONE	60	70
15	<0.1	0.6	100	13.4	19.5	60	68
16	—	—	—	13.3	NONE	60	70
17	0.1	0.6	100	13.2	19.5	61	71
18	—	—	—	13.1	NONE	60	68
19	—	—	—	13.0	NONE	61	69
20	0.1	0.4	75	12.9	24.0	57	65
21	—	—	—	12.8	NONE	61	68
22	0.1	0.5	100	12.7	19.5	62	78
23	—	—	—	12.6	NONE	61	68
24	0.1	0.5	100	12.5	19.5	62	72
25	—	—	—	12.4	NONE	62	71
26	—	—	—	12.3	NONE	62	71
27	0.1	0.4	85	12.2	19.5	62	71
28	—	—	—	12.1	NONE	63	72
29	<0.1	0.4	75	12.0	19.5	65	[illegible]
30	—	—	—	11.9	NONE	62	72
31	—	—	—	11.8	NONE	64	74

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

APRIL, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	0.3	0.4	100	13.9	19.5	42	52
2	0.3	0.6	125	13.8	19.5	43	53
3	0.3	0.6	125	13.7	19.5	46	54
4	0.3	0.6	125	13.6	19.5	46	54
5	0.3	0.6	125	13.5	19.5	44	54
6	0.3	0.6	125	13.4	19.5	42	52
7	0.3	0.6	125	13.3	19.5	42	52
8	0.3	0.5	125	13.2	19.5	42	52
9	—	—	—	13.1	NONE	49	59
10	0.1	0.6	100	13.0	19.5	48	58
11	—	—	—	12.9	NONE	49	59
12	0.1	0.5	100	12.8	19.5	49	59
13	—	—	—	12.7	NONE	50	60
14	—	—	—	12.6	NONE	50	60
15	0.1	0.6	110	12.5	19.5	52	62
16	—	—	—	12.4	NONE	52	61
17	0.2	0.6	60	12.3	13.5	53	62
18	0.2	0.6	65	12.2	9.0	53	62
19	0.2	0.5	100	12.1	19.5	52	61
20	—	—	—	12.0	NONE	53	63
21	—	—	—	11.9	NONE	53	63
22	0.2	0.4	100	11.8	19.5	54	63
23	—	—	—	11.7	NONE	54	64
24	0.2	0.4	75	15.5	19.5	53	62
25	—	—	—	15.4	NONE	54	64
26	0.2	0.5	100	15.3	19.5	54	64
27	—	—	—	15.2	NONE	54	64
28	—	—	—	15.1	NONE	54	54
29				15.0	NONE	55	55
30	—	—	—	14.9	NONE	55	55
31							

* Calculated

Consolidated Edison Co. of N.Y., Inc. | Indian Point Station

MARCH, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	0.1	0.5	85	14.2	19.5	33	41
2	0.2	0.5	100	14.1	19.5	35	44
3	0.2	0.5	100	14.0	19.5	36	44
4	0.3	0.3	70	13.9	19.5	38	46
5	0.5	0.3	120	13.8	19.5	39	47
[illegible]	0.3	0.5	120	13.7	19.5	38	47
7	0.2	0.4	100	13.6	19.5	38	48
8	0.3	0.4	100	13.5	19.5	40	48
9	0.3	0.4	100	13.4	19.5	39	49
10	0.3	0.4	100	13.3	19.5	38	48
11	0.3	0.4	100	13.2	19.5	36	44
[illegible]	0.2	0.5	100	13.1	19.5	34	44
13	0.1	0.6	100	13.0	19.5	33	43
14	0.2	0.5	95	12.9	19.5	34	43
15	0.3	0.4	85	12.8	19.5	34	43
16	—	—	—	12.7	NONE	34	34
17	—	—	—	12.6	NONE	35	35
18	0.3	0.3	70	15.3	19.5	36	46
19	0.2	0.5	100	15.2	19.5	36	44
20	0.3	0.2	60	15.1	19.5	34	45
21	0.3	0.4	90	15.0	19.5	35	45
22	0.3	0.5	100	14.9	19.5	35	46
23	—	—	—	14.8	NONE	40	40
24	—	—	—	14.7	NONE	42	42
25	0.3	0.5	100	14.6	19.5	40	50
26	0.3	0.5	100	14.5	19.5	40	50
27	0.3	0.5	100	14.4	19.5	39	49
28	0.3	0.5	100	14.3	19.5	39	49
[illegible]	0.3	0.5	100	14.2	19.5	40	50
30	0.3	0.4	100	14.1	19.5	41	51
31	0.3	0.3	75	14.0	19.5	42	51

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

FEBRUARY 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	0.2	0.3	75	13.4	19.5	35	45
2	0.2	0.3	75	13.3	19.5	36	46
3	0.2	0.3	75	13.2	19.5	40	50
4	0.2	0.3	75	13.1	19.5	37	46
5	0.2	0.1	50	13.0	19.5	37	45
6	0.1	0.3	75	12.9	19.5	35	44
[illegible]	0.1	0.2	50	12.8	19.5	34	42
8	0.1	0.5	100	12.7	19.5	35	42
9	0.1	0.5	100	12.6	19.5	34	42
10	0.2	0.4	100	12.5	19.5	[illegible]	44
11	0.2	0.4	100	12.4	19.5	37	44
[illegible]	0.2	0.2	75	12.3	19.5	34	42
13	0.2	0.4	100	12.2	19.5	33	[illegible]
14	0.1	0.4	85	12.1	19.5	[illegible]	[illegible]
15	<0.1	0.5	80	11.0	19.5	32	42
16	0.1	0.5	110	11.9	19.5	32	42
17	0.1	0.6	115	11.8	19.5	32	42
18	0.2	0.4	100	11.7	19.5	31	40
19	0.2	0.3	70	11.6	19.5	30	41
20	0.1	0.5	100	11.5	19.5	32	42
21	0.1	0.5	75	15.1	19.5	[illegible]	41
22	0.1	0.6	85	15.0	19.5	32	41
23	<0.1	0.7	90	14.9	19.5	32	41
24	0.1	0.7	100	14.8	19.5	32	41
25	0.1	0.5	75	14.7	19.5	34	42
26	0.1	0.5	75	14.6	19.5	34	[illegible]
27	0.2	0.4	75	14.5	19.5	34	44
28	0.2	0.5	100	14.4	19.5	34	44
[illegible]	0.2	0.4	75	14.3	19.5	34	44
30	[illegible]	[illegible]	75	[illegible]	19.5	[illegible]	[illegible]
31	[illegible]	[illegible]	75	[illegible]	[illegible]	[illegible]	[illegible]

* Calc [illegible]

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
JANUARY, 1968

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	0.1	0.5	75	14.7	19.5	34	45
2	0.1	0.7	100	14.6	19.5	32	43
3	0.2	0.6	100	14.5	19.5	42	52
4	0.2	0.4	75	14.4	19.5	42	52
5	0.2	0.2	50	14.3	19.5	45	58
6	0.1	0.3	50	14.2	19.5	44	54
7	0.2	0.2	50	14.1	19.5	38	52
8	0.2	0.2	50	14.0	19.5	38	52
9	0.1	0.4	80	13.9	19.5	33	42
10	0.1	0.4	80	13.8	19.5	31	42
11	0.3	0.2	80	13.7	19.5	33	42
12	0.3	0.2	80	13.6	19.5	33	42
13	0.4	0.1	60	13.5	19.5	34	45
14	—	—	—	—	NONE	35	35
15	0.1	0.3	55	13.3	19.5	36	44
16	<0.1	0.4	110	15.0	36.5	34	42
17	<0.1	0.6	90	14.9	19.5	35	42
18	0.1	0.6	90	14.8	19.5	37	44
19	0.1	0.7	105	14.7	19.5	38	45
20	0.1	0.6	95	14.6	19.5	38	46
21	0.1	0.5	75	14.5	19.5	38	46
22	0.1	0.6	100	14.4	19.5	35	44
23	0.2	0.5	100	14.3	19.5	36	43
24	0.2	0.5	100	14.2	19.5	35	43
25	0.2	0.4	80	14.1	19.5	34	42
26	0.2	0.5	100	14.0	19.5	34	42
27	0.2	0.4	90	13.9	19.5	34	42
28	0.1	0.4	75	13.8	19.5	35	43
29	0.1	0.4	70	13.7	19.5	35	43
30	0.3	0.2	75	13.6	19.5	34	44
31	0.2	0.3	75	13.5	19.5	34	44

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
DECEMBER, 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	—	—	—	—	NONE	42	42
2	—	—	—	—	—	41	41
3	—	—	—	—	—	42	42
4	—	—	—	—	—	42	42
5	—	—	—	—	—	42	42
6	—	—	—	—	—	41	41
7	—	—	—	—	—	41	41
8	—	—	—	—	—	42	42
9	—	—	—	—	—	41	41
10	—	—	—	—	—	38	38
11	—	—	—	—	—	40	40
12	—	—	—	—	—	40	40
13	—	—	—	—	—	40	48
14	—	—	—	—	—	40	49
15	<0.1	1.3	150	16.4	15.0	40	52
16	0.5	1.4	45	16.3	4.5	38	40
17	0.5	1.5	65	16.2	3.9	38	40
18	0.3	0.8	115	16.1	19.5	36	46
19	0.1	0.7	100	16.0	19.5	40	47
20	0.1	0.7	110	15.9	19.5	40	47
21	0.1	0.7	110	15.8	19.5	[illegible]	[illegible]
22	0.1	0.7	110	15.7	19.5	40	48
23	0.1	0.8	110	15.6	19.5	39	47
24	0.1	0.8	115	15.5	19.5	38	48
25	0.3	0.4	150	15.4	13.5	36	45
26	0.3	0.5	85	15.3	19.5	38	45
27	0.4	0.5	100	15.2	19.5	35	44
28	0.2	0.4	75	15.1	19.5	33	43
29	0.1	0.5	75	15.0	19.5	32	41
30	0.1	0.7	100	14.9	19.5	35	43
31	0.2	0.9	125	14.8	19.5	34	42

* Calculated

[illegible] Indian Point Station

October 1967

COOLING WATER DATA

D[illegible]	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated ($10^{[illegible]}$ Gals)	Temp.	
	Residual	Demand	Gals.	% (conc.)			
	0.4	0.6	25	14.4	4.5	69	69
	0.2	0.6	30	14.3	5.2	72	72
	—	—	—	—	NONE	68	68
	—	—	—	—	NONE	69	69
	—	—	—	—	NONE	70	70
	—	—	—	—	NONE	70	70
	—	—	—	—	NONE	64	64
	—	—	—	—	NONE	63	63
	—	—	—	—	NONE	68	68
	—	—	—	—	NONE	67	67
	—	—	—	—	NONE	68°	68°
	—	—	—	—	NONE	68	68
	—	—	—	—	"	65°	65°
	—	—	—	—	"	65°	65°
	—	—	—	—	"	64	64
	—	—	—	—	"	[illegible]	[illegible]
	—	—	—	—	"	66	66
	—	—	—	—	"	64°	[illegible]
			—	—	"	[illegible]	[illegible]
	—	—	—	—	"	[illegible]	[illegible]
	—	—	—	—	"	62	[illegible]
	—	—	—	—	"	60	[illegible]
	[illegible]	0.8	50	[illegible]	5.2	[illegible]	[illegible]
	0.4	0.6	70	12.1	5.6	62	62
	0.4	0.3	20	12.0	5.6	62	62
	0.4	0.6	45	11.9	5.6	61	61
	0.3	0.6	40	11.8	5.6	60	60
	0.3	0.5	35	11.7	5.6	60	60
	0.3	0.4	30	11.6	5.6	60	[illegible]
	—	—	—	—	[illegible]	57	57
	—	—	—	—	[illegible]	57	57
						64.4	

* Calculated

Consolidated Edison Co. of N.Y., Inc. Indian Point Station

SEPTEMBER, 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	<0.1	1.1	150	14.3	19.5	74	85
2	0.1	0.7	70	14.2	19.5	75	85
3	0.3	1.2	35	14.1	3.8	74	79
4	<0.1	1.0	125	14.0	19.5	74	84
5	0.2	0.8	50	13.9	12.0	75	85
6	<0.1	1.0	130	13.8	19.5	75	84
7	<0.1	0.9	130	13.7	22.5	75	85
8	<0.1	1.5	240	13.6	19.5	74	84
9	0.2	0.7	30	13.5	4.5	74	84
10	<0.1	0.6	100	13.4	19.5	73	83
11	<0.1	0.8	225	13.3	39.5	70	80
12	<0.1	0.6	100	13.2	19.5	72	83
13	<0.1	0.8	125	13.1	19.5	73	83
14	<0.1	0.8	115	13.0	19.5	73	84
15	0.2	1.1	400	14.8	45.0	73	84
16	<0.1	1.2	175	14.7	19.5	72	82
17	<0.1	1.1	150	14.6	19.5	72	82
18	<0.1	1.1	430	14.5	54.0	72	82
19	<0.1	1.2	155	14.4	19.5	72	82
20	<0.1	1.4	200	14.3	19.5	73	83
21	0.1	1.6	230	14.2	19.5	72	82
22	0.1	1.6	625	14.1	54.0	72	82
23	<0.1	1.6	225	14.0	19.5	72	82
24	0.3	1.4	200	13.9	16.5	72	82
25	0.1	1.3	360	15.0	42.3	71	81
26	0.1	1.2	160	14.9	19.5	70	80
27	<0.1	1.2	150	14.8	19.5	70	80
28	<0.1	1.1	140	14.7	19.5	70	80
29	<0.1	1.0	300	14.6	42.6	69	79
30	0.4	0.9	35	14.5	4.5	69	69
31							

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
AUGUST, 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp.	
	Residual	Demand	Gals.	*%(conc.)		In	Out
1	<0.1	1.2	175	13.5	19.5	80	90
2	<0.1	1.2	175	13.4	19.5	80	90
3	<0.1	1.4	200	13.3	19.5	79	89
4	<0.1	1.2	175	13.2	19.5	78	89
5	<0.1	1.1	175	13.1	18.0	80	90
6	<0.1	1.1	175	13.0	19.5	80	90
7	<0.1	1.1	175	12.9	19.5	79	90
8	0.3	1.0	150	15.0	18.0	79	89
9	0.1	1.3	150	14.9	18.0	80	90
10	0.3	1.7	225	14.8	19.5	79	91
11	0.2	1.2	150	14.7	19.5	78	89
12	<0.1	1.1	150	14.6	19.5	78	89
13	<0.1	1.3	175	14.5	19.5	78	88
14	<0.1	1.1	150	14.4	19.5	79	89
15	<0.1	1.0	125	14.3	19.5	79	89
16	<0.1	1.1	150	14.2	19.5	79	89
17	<0.1	1.2	175	14.1	19.5	78	89
18	<0.1	1.2	175	14.0	19.5	77	89
19	<0.1	1.1	160	13.9	19.5	79	89
20	<0.1	1.1	150	13.8	19.5	78	89
21	0.1	1.0	150	13.7	19.5	78	89
22	<0.1	1.2	190	13.6	19.5	79	90
23	<0.1	1.4	300	13.5	19.5	78	89
24	<0.1	1.0	140	15.0	19.5	78	89
25	0.4	0.6	115	14.9	19.5	77	88
26	<0.1	0.9	120	14.8	19.5	77	88
27	<0.1	0.9	125	14.7	19.5	78	89
28	<0.1	1.2	150	14.6	19.5	77	87
29	<0.1	0.6	100	14.5	19.5	76	87
30	<0.1	0.6	100	14.4	19.5	77	87
31							

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

July, 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	0.1	1.1	225	10.1	21.0	72	82
2	<0.1	1.2	275	8.8	19.5	71	82
3	<0.1	1.1	320	7.6	22.5	74	84
4	<0.1	1.0	180	6.1	10.5	74	84
5	<0.1	0.9	110	14.7	21.0	74	84
6	<0.1	0.9	125	14.6	19.5	72	83
7	<0.1	0.8	100	14.5	19.5	72	83
8	<0.1	0.6	80	14.4	19.5	74	84
9	<0.1	0.9	120	14.3	19.5	74	84
10	<0.1	1.0	140	14.2	21.0	75	86
11	<0.1	0.9	110	14.1	17.8	74	86
12	<0.1	1.0	125	14.0	19.5	75	86
13	0.1	0.4	125	13.9	19.5	75	85
14	0.1	1.1	175	13.8	21.0	74	85
15	0.1	1.2	175	13.7	19.5	75	81
16	<0.1	1.1	175	13.6	21.0	75	86
17	0.2	1.0	175	13.5	19.5	76	87
18	<0.1	1.4	275	13.4	24.5	76	87
19	0.2	1.2	215	13.3	19.5	76	87
20	<0.1	0.6	110	13.2	19.5	76	87
21	<0.1	0.7	165	14.6	23.1	76	87
22	0.5	1.1	50	14.5	5.1	76	81
23	<0.1	0.5	100	14.4	19.5	75	85
24	<0.1	1.4	255	14.3	25.5	78	88
25	<0.1	1.2	175	14.2	19.5	79	89
26	<0.1	1.4	210	14.1	19.5	78	88
27	<0.1	1.2	190	14.0	19.5	77	87
28	<0.1	1.2	190	13.9	19.5	77	87
29	—	—	—	—	None	78	90
30	—	—	—	—	None	77	90
31	<0.1	1.1	185	13.6	19.5	80	90

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

MAY, 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	0.2	0.2	75	13.3	19.5	48	58
2	0.1	0.3	85	13.2	19.5	52	57
3	0.1	0.2	75	13.1	19.5	49	58
4	<0.1	0.4	85	13.0	19.5	51	59
5	0.1	0.5	100	12.9	19.5	52	61
6	0.1	0.5	100	12.8	19.5	50	61
7	0.1	0.3	75	12.7	19.5	51	61
8	0.1	0.2	70	12.6	19.5	51	62
9	0.1	0.2	75	12.5	19.5	52	64
10	0.1	0.2	75	12.4	19.5	53	62
11	0.1	0.4	100	12.3	19.5	52	63
[illegible]	0.2	0.2	75	12.2	19.5	53	63
13	0.1	0.3	55	12.1	19.5	54	64
14	0.1	0.2	90	12.0	19.5	54	64
15	0.2	0.3	100	11.9	19.5	52	64
16	0.2	0.1	75	11.8	19.5	54	64
17	0.1	0.1	75	11.7	19.5	54	65
18	0.2	0.3	100	11.6	19.5	54	66
19	0.1	0.2	55	14.5	19.5	55	67
20	0.1	0.2	60	14.4	19.5	56	68
21	0.1	0.3	75	14.3	19.5	55	68
22	<0.1	0.2	60	14.2	19.5	56	68
23	0.1	0.5	95	14.1	19.5	57	67
24	0.2	0.5	100	14.0	19.5	57	68
25	0.1	0.5	100	13.9	19.5	58	68
26	0.2	0.4	100	13.8	19.5	58	68
27	0.2	0.4	100	13.7	19.5	58	67
28	0.3	0.3	100	13.6	19.5	58	67
[illegible]	0.3	0.3	100	13.5	19.5	56	67
30	0.1	0.4	90	13.4	19.5	56	67
31	0.2	0.4	100	13.3	19.5	57	68

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

APRIL, 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	Demand	Gals.	* %(conc.)		In	Out
1	<0.1	0.2	55	12.3	19.5	37	48
2	<0.1	0.2	55	12.2	19.5	37	48
3	<0.1	0.3	75	12.1	19.5	42	53
4	<0.1	0.3	75	12.0	19.5	43	53
5	<0.1	0.2	70	11.9	19.5	43	54
6	<0.1	0.3	75	11.8	19.5	43	53
7	<0.1	0.5	100	11.7	19.5	43	52
8	0.1	0.4	95	11.6	18.9	45	52
9	<0.1	0.4	85	11.5	18.9	45	54
10	0.1	0.2	60	15.4	19.5	45	55
11	0.1	0.2	60	15.3	19.5	46	55
	0.1	0.2	80	15.2	19.5	48	57
13	0.6	0.2	35	15.1	9.0	48	58
14	0.5	0.2	25	15.0	9.0	48	57
15	0.4	0.2	20	14.9	9.0	47	57
16	0.5	0.2	25	14.8	9.0	47	57
17	0.1	0.1	50	14.7	20.1	47	59
18	0.1	0.1	50	14.6	19.5	46	57
19	0.1	0.3	80	14.5	19.5	46	55
20	<0.1	0.3	70	14.4	19.5	47	58
21	0.1	0.4	90	14.3	19.5	46	55
22	—	—	—	—	NONE	47	58
23	—	—	—	—	NONE	47	52
24	0.1	0.4	85	14.0	19.5	46	55
25	0.1	0.4	85	13.9	19.5	48	57
26	0.1	0.3	75	13.8	19.5	48	57
27	0.1	0.4	90	13.7	19.5	50	57
28	0.1	0.6	110	13.6	19.5	48	57
	0.2	0.4	90	13.5	19.5	48	57
30	0.2	0.3	75	13.4	19.5	49	59
31							

* Calculated

[illegible]ated Edison Co. of N.Y., Inc. Indi[illegible]

March , [illegible]

COOLING WATER DATA

[illegible] of [illegible]	Maximum Chlorine (ppm)		NaOCl Feed		Volume Treated (10^6 Gals)	Temp.	
	Residual	Demand *	Gals.	% (conc.)		[illegible]	[illegible]
[illegible]	0.1	[illegible]	50	15.4	18.0	40	49
2	<0.1	0.1	50	15.3	18.0	37	50
[illegible]	0.1	0.1	50	15.2	18.0	36	48
4	0.1	0.1	50	15.1	18.0	36	48
5	0.1	0.1	50	15.0	18.0	36	49
6	<0.1	0.1	50	14.9	18.0	37	48
[illegible]	0.1	0.3	75	14.8	18.0	36	46
[illegible]	<0.1	0.1	50	14.7	18.0	37	49
[illegible]	0.1	0.3	50	14.6	18.0	37	48
10	0.1	0.3	75	14.5	18.0	37	51
11	0.5	0.2	25	14.4	4.8	37	37
12	-	-	-	-	None	37	37
13	0.1	0.1	50	14.2	18.0	38	47
14	0.1	0.1	50	14.1	18.0	38	49
[illegible]	0.1	0.1	50	14.0	18.0	32	48
16	0.1	0.3	75	13.9	18.0	37	47
17	0.1	0.3	75	13.8	18.0	37	46
[illegible]	<0.1	0.3	75	13.7	18.0	36	46
19	<0.1	0.3	75	13.6	18.0	36	46
20	0.1	[illegible]	100	13.5	18.0	37	47
[illegible]	0.1	[illegible]	50	13.4	18.0	37	48
22	0.1	0.2	60	13.3	18.0	37	46
[illegible]	[illegible]	0.1	50	13.2	18.0	38	47
[illegible]	[illegible]	[illegible]	75	13.1	18.0	39	48
[illegible]	[illegible]	[illegible]	75	[illegible]	18.0	38	46
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39	48
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39	48
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	48
[illegible]	[illegible]	[illegible]	50	[illegible]	[illegible]	39	[illegible]
			[illegible]	[illegible]	20.3	37	[illegible]

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station
February, 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^6 Gals)	Temp. (°F)	
	Residual	* Demand	Gals.	* %(conc.)		In	Out
1	0.1	0.5	100	14.0	20.1	34	44
2	0.1	0.6	100	13.9	18.0	34	46
3	0.1	0.4	75	13.8	18.0	33	46
4	—	—	—	—	NONE	35	35
5	0.1	0.4	80	13.6	18.0	36	49
6	0.2	0.5	100	13.5	18.0	40	53
7	0.1	0.6	100	13.4	18.0	36	48
8	0.4	0.3	75	13.3	17.4	37	49
9	0.2	0.2	60	13.2	18.0	36	50
10	0.6	0.0	75	13.1	16.5	36	53
11	0.1	0.1	50	13.0	18.0	36	52
12	0.1	0.1	50	12.9	18.0	35	48
13	0.1	0.1	50	12.8	18.0	36	49
14	0.1	0.1	50	12.7	18.0	40	54
15	<0.1	0.3	100	12.6	18.0	42	52
16	<0.1	0.3	80	12.5	18.0	34	36
17	0.1	0.4	100	12.4	18.0	34	46
18	1.2	0.1	45	12.3	4.4	34	36
19	0.8	0.1	30	12.2	4.4	34	34
20	0.2	0.2	75	12.1	18.0	32	44
21	0.2	0.2	75	12.0	18.0	34	44
22	0.1	0.4	100	11.9	18.0	34	45
23	0.1	0.6	125	11.8	18.0	34	43
24	0.1	0.4	100	11.7	18.0	34	45
25	0.1	0.4	100	11.6	18.0	32	42
26	0.2	0.3	100	11.5	18.0	35	49
27	0.1	0.3	125	11.4	22.2	38	50
28	<0.1	0.2	50	15.6	18.0	39	50
[illegible]							
30							
31							

* Calculated

Consolidated Edison Co. of N.Y., Inc. | Indian Point Station
JANUARY , 1967

COOLING WATER DATA

Day of Month	Maximum Chlorine (ppm)		NaOCl Used		Volume Treated (10^5 Gals)	Temp. (°F)	
	Residual	Demand *	Gals.	* %(conc.)		In	Out
1	0.1	0.7	100	13.3	18.0	40	40
2	0.1	0.7	100	13.2	18.0	38	48
3	0.1	0.7	100	13.1	18.0	38	48
4	0.2	0.5	100	13.0	18.0	38	48
5	0.1	0.4	85	12.9	18.0	38	48
	0.1	0.5	100	12.8	18.0	38	48
7	<0.1	0.9	75	12.7	11.4	38	48
8	0.1	1.6	275	12.6	26.4	36	42
9	—	—	—	—	NONE	38	48
10	0.1	1.4	150	15.4	18.9	38	48
11	0.2	0.6	100	15.3	18.0	38	48
12	0.1	1.0	130	15.2	18.0	38	48
13	<0.1	1.1	210	15.1	28.2	38	48
14	0.1	0.6	100	15.0	18.0	40	50
15	0.1	0.9	135	14.9	18.6	40	50
16	0.1	0.6	100	14.8	18.0	40	50
	0.2	0.5	125	14.7	23.4	40	50
18	0.1	0.6	100	14.6	18.0	37	47
19	0.1	0.6	100	14.5	18.0	37	47
20	0.1	0.6	100	14.4	18.0	37	47
21	0.1	0.6	110	14.3	18.0	37	47
22	0.1	0.4	100	14.2	18.0	38	48
23	0.1	0.5	100	14.1	18.0	39	48
24	0.1	0.6	110	14.0	18.0	39	48
25	<0.1	0.6	100	13.9	18.0	37	48
26	0.1	0.6	100	13.8	18.0	36	46
27	0.1	0.5	100	13.7	18.0	37	47
	0.1	0.5	100	13.6	18.0	38	48
29	0.2	0.4	85	14.3	18.0	35	45
30	0.1	0.4	75	14.2	18.0	34	44
31	0.1	0.4	75	14.1	18.0	33	43

* Calculated

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

December, 1966

COOLING WATER DATA

Day of Month	Chlorine Residual (ppm)	Chlorine Demand (ppm)	NaOCl Used (gals.)	Volume Treated (10^6 gal.)	Temperature, °F. In	Temperature, °F. Out
1	0.1	0.8	100	18.0	50	60
2	0.1	0.8	100	18.0	50	60
3	0.1	0.7	100	18.0	50	60
4	0.1	0.7	100	18.0	48	58
5	0.1	0.7	100	18.0	47	57
6	0.2	0.8	125	18.0	47	57
7	<0.1	0.7	100	18.0	47	56
8	<0.1	0.7	100	18.0	47	57
9	<0.1	0.8	125	18.0	47	57
10	0.1	0.7	100	18.0	47	52
11	<0.1	0.7	100	18.0	47	52
12	0.1	0.6	100	18.0	48	58
13	0.1	0.6	100	18.0	45	56
14	0.2	0.6	100	18.0	45	56
15	0.1	0.6	100	18.0	46	56
16	<0.1	0.7	100	18.0	44	55
17	<0.1	0.7	100	18.0	44	55
18	<0.1	0.7	100	18.0	45	54
19	0.1	0.7	100	18.0	42	52
20	0.1	0.7	100	18.0	42	52
21	0.1	0.8	100	18.0	42	52
22	0.1	0.8	100	18.0	44	52
23	0.1	0.7	100	18.0	44	51
24	<0.1	0.7	100	18.0	41	51
25	<0.1	0.6	100	18.0	42	52
26	0.1	0.6	100	18.0	41	51
27	<0.1	0.6	100	18.0	40	50
28	0.1	0.6	100	18.0	40	50
29	0.2	0.5	100	18.0	38	48
30	0.1	0.7	100	18.0	40	50
31	0.1	0.7	100	18.0	40	50

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

NOVEMBER, 19[illegible]

COOLING WATER DATA

Day of Month	Chlorine Residual (ppm)	Chlorine Demand (ppm)	NaOCl Used (gals.)	Volume Treated (10^6 gal.)	Temperature, °F.	
					In	Out
1	0.2	1.1	125	18.9	56	67
2	0.1	0.8	100	18.0	57	68
3	0.1	1.3	150	18.0	57	68
4	0.2	0.7	100	18.0	58	69
5	0.1	0.7	100	18.0	57	67
6	0.2	0.7	100	18.0	58	68
7	0.1	0.8	100	18.0	56	66
8	0.1	0.7	100	18.9	56	66
9	0.1	0.7	150	27.0	56	66
10	0.1	1.2	150	18.0	56	66
11	0.1	1.0	125	18.0	56	66
12	0.2	0.8	100	18.0	56	66
13	0.1	0.9	125	18.0	55	65
14	0.1	1.0	125	18.0	54	67
15	0.1	0.7	100	18.0	55	65
16	<0.1	0.8	125	18.0	54	64
17	<0.1	1.2	140	18.0	53	64
18	<0.1	0.7	100	18.0	54	64
19	0.1	1.1	150	18.0	53	63
20	0.1	1.1	150	18.0	52	56
21	<0.1	0.9	125	18.0	52	64
22	<0.1	1.2	150	23.1	52	60
23	<0.1	1.1	125	18.0	51	61
24	0.2	0.8	100	18.0	51	61
25	0.1	0.7	100	18.0	50	60
26	0.1	0.5	100	18.0	52	61
27	<0.1	1.0	125	18.0	51	61
28	<0.1	0.7	100	18.0	51	61
29	0.1	0.9	125	18.0	51	61
30	<0.1	0.9	125	19.5	51	61
31						

54.0

Consolidated Edison Co. of N.Y., Inc.

Indian Point Station

October , 1966

COOLING WATER DATA

Day of Month	Chlorine Residual (ppm)	Chlorine Demand (ppm)	NaOCl Used (gals.)	Volume Treated (10^6 gal.)	Temperature, °F.	
					In	Out
1	—	—	—	NONE	—	—
2	—	—	—	NONE	—	—
3	—	—	—	NONE	—	—
4	—	—	—	NONE	—	—
5	—	—	—	NONE	—	—
6	—	—	—	NONE	—	—
7	—	—	—	NONE	—	—
8	<0.1	2.1	400	32.4	68	74
9	—	—	—	NONE	—	—
10	0.2	1.8	350	24.9	65	75
11	<0.1	2.0	225	18.0	64	73
12	<0.1	1.6	200	18.0	63	72
13	0.2	1.2	300	20.4	62	72
14	0.3	1.0	400	33.9	62	72
15	0.1	1.4	225	28.5	63	73
16	0.2	1.6	160	18.1	63	73
	0.3	1.0	125	18.3	63	67
18	0.2	1.5	160	18.0	63	67
19	0.2	1.5	155	18.0	63	73
20	0.2	1.0	150	20.1	62	71
21	0.2	1.1	135	18.0	61	70
22	0.2	1.0	130	18.0	60	71
23	0.2	1.4	190	20.4	60	71
24	0.1	1.6	175	18.0	60	70
25	0.2	1.2	150	18.0	59	65
26	0.2	1.3	150	18.0	59	68
27	0.3	1.2	150	18.0	58	68
28	0.3	1.4	160	18.0	58	69
29	0.4	1.4	170	18.0	59	69
30	0.4	1.5	165	18.0	57	68
31	0.2	1.1	125	18.0	56	67

35-1

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