CHAPTER III

AQUATIC IMPACT

For each kilowatt hour of electricity generated, a steam power plant burning fossil fuel must dispose of about 4,400 BTU of heat via its condenser, and a nuclear power plant must dispose of about 6,600 BTU. Most Maryland power plants use once-through cooling systems to transport this waste heat from the plant. In these systems, water is drawn into the plant, heated 10 to 17°F in the condenser, and discharged into a receiving body of water. Approximately 1 million gallons of water per minute (or 63 m^3/sec) is required for each 1000 MW of generating capacity. Even when closed cycle cooling can be used to reduce water withdrawal (as discussed in Chapter VI), there may still be a significant amount of water withdrawn.

The Chesapeake Bay and its tributaries serve as the major source of cooling water in Maryand. At the same time, they also support complex aquatic food chains that produce renewable resources of fish and shellfish. A major concern of the Power Plant Siting Program is that power plants, while providing electricity at a reasonable cost, do not interfere with the maintenance of sustained yields of resource species, which are dependent on all food chain components. Thus, the impact of power plants on the aquatic ecosystem as a whole must be evaluated and measures to mitigate this impact should be examined for their potential benefits and costs.

As water is drawn through the power plant and returned to its source, aquatic organisms interact with cooling system structures, with intake and discharge velocity fields, with the heated effluent, and with other alterations of the environment caused by plant operations as explained below.* The locations and nature of these interactions are shown schematically in Figure III-1. The following types of interactions and stresses are encountered by aquatic organisms:

- Entrapment

  Two of the largest Maryland power plants (Calvert Cliffs and Morgantown) have intake embayments partially shut off from the main bay or river by a curtain wall, i.e., a wall reaching from above the surface of the water to some depth below the surface. The function of the curtain wall is to permit the plant to draw its cooling water from the deeper portions of the water column, where temperatures tend to be lower than at the surface during summer months. Large numbers of fish congregate in intake embayments during the summer where they may be entrapped. During the summer months, dissolved oxygen (DO) concentrations in the water often drop to levels below that needed to sustain adult and juvenile fish. The drop is pronounced in the deeper water entering the embayment under the curtain wall. Fish kills may result, and the killed (or weakened) fish may then impinge in large numbers on the protective intake screens.

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* Radiological effects are discussed in Chapter IV.

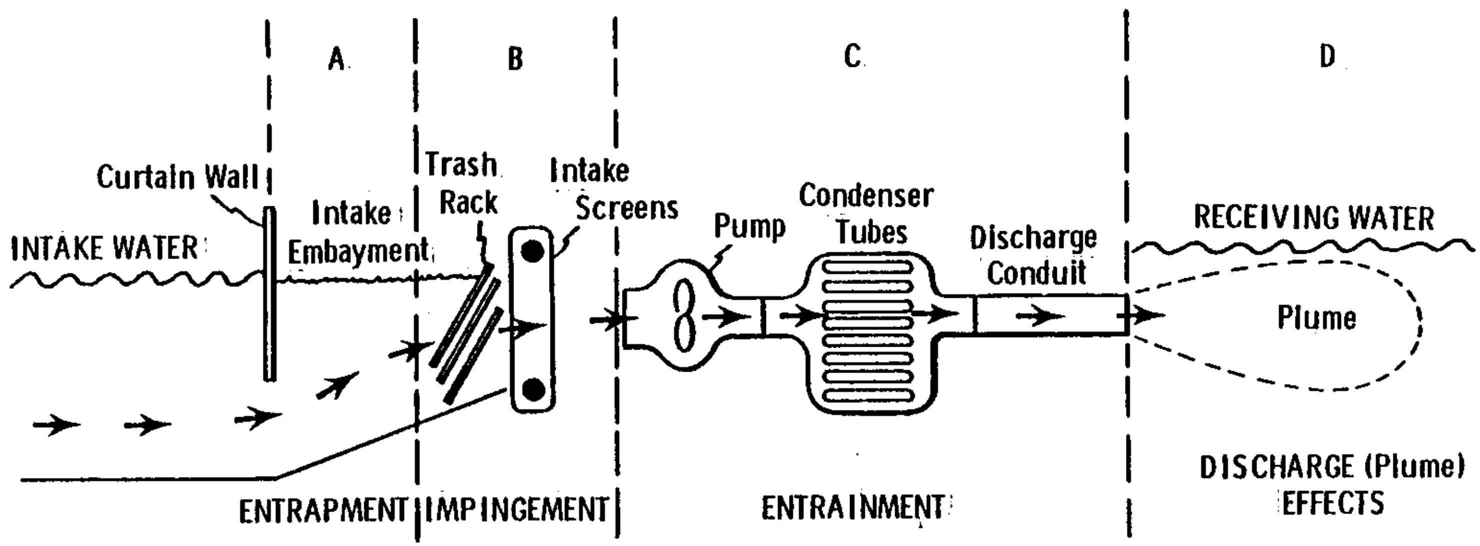

Figure III-1. Path of cooling water flow through a power plant and locations of plant-organism interactions.

A. Fish may be entrapped in the intake embayment and may suffer prolonged exposure to water of low dissolved oxygen content drawn from below the curtain wall.

B. Organisms may be trapped on intake screens; the screens are rotated to wash fish and crabs from the screens back into the receiving water.

C. Small organisms in the water column (plankton) pass through the cooling system; they experience a temperature rise and also shear and pressure forces during their cooling system transit.

D. Organisms in the receiving water may encounter plume temperature rises (and may be affected by the velocity of the discharge).

- Impingement

  The circulating pumps for the cooling water are protected by intake screens (usually 3/8 inch mesh). Organisms too large to pass through these screens may be impinged, i.e., pinned against it by the pressure of the passing water, a prospect that is markedly increased when the organisms (fish or crabs) are weakened by stresses such as low DO condition. The screens are rotated periodically and the impinged matter is washed off and usually flushed back into the cooling stream discharge. Some species survive this treatment, but others suffer a high rate of mortality.

- Entrainment

  Organisms small enough to go through the intake screens pass through the entire cooling system, where they are stressed by mechanical forces due to physical contact with pumps and pipes, and pressure and shear forces generated by complex flow patterns and turbulence.

  While passing through the condenser, the entrained biota will be subjected to a sudden temperature rise. The biological response to this heating depends on the magnitude of the temperature rise, the length of exposure to the elevated temperature, and the initial ambient temperature. Temperature rise varies from 10°F to 17°F in Maryland plants, and exposure time from a few minutes to almost two hours (including retention time in effluent canals). Thus, thermal stress "dose," i.e., product of temperature and time is quite variable.

  Additional stress is experienced by entrained biota at plants where biocide (usually chlorine) is added to the cooling water to prevent clogging of the cooling system by built-up biomass.

- Discharge Effects

  The alteration of local habitat produced by the discharge of cooling water can manifest itself in several ways. Aquatic organisms can be "entrained" into the discharge plume, where they will be exposed to higher-than-ambient temperature and biocide residuals. Other toxic substances released with the cooling water (e.g., copper) may affect the stationary benthic communities near the plume. Finally, fast-moving discharge flows cause alterations in the characteristics of bottom sediment in the discharge zone, and also directly influence the behavior of some organisms.

The trophic levels and life stages of organisms interacting with the power plant can be grouped as follows:

- phytoplankton
- zooplankton
- benthos

- ichthyoplankton

- juvenile and adult fish and crabs

Individual groups may be more susceptible to damage by one type of power plant interaction than by another (Table III-1). Entrapment can stress juvenile fish. Entrainment stresses planktonic organisms, which serve as food for many resource species, as well as the planktonic larval stages of many resource and forage species. All aquatic biota may experience discharge effects but benthic species, because of their predominantly immobile life style, would be most stressed.

Mortalities resulting from plant-organism interactions can cause a decline in a population if they are not offset by biological compensation mechanisms such as increases in growth rate, fecundity and/or early survival. In the case of phytoplankton or zooplankton, losses due to entrainment are generally recouped quickly as a result of rapid reproduction (generation times of hours to days). Other organisms have much longer generation times. Fish spawn only once a year, and may not reproduce until several years of age. For species utilizing a very localized spawning or nursery area adjacent to a power plant, high entrainment losses can occur unless cooling towers with carefully controlled blowdown are used to reduce the exposure. The potential for such losses is much less for ubiquitous species which spawn in or inhabit wide areas of the Bay.

Plant operations can indirectly cause decline of a population by decreasing the abundance of its food supply. The dominant groups in the Bay which are important as forage are phytoplankton, zooplankton, benthic organisms, and small fish species (e.g., Bay anchovy and menhaden). Although fish populations are more likely to be affected by the entrainment of their ichthyoplankton, they could also be affected by a change in the density of their food (see Figure III-2). These indirect effects may propagate through several trophic levels, although they are unlikely to be measurable beyond one link along the food chain.

Plant operations also affect particular species through modification of the physical/chemical environment. Biocide residuals may accumulate in areas around the plant, and temperatures are elevated by varying amounts in the discharge vicinity. Discharge jets may also scour the bottom sediments, creating locally uninhabitable zones for benthic organisms. If such habitat modificatons make an area unsuitable for use by some species, a subsequent decline in their abundance can occur locally.

A. Aquatic Habitat

The central concept underlying the cumulative aquatic assessment presented here is that Chesapeake Bay and tributary estuarine waters are composed of distinct habitat types. These habitat types are defined by water salinity, which is the environmental variable most important in controlling distributions of organisms in estuaries. Each of these habitats can be identified with unique functions in producing or supporting important resource elements, although their biotic compositions gradually change into one another, and their extent varies seasonally. Cumulative impact will be assessed in terms of

Table III-1. Major types of aquatic effects of power plant operations

Sources of Effects	Primary Susceptible Organisms	Type of Stress				
		Low DO[a]	Mechanical	Thermal	Chemical	Habitat Alteration
Entrapment	Fish	x	-	-	-	-
Impingement	Juvenile fish, crabs	-	x	-	-	-
Entrainment	Ichthyoplankton[b] Zooplankton[c] Phytoplankton[d]	-	x	x	x	-
Discharge Effects	Adult and juvenile fish, benthos[e] shellfish	-	-	x	x	x

(a) Low dissolved oxygen concentrations -- oxygen deficiency
(b) Eggs and larvae of fish
(c) Minute animals present in the water
(d) Minute plants present in the water
(e) Organisms living in or on the bottom

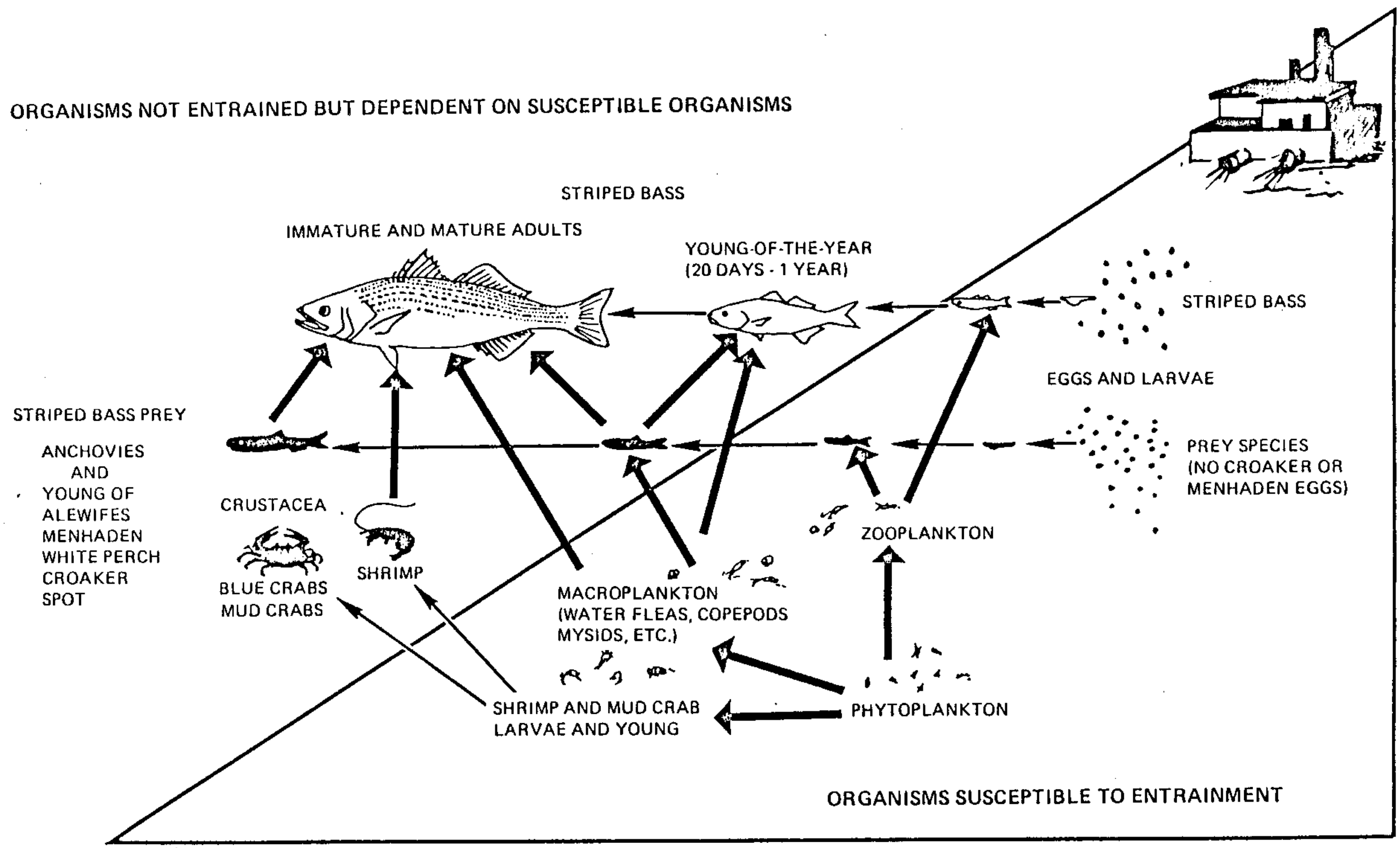

Figure III-2. Areas of potential power plant entrainment impact on striped bass and associated food items.

significant effects on the biota over the entire extent of each characteristic habitat type within Maryland, with the emphasis on whether the long-term integrity of each estuarine habitat and its characteristic functions are maintained.

The salinity zones designating the habitat types can be defined by the Venice system of classification (1) as:

Habitat	Salinity Ranges
Euhaline (Marine)	30.0 ppt - 35.0 ppt
Polyhaline	18.0 ppt - 30.0 ppt
Mesohaline	5.0 ppt - 18.0 ppt
Oligohaline	0.5 ppt - 5.0 ppt
Tidal fresh	0 ppt - 0.5 ppt
Riverine	0 parts per thousand (ppt)

The following major ecological functions of each habitat may be listed:

- Polyhaline and Marine

  These high salinity waters are primary sites of blue crab spawning and development, and also support hard clams. Several fish species, (e.g., spot, croaker, and menhaden) whose young and adults seasonally feed in upper estuarine zones, spawn and develop in these regions. These zones generally do not exist in the Maryland portion of the Chesapeake Bay.

- Mesohaline

  These medium salinity regions are the primary areas of shellfish production (clams, oysters) whose early life stages are planktonic. Mesohaline waters also support the adult crab populations. They produce most of the estuarine forage fish biomass, and therefore, serve as feeding areas for large predator fish (e.g., bluefish, striped bass).

- Oligohaline

  These brackish water environments support resident estuarine fish populations, and serve as spawning and nursery grounds for them. These fish populations serve primarily as forage organisms for larger fish, but may also be exploited by man (e.g., white perch). The areas are also feeding grounds for migratory marine and estuarine species such as menhaden and white perch. Some spawning of anadromous fish also occurs here.

- Tidal Fresh

  Segments of estuaries within tidal influence but without a significant salt intrusion provide spawning and nursery areas for anadromous fish species, also supporting their larvae and juveniles during spring and summer months. In addition, resident fish species, some adapted to both this and riverine environments, spend their entire life cycles in this zone. The striped bass is a particularly important example of a species using this environment as a spawning and nursery area.

- Riverine

  These freshwater habitats beyond the head of the estuary have resident fish populations and supporting bottom (benthic) communities adapted to constant freshwater conditions.

The location of these zones change seasonally as a result of changes in the amount of freshwater inflow (see Figure III-3). Table III-2 indicates the zones in which power plants in Maryland are located, and shows locations according to season. The majority of plants in Maryland are situated in tidal fresholigohaline regions. However, the largest in the State (Calvert Cliffs, Chalk Point, and Morgantown) are sited in mesohaline regions (at least in the fall) and new plants (e.g. Elms) will also be in the mesohaline habitat. There are no power plants in the polyhaline and marine habitats along the Atlantic shoreline in Maryland.

B. Assessment and Mitigation of Impact

Environmental impact assessments are carried out by the Maryland Power Plant Siting Program. These assessments consist of predictions of the effects of the power plant construction and operation, evaluations of the impact of these effects upon the aquatic resources of the State and determination of measures to minimize adverse impacts.* At several existing plants there are monitoring programs for detecting and quantifying these effects and for measuring and analyzing their impact.

For new plants, after regional surveys have quantified the existing populations, the local impact of each effect is predicted and related to regional impact on populations of affected organisms. The aquatic impacts are, as much as possible, described in terms of percent reduction of local and regional populations, the possible indirect effects on other organisms, and the impact on man's use of the resources. Where appropriate, a sensitivity analysis is performed to reveal the consequences of uncertainties in knowledge or assumptions. Feasible alterations in plant design which might reduce impacts are evaluated with respect to benefits and costs. Those alterations which are found to have sufficient benefits are recommended to the appropriate regulatory agency (e.g., the Public Service Commission or the Nuclear Regulatory Commission) for incorporation into the decision process for a construction permit. For example, in the course of the detailed site evaluation of Douglas Point, a plant design alternative was identified which would reduce the water withdrawn from the Potomac River by a factor of three. Entrainment of fish eggs and larvae would thus be reduced by the same factor. This proposed design alternative was accepted by the utility. Sometimes detailed predictions of the most probable impact are not possible, and a conservative analysis must be used (e.g., assuming 100% mortality of impinged fish where no specific mortality studies have been done).

The monitoring phase consists of detection and quantification of power plant effects, and evaluation of the significance of these effects in altering resource

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* An effect is a measurable change. An impact is an effect that is judged to be significant.

Figure III-3. Spring and autumn salinity distributions in the Chesapeake Bay. From: The Chesapeake Bay in Maryland. Editor Alice Jane Lippson. The Johns Hopkins University Press. Baltimore. Copyright 1973 by the Johns Hopkins University Press (by permission).

Table III-2. Power plant location by salinity regime

Power Plant	SPRING				FALL			
	Riverine	Tidal-fresh	Oligo-haline	Meso-haline	Riverine	Tidal-fresh	Oligo-haline	Meso-haline
Benning Rd.		x				x		
Brandon Shores		x					x	
Buzzard Pt.		x				x		
Calvert Cliffs				x				x
Chalk Pt.			x					x
C.P. Crane		x					x	
Dickerson	x				x			
Douglas Pt.			x				x	
Gould St.		x					x	
Riverside		x					x	
Wagner		x					x	
Westport		x					x	
Morgantown			x					x
Possum Pt.		x					x	
Potomac River		x				x		
R.P. Smith	x				x			
Summit *								
Vienna			x				x	
Conowingo (Hydro)	x				x			

* Theproposed Summit plant is on the C&D canal. Salinity varies irregularly from tidal fresh to mesohaline. The monthly average at the plant site is generally below 5 ppt (37).

yield and ecosystem stability. To learn how losses of organisms due to entrainment, impingement, and plume effects indirectly alter population sizes in the receiving body, populations must be monitored over a considerable span of distance and time. Plant-induced changes (if any) must be separated from natural and other man-induced changes that occur seasonally, annually, or irregularly. To determine the direct damage caused by entrainment, the number and condition of organisms are measured as they enter and leave the plant with the cooling water. Impingement damage for each species is determined from samples taken from screens. These measurements show which species are directly affected in-plant, and to what extent they are affected. Plume effects are determined by measuring changes in abundance or distribution of organisms in the area exposed to temperature increases and other discharge related environmental alterations.

The results of ongoing studies at existing plants are applied to mitigate impact. Where these studies identify plant-related effects, alternative operating schemes and changes in plant design are evaluated as to their benefits and costs. Examples of this are changes in the intake structure at Calvert Cliffs (discussed under the mesohaline section of this chapter) and the ongoing evaluation of augmentation pumping at Chalk Point and Morgantown (2,3). Monitoring results will be applied to the design of future plants. For example, it is extremely unlikely that any new plant would be built with a long discharge canal or low velocity discharge because of the deleterious effects that have been associated with such systems (2,3,4).

The procedures used to assess the ecological significance of plant-induced population changes will vary according to the group of biota considered. For plankton, the concern may be about the result of a localized depletion in terms of yields of higher trophic levels. In the case of fish, the magnitude of plant-related kills might be compared to commercial or recreational harvests. Once the effect has been quantified, the determination of the acceptibility or unacceptibility requires a value judgement, and thus there is a degree of subjectivity associated with the specific determination.

C. Aquatic Impact

Because aquatic impact is a consequence of withdrawal and discharge of cooling water, the magnitude of cooling water flows in relation to the size and flow rates of the water bodies on which plants are sited provides an index of potential impact. These flows contribute to the mixing and transport of the cooling water effluent, and they determine the size of the zone of physical and potential biological alterations. The dilutions of heated water and toxic materials, and the mixing of biota-depleted volumes of cooling water into ambient waters, influence the ability of the habitat to accept the power plant effects without significant ecosystem alterations.

In riverine waters, flow is unidirectional and varies with the amount of rain water run-off. The ability of such a flow regime to meet cooling flow requirements of a power plant, while maintaining environmental integrity, is indicated to some extent by the relative amounts of river flow (usually mean annual low flow) and plant cooling flow.

Estuarine flows are complex and vary from the upper to the lower reaches. Tidal oscillations of the water are superimposed on the unidirectional river flow, and usually exceed it in magnitude. Thus, although water masses may oscillate several times past a given location, net river flow continually brings new water from upstream and flushes "resident" water downstream. Because of tidal influence, discharges from estuarine power plants have residence times near a particular location which are greater than at riverine plants. However, because of the large volume tidal flows, effluents are more readily dispersed and diluted than in rivers.

As salinity increases down-estuary, the non-tidal circulation patterns in the estuary become more complex (see Figure III-4). As the fresh river water flows downstream, it entrains denser (i.e., heavier) salt water from below. A gravitational convection pattern (enhanced by tidal mixing) develops in the lower estuary (extending to some degree to the tidal fresh region). Downstream mass transport in the upper layer will now exceed the river input. To maintain continuity of mass, saline bottom water from downstream must replace the water convected vertically upwards creating an upstream net flow in the lower layers. Thus, opposing non-tidal flows develop, flowing downstream on the top and upstream on the bottom. These flows are superimposed on the tidal flow and may exceed the river input both in the upstream and downstream direction. The difference between these opposing flows is, however always equal to the river input at any point along the estuary. In a general way, we can view these large non-tidal flows as providing high rates of flushing of power plants effluents, while the tidal flows generate dispersion and dilution.*

In this context, there are several characteristics of each power plant and its adjacent water body which are important in assessing the potential impact of the plant. As a result of tidal flows which reverse direction over a single cycle, water originally outside the plant will make an upstream or downstream excursion from that point over the period of that cycle. These double tidal excursion distances define a localized reference volume and area, (see Figure III-4), to which the amount of water used by the plant and the dimensions of the discharge plume may be compared. Ratios of non-tidal river flow to plant flow given an index of the rate of advection (flushing of discharge) away from the site. Ratios of root-mean-square tidal flow to plant flow can be considered as indicators of dispersive potential at a site. The tidal surface area can be compared to the area of the thermal plume (which represents an area over which a direct physical effect is measurable).

The volume of water present within a double tidal excursion distance of the plant can be compared to the volume of water which has passed through the plant over various significant periods of time. Such comparisons have greatest relevance when considering potential plant effects on phytoplankton and zooplankton. These organisms exhibit rapid reproduction (5) (phytoplankton cells typically double in numer in a single day; zooplankton have generation times on the order of seven days). If it were assumed that all entrained organisms

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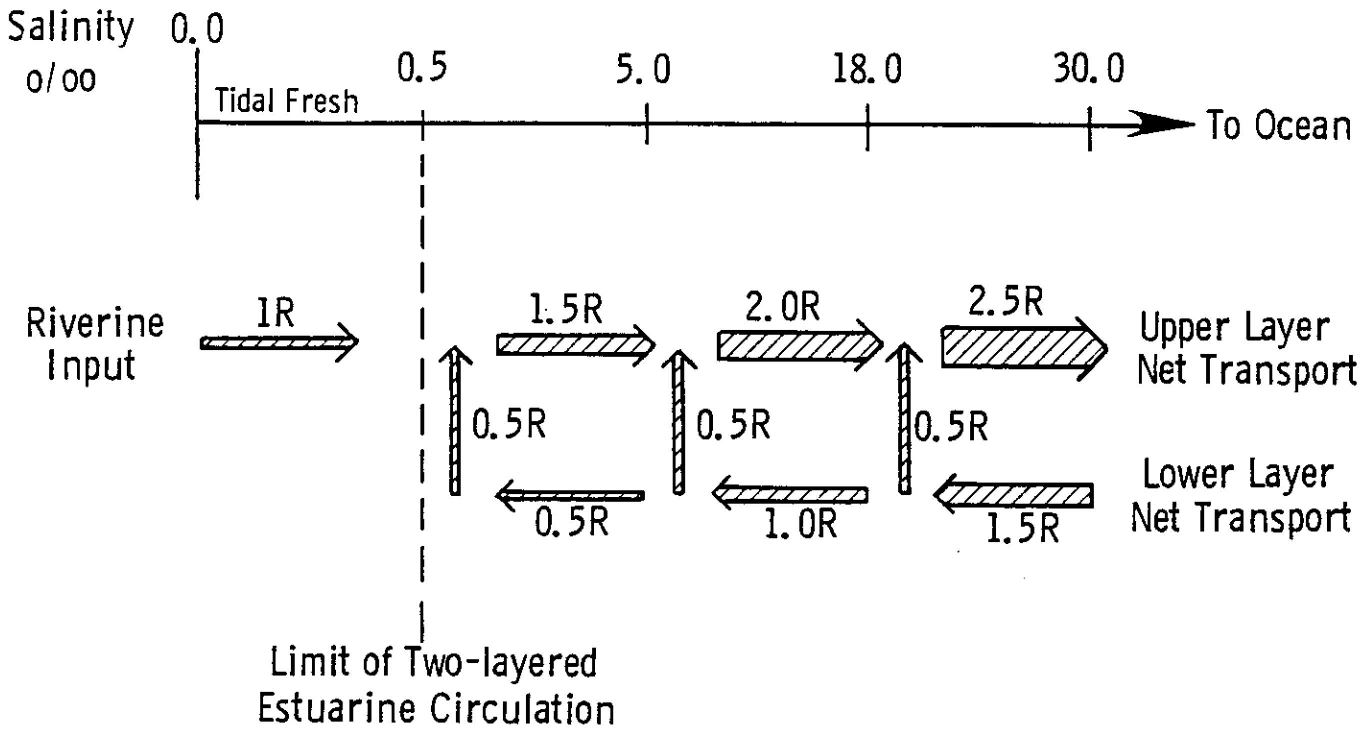
* The extent of the immediate area physically and biologically altered also depends on the width, depth, and velocity gradients of the river. In addition, specific intake and discharge designs will influence the size and shape of the areas affected by intake and discharge flows.

A.



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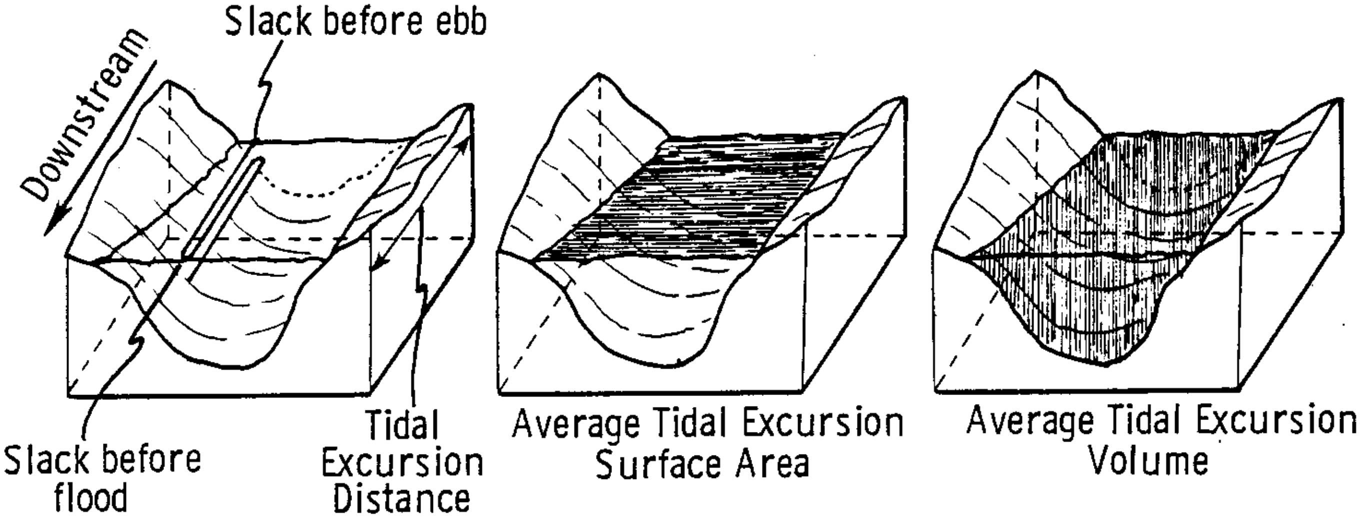

Figure III-4. (A) Estuarine circulation patterns
(B) Tidal excursion

were killed, and that the remaining organisms in the tidal excursion volume continued to be homogeneously distributed (i.e., instantaneously mixed), then the ratio of plant withdrawal volume, during the doubling time, to the tidal excursion volume would represent the percentage reduction in population growth rate attributable to entrainment losses. For populations that are limited in growth due to other factors (such as nutrients), the effect of lowering growth rate by 10-20 percent will probably only affect the time required to reach the limiting level, not the overall standing stock.

Table III-3 and III-4 show these various flows and volumes for plants in Maryland and on Maryland-related water bodies. These areal and volumetric relationships indicate a potential impact of power plants based on scaling alone. Based upon these ratios alone, one would, for example, expect the C.P. Crane, Benning Road, Chalk Point, Buzzard Point, Vienna, and, as a group, the Baltimore BG&E plants, to have a greater potential for aquatic impact. Detailed studies are required, however, to confirm or deny the existence of any in-plant effect.

Having discussed the possible impacts of plants from a physical comparison of the water body size to the plant water needs, we shall now turn to the results of evaluation and monitoring studies for each site within the various salinity regimes.

Mesohaline

This medium salinity zone accounts for the greatest percentage of aquatic habitat in the Maryland portion of the Chesapeake Bay. It serves as the primary area of shellfish and forage fish production, and as nursery and feeding ground of most commercially and recreationally valuable fish species and blue crabs. The three plants located in this zone (Calvert Cliffs, Chalk Point, and Morgantown [summer-fall]) are the largest and newest in the State. All three of these plants have been and are being intensively studied. Preliminary findings of Calvert Cliffs monitoring studies covering the first two years of operation of Unit 1, have been reported (6,7). Morgantown monitoring findings have also been summarized (2,3). Chalk Point was the subject of study in the 1960's (4), and is currently being extensively studied.

- Entrainment

  Inplant losses of about 30-70 percent of entrained zooplankton have been observed at Calvert Cliffs. Loss of entrained phytoplankton have also been observed, primarily in late summer and fall (6,7). In both cases, no nearfield depletion has been observed. Regional reduction in zooplankton density and phytoplankton assimilation was noted in 1975, but the widespread nature of the changes suggest the plant was not the causative agent (6,7).

  High zooplankton mortalities (50 percent) have been measured as a result of entrainment at Morgantown only under the most severe thermal and chlorine stress conditions. Phytoplankton productivity was also reduced during those periods (2). However, no changes in zooplankton and phytoplankton populations in the river were detected (2). It was estimated that 2 percent of the plankton transported

Table III-3. Water flows at Maryland power plants.

	MW Nameplate Rating	Plant Withdrawal (m^3/sec)	Mean River Discharge (m^3/sec)		Root Mean Square Tidal Flow ($10^3 m^3$/sec)		Double Tidal Excursion Distance (Nautical Mi.)	Average Tidal Excursions Volume ($x10^6 m^3$)	Mean of Two Tidal Tidal Excursions Surface Area ($x10^6 m^2$)
			Spring	Fall	Spring	Fall			
Benning Road [a]	749	6.1	6.2	2.4	0.003	0.003	2.1	1.5	1.70
Brandon Shores [b]	1220	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Buzzard Point	235	3.5	6.2	2.4	0.37	0.37	3.0	9.0	2.10
Calvert Cliffs	1828	156.4	2300.0	400.0	61.40	56.70	11.8	2263.5	250.00
Chalk Point [c]	1387	23.4	20.0	8.0	2.03	1.89	13.1	113.5	45.40
C.P. Crane [d]	400	21.0	0.5	0.5	0.56	0.44		5.0	3.00
Dickerson [e]	588	14.7	358.0	144.0		-	-	-	-
Douglas Point [f]	2200	1.4	451.0	181.0	9.42	8.99	8.1	318.2	79.70
Gould St. (g)	174	67.0							
Riverside	334	13.8	9.0	3.0	1.80	1.80		486.6	68.00
Wagner	1043	41.6							
Westport	194	10.0							
Morgantown	1252	61.1	487.0	197.0	12.40	11.40	11.8	636.0	102.70
Possum Point	478	14.8	475.0	195.0	4.44	4.13	6.6	199.3	37.70
Potomac River	514	9.7	470.0	190.0	1.38	1.20	10.5	50.4	19.75
R.P. Smith [e]	110	3.5	200.0	30.0		-	-	-	-
Summit [f]	900	0.7	96.3 [h]	53.8 [h]	1.27	1.18	20.4	61.6	6.00
Vienna [i]	230	3.7	4.3	1.4	1.74	1.62	19.7	54.0	15.50

(a) 250 MW with cooling towers

(b) Withdraws cooling water from Wagner discharge canal, uses cooling tower

(c) Units 1 and 2 have once-through cooling, Unit 3 has cooling tower (withdrawal not including augmentation pumps)

(d) Withdraws from Seneca Creek, discharges into Saltpeter Creek

(e) River plant

(f) Proposed plants, with cooling towers

(g) Total for the four plants

(h) Based on net non-tidal transport through C & D Canal

(i) Units 5, 6, 7 have once-through cooling systems

Table III-4. Relationships between plant withdrawal volumes and tidal volumes; plant withdrawal rate and tidal and river flow rates.

	$\frac{VP_1}{VT}$ %	$\frac{VP_7}{VT}$ %	$\frac{QP}{QT}$ %		$\frac{QP}{QR}$ %	
			Spring	Fall	Spring	Fall
Benning Road [a]	35.1	246.0	203.33	203.33	98	254
Brandon Shores [b]	N/A	N/A	N/A	N/A	N/A	N/A
Buzzard Pt.	3.4	23.5	0.95	0.95	56	146
Calvert Cliffs	0.6	4.2	0.25	0.28	7	39
Chalk Pt. [c]	1.8	12.5	1.15	1.24	117	293
C.P. Crane [d]	36.3	254.0	3.75	4.77	4200	4200
Dickerson [e]	N/A	N/A	N/A	N/A	4	10
Douglas Pt. [f]	< 0.1	0.3	0.01	0.02	< 1	1
Gould St., Riverside, Wagner, Westport [g]	1.3	9.0	4.00	4.00	801	2403
Morgantown	0.8	5.8	0.49	0.54	13	31
Possum Pt.	0.6	4.5	0.33	0.36	2	5
Potomac River	1.7	11.6	0.70	0.81	3	8
R.P. Smith [e]	N/A	N/A	N/A	N/A	2	12
Summit [f]	0.1	0.7	0.06	0.06	1 [h]	1 [h]
Vienna [i]	0.6	4.1	0.21	0.23	86	264

Key:

VP_1 = plant withdrawal volume - 1 day
VT = tidal volume
VP_7 = plant withdrawal volume - 7 days

QP = plant withdrawal rate
QT = tidal flow
QR = flow of river (or net flow up estuary)

NOTE: For footnotes, see Table III-3

past the plant would be destroyed by entrainment (2,3). No adverse impact would result from losses of this magnitude to the rapidly reproducing plankton populations.

Large kills (up to 100 percent) of entrained organisms have been observed at Chalk Point* with thermal and biocide stresses appearing to both be important as causes. Near-plant depletions of jellyfish were noted, but no changes in river populations of copepods were found (4).

The findings at all three plants are consistent. Entrainment losses of phytoplankton and zooplankton do occur but high reproduction rates of the affected populations compensate for plant effects. Cumulative effects would not be expected. Studies to verify this are now underway.

Chalk Point has an additional entrainment effect due to the lack of screens in front of the augmentation pumps used during the summer months. Without these screens, fish and crabs that would normally be impinged may be entrained into the pumps. Studies to quantify the magnitude of these losses are now in progress (9).

Eggs and larvae of Bay anchovy, naked goby and hogchoker (all forage species) are found in the Calvert Cliffs vicinity and are entrained. Densities near the plant have not differed significantly from those observed beyond the area of plant influence (6). Thus, nearfield losses caused by entrainment were not detected. The same species of larvae are found at Chalk Point and Morgantown. Nearfield ichthyoplankton depletions were also not detectable at Morgantown (2). Localized losses of ichthyoplankton of these species, which spawn virtually throughout the Maryland portion of the Bay, are insufficient to decrease Bay populations.

- Impingement

Fish and crab impingement data from Calvert Cliffs, Morgantown and Chalk Point are summarized in Table III-5. Menhaden and spot dominate the fish impingement at these plants, except for Calvert Cliffs impingement in 1975 which shows greater variability in species composition. The six species listed in the table are all abundant, ubiquitous species that occur throughout mesohaline regions of the Bay and its tributaries. These species also dominate net catches made during surveys conducted at these sites (3,6), confirming the non-selective nature of cropping by power plants. The plants appear to be impinging fish at a rate proportional to their abundance in the plant vicinity. There is insufficient knowledge of population size and dynamics of all of the listed species to predict the exact consequence of plant-induced losses, but no changes in fish density or community composition in the vicinity of these plants have been observed. This implies that impingement losses are too small to significantly alter the size of Bay populations. One way of putting impingement losses in perspective is to compare them to other population

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* PEPCO has indicated that more recent, unpublished studies may lower entrainment mortality estimates (8).

Table III-5. Estimated total impingement by species at mesohaline power plants (number of individuals). Data have been obtained by summing monthly totals estimated from samplings during that month. Sampling schedules (frequency and duration) vary from plant to plant and from time to time. (See references for details.)

	1975		1976			
Species	Morgantown[a]	Calvert Cliffs[b]	Calvert Cliffs[b]	Chalk Point[c]	Morgantown[d]	Total[e]
Menhaden[f]	414,376 (57%)	189,873 (11%)	454,209 (20%)	552,782 (59%)	759,680 (55%)	1,766,671 (39%)
Spot[f]	200,972 (27%)	261,964 (15%)	1,280,094 (58%)	254,404 (27%)	286,869 (21%)	1,821,367 (40%)
Hogchoker	2,510 (0.3%)	99,154 (6%)	188,367 (8%)	50,893 (5%)	36,167 (3%)	275,427 (6%)
Bay Anchovy	30,969 (4%)	672,709 (38%)	77,271 (3%)	10,421 (1%)	47,851 (3%)	135,543 (3%)
Croaker[f]	3,069 (0.4%)	338,531 (19%)	106,799 (5%)	5,102 (0.5%)	--	111,901 (3%)
White Perch	60,648 (8%)	3,921 (0.2%)	4,752 (0.2%)	4,365 (0.5%)	96,993 (7%)	106,110 (2%)
Others	19,576 (3%)	199,050 (10.8%)	111,881 (5%)	59,030 (7%)	147,721 (11%)	318,632 (7%)
TOTAL FISH	732,081 (100%)	1,765,202 (100%)	2,223,373 (100%)	936,997 (100%)	1,375,281 (100%)	4,535,651 (100%)
Crabs	--	294,975	434,004	1,106,269	280,704	1,820,977

(a) March and June-December (6)

(b) January - December (7)
(Does not include large episodic fish kills - see text)

(c) June - December

(d) May 15, 1976 - May 28, 1977 (6)

(e) For periods indicated

(f) Predominantly juveniles

losses (i.e., due to predation, fishing, natural die-offs, etc.). Such data are available for the major impinged species discussed below. Detailed studies are now in progress to improve our knowledge of these species.

-- Menhaden is one of the major commercial finfish species in the Bay, usually accounting for over 40 percent of total landed weight (Table III-6). Populations are mobile, and they are distributed throughout mesohaline and oligohaline regions of the Bay. In some cases, the impingement data in Table III-5 do not span an entire year, but do cover the summer-fall period when menhaden are most abundant. Impingement mortality for menhaden is considered to be 100 percent. As an approximation of a single year's impingement weight total of menhaden for the 3 mesohaline plants, the 1976 number totals were multiplied by the average weight of menhaden impinged at Calvert Cliffs (20 g = .043 lbs) to give total impinged weight estimates of 76,000 pounds. This is about 1.25 percent of the 1976 Maryland landings of 6 million lbs (Table III-6). Although the mean weight of commercially harvested menhaden is not known, they are larger (older) than the juveniles being impinged. The number of juvenile menhaden impinged is, therefore, much more than 1 percent of the number of adult menhaden commercially caught. However, since these juveniles would have suffered considerable natural mortality (typically 90 percent) before reaching harvestable size, the plant related losses would probably cause a much smaller decline in subsequent years.

   Menhaden experience large natural die-offs throughout the Bay during summer months. Many of these kills are unreported or unquantified. Reported kills of menhaden in 1974 and 1975 totaled 100 million and 1.9 million individuals, respectively (10). The 1976 impingement total for the 3 plants is estimated to be 1.8 million individuals.

   Menhaden are also a favorite prey of the two major predatory fish in the Bay: bluefish, and striped bass. Daily rations for these species are about 3-5 percent of their body weight/day (11). Total stock of bluefish and striped bass in the Bay is unknown, but the amount harvested, which may represent only a small percentage of the stock, can be used to give some insight into the amounts of forage fish consumed by predators. From May to October in 1976, sportfishermen landed 535,800 lbs of striped bass and 2,915,179 lbs of bluefish in the upper Bay (12). If these totals are combined with commercial landings over the entire Bay during the same period, total weight of both species landed was 5,246,000 lbs. Assuming 4 percent of body weight consumed each day for a 5 month period, total forage which would have been utilized by these landed fish is 32,525,000 lbs, much of which would have been menhaden. The estimated impinged total of 76,000 lbs is about 0.23 percent of that total. All of the above comparisons demonstrate that menhaden impingement kills represent a small perturbation on the Bay.

-- Spot and croaker juveniles are abundant in mesohaline areas. Their impingement mortality is considered to be near 100 percent (13).

Table III-6. Maryland commercial landings

	1972		1973		1974		1975		1976	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Fish										
Alewives(a)	1,654,641	$ 33,098	2,331,424	$ 45,254	1,387,676	$ 31,801	696,477	$ 16,075	121,990	$ 5,320
Bluefish	59,075	5,802	275,330	23,097	372,738	28,357	271,914	25,671	489,399	28,589
Catfish and Bullheads	386,340	39,567	295,083	31,125	302,628	37,908	260,050	30,485	230,023	28,409
Eels	229,764	33,164	180,466	44,118	144,527	42,984	204,667	69,725	165,725	58,004
Menhaden	6,212,002	124,614	9,686,956	221,059	4,932,962	128,631	6,228,700	166,003	6,105,600	192,607
Sea Trout	313,428	34,125	539,520	74,615	372,832	47,754	892,718	79,414	428,786	46,283
Shad(a)	954,145	117,299	597,914	105,573	221,444	46,000	182,352	44,606	110,639	42,028
Spot	68,171	10,974	27,322	5,244	10,018	1,383	89,900	8,314	15,737	2,838
Striped bass(a)	3,185,929	917,548	4,677,617	1,451,800	3,382,852	880,329	2,763,509	1,083,710	1,813,910	990,863
White perch(a)	1,108,033	204,784	762,719	162,697	497,755	93,402	568,900	112,049	407,700	107,046
Yellow perch	101,465	13,549	35,523	7,150	35,409	5,070	29,818	5,323	22,744	4,973
Other finfish and Unclassified	897,610	185,717	1,179,483	246,222	1,602,952	277,375	2,785,551	510,279	3,714,130	805,787
TOTAL FISH	15,170,603	$1,720,241	20,589,357	$2,417,954	13,263,793	$1,620,994	14,974,556	$2,152,095	13,626,383	$2,312,747
Anadromous fish above and $ of total fish		$1,272,729 (74%)		$1,765,324 (73%)		$1,051,532 (65%)		$1,256,440 (58%)		$1,145,257 (50%)
Shellfish										
Blue crabs (hard, soft, peeler)	25,050,531	$3,114,209	20,723,286	$3,484,057	24,973,677	$4,631,815	25,917,890	$5,149,768	20,885,600	$5,649,968
Soft clams	1,949,520	1,014,782	668,688	557,240	1,766,136	1,501,210	1,246,128	1,174,340	1,742,604	2,767,698
Oysters	19,052,800	11,963,272	19,055,700	12,561,489	17,263,970	11,588,664	16,402,300	13,126,666	15,827,708	16,428,117
Turtles (snapper)	18,023	3,597	24,353	5,189	36,540	10,226	83,144	26,644	48,085	14,136
Terrapin (Diamondback)	3,545	1,523	1,458	709	1,733	1,016	5,058	3,319	1,201	791
ABOVE SHELLFISH(b)	46,074,419	$16,097,383	40,473,485	$16,608,684	44,042,056	$17,732,931	43,654,520	$19,472,737	38,505,198	$24,860,710
GRAND TOTAL	61,245,022	$17,817,624	61,062,842	$19,026,638	57,058,849	$19,353,925	58,629,076	$21,624,832	52,131,581	$27,173,457

(a) Anadromous species

(b) Exclusive of the following species limited primarily to Atlantic Ocean waters: lobsters, hard and surf clams, conch, and squid.

Source: "Maryland Landings," Current Fisheries Statistics, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, December 1973-76.

The estimated annual impingement in 1976 at Morgantown, Chalk Point, and Calvert Cliffs was about 1,800,000 spot and 112,000 croaker with mean weights of 0.0112 and 0.018 lbs, respectively. Trawl surveys at Morgantown and Calvert Cliffs show that both spot and croaker juveniles are very abundant in these areas. We estimate, from catches at Calvert Cliffs, that the total number of spot impinged in June 1976 (346,800, the highest monthly total for the year) was equivalent to the number of spot occupying about 100 acres of Bay bottom at that time, representing approximately 0.01 percent of the suitable habitat in the Bay (14). Another indication of the density that occasionally occurs is that 23,000 juvenile spot were taken in a single tow in the fall of 1976 during the scientific sampling program.

To determine the impact of this impingement, we can compare to sports and commercial catches. In making such a comparison, it must be kept in mind that the juveniles impinged in the lower mesohaline habitats (e.g., Calvert Cliffs) would have spend their adult life in a region extending from the higher mesohaline environment at the Maryland-Virginia border to the marine environment of the ocean. Thus, any effect of juvenile kills at Calvert Cliffs would manifest itself in depletions in the lower Bay and the ocean. Because of relatively high natural mortality in developing from juveniles to adults, the effect of juvenile impingement mortalities would be greatly attenuated as it propagates through the age structure of the species. It must also be kept in mind, that both spot and croaker are very lightly exploited resources in Maryland, with modest sports and commercial catches.

The available data (12) indicates that the sport harvest in the upper Bay during May through October 1976 was about 52,800 spot and 10,950 croaker of an average weight of 0.3 to 0.1 lb, respectively (clearly a different age class from the impinged fish). These low numbers are reasonable, considering the preference of the adult fish for higher salinity waters. Commercial landings in the Bay for 1976 were 5,723 lbs in Maryland and 1,203,766 lbs in Virginia for spot, and 1,089 lbs in Maryland and 2,871,420 lbs in Virginia for croaker (Table III-6). (Total Maryland commercial landings in 1975, mainly from the ocean, were 89,900 lbs and 639,000 lbs for spot and croaker, respectively.) Converted to number of individuals, the Bay commercial catch of 4 million spot and 3.2 million croaker can be compared to an estimated adult stock loss 0.22 million spot and 0.012 million croaker due to impingement (assuming 10 percent of juveniles survive to adulthood).

The conclusion is that the juvenile impingement losses of spot and croaker, lightly exploited species, are insignificant, based on the great abundance of these juveniles in the mesohaline habitat.

-- Hogchoker, a very hardy species, suffer less than 1 percent mortality as a result of being impinged. Thus, no plant influence on hogchoker populations can be expected.

-- Anchovy, the remaining major impinged fish species, is distributed throughout the Bay. Acoustic surveys have revealed densities on the order of 7-25 fish per m^3 of water (6). At a density of 13-14 fish per m^3, the total impinged in one year at the three plants would occupy only about 10,000 m^3 (a volume approximately 100 by 100 feet wide and 30 feet deep), 1/4 of 1 percent of the total mesohaline volume of the Bay. Impingement mortality is 100 percent (13).

-- Crabs are impinged at all 3 plants. In 1976, Morgantown impinged about 281,000 crabs. From June to December 1976, Chalk Point impinged approximately 1 million crabs,* which was 3 times the commercial catch in the Patuxent and equal to the estimated sport harvest. In 1976, Calvert Cliffs impinged approximately 440,000 crabs. Mortality studies have demonstrated that crabs suffer less than 1 percent mortality from impingement (13). Thus, unless the crabs should suffer delayed mortality as a result of the impingement episode (and there is no evidence of this), no impact would result from the mechanical effects of impingement. Post-impingement mortalities could occur where crabs are washed into a discharge canal (such as at Chalk Point or Morgantown) where they are exposed to chlorinated and heated effluent. This possibility is currently being assessed at Chalk Point.

The impingement rate at the Calvert Cliffs plant has changed considerably since the first summer of operation. During July/August 1975, several large impingement episodes of 500,000 fish or larger crushed intake screens and forced shut-down of the power plant (7). It was theorized that entrapment (explained previously), coupled with low DO caused by certain wind conditions weakened the fish, causing them to impinge in large numbers. To combat this problem, BG&E now removes four panels from the curtain wall during the summer months, allowing surface water (presumably higher in oxygen) to enter and allowing an escape route for the fish. Since this adjustment, only one large episode has occurred: during routine impingement studies at the plant on June 13, 1978, approximately 72,000 fish were collected during one hour (15).

- Discharge Effects and Habitat Modification

The thermal plume produced by Calvert Cliffs Unit 1 averaged 10 acres within the 2°C excess temperature isotherm (6). The maximum extent of this isotherm along the Bay was 2/5 mile from the point of discharge (approximately 1/10 the width of the Bay at that point). In studies of fish, plankton and benthos, no changes in community composition or abundance could be found which were attributable to this thermal influence. Benthic communities were altered only in about a 60-acre bottom area from which loose sediments have been swept by the high velocity discharge. No deleterious effects on oyster growth or mortality nor uptake of copper by oysters were observed (6).

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* Based on extrapolation of impingement data taken during 465 half-hourly sampling periods from June through December. The utility (PEPCO) feels that a saturation effect may limit the number of crabs impinged during actual operation.

The thermal plume produced by Calvert Cliffs Unit 1 and 2 combined averaged 30-40 acres within the 2°C excess temperature isotherm and occasionally exceeded 60 acres in size (16). Studies to quantify any discharge effects are presently in progress.

Morgantown findings are consistent with Calvert Cliffs results. The thermal plume as defined by the 2°C isotherm, was generally about 3-4 acres in size, but occasionally as great as 80 acres. No significant influence of this thermal discharge has been found (3).

Temperature elevations caused by Chalk Point operations have been detected over 1 mile from the plant (17). Because the estuary is shallow and has low flows (Table III-4), thermal influence would be experienced over greater areas than at Calvert Cliffs or Morgantown. Despite this fact, the monitoring studies conducted in the 1960's revealed few plant effects. Erosion of copper from condenser tubes was noted, and uptake of copper discharged from the plant by oysters was found. This situation was apparently corrected later (18) Large concentrations of fish in the discharge canal have appeared in fall and winter, and the area now supports an intensive sport fishery. Large kills of fish and crabs in the discharge channel were reported in the 1960's, attributed to accidental excessive discharge of chlorine (4,19). Similar kills have not been reported in recent years, and no detectable effects on zooplankton or ichthyoplankton were found. Additional monitoring is currently proceeding at this plant.

When results of studies at the three plants are compared, a consistent picture emerges indicating low probability of cumulative impact on the mesohaline environment. Plankton entrainment losses have been measured inside several of the power plants. These losses, however, do not show up as any measurable plankton depletion in the waters around the plant. This lack of measurable effects is probably due to the high reproduction rate of the plankton, and indicates that there is no impact due to plankton entrainment. No important commercial or recreational species spawn in this habitat, and entrainment losses of ichthyoplankton are thus of little significance. Localized effects on benthic organisms, including shellfish, are sometimes evident. These effects have no significance beyond the immediate discharge areas.

Tidal Freshwater/Oligohaline

These habitat zones have significant value as the major spawning area of anadromous fish, which as a group have accounted, on the average, for about 65% of total monetary value of commercially harvested finfish from 1972 to 1976 in Maryland (Table III-6). Anadromous spawning occurs in spring so the plants of most concern are those in the tidal fresh zone at that time (Table III-2). The nine plants so located can be divided into three geographical regions.

The Baltimore Plants (C.P. Crane, Gould St., Riverside, H.A. Wagner, and Westport) are located on the Patapsco River and its tributaries and on Seneca Creek. In the past, environmental degradation which is not related to these plants has eliminated the area as an important anadramous spawning ground (20), and the area also does not serve as a major nursery area for juveniles of most important fish species. White perch is the most common fish. With the exception of Wagner and Crane, these plants are all older than 20 years, are used for peaking service, and have seen decreased service since Calvert Cliffs came on line.

The Washington Area Plants (Benning Road, Buzzard Point, and Potomac) are located in the upper Potomac Estuary where chronic oxygen deficiencies have been reported (21). This decline in water quality has been reflected in a reduction in diversity and abundance of fish (22). However, if the other pollution sources should be cleaned up, and these areas became productive again, power plants should not be allowed to adversely affect the environment. Thus, assessment of the potential impact of these plants is appropriate despite the present absence of major aquatic resources nearby.

The Possum Point plant is located in a segment of the Potomac River where striped bass spawn, and Douglas Point located across the river is a proposed site for a new power plant. The proposed plant, the effect of which has been extensively studied, would utilize cooling towers so that cooling water withdrawals would be small (estimated 50 cfs) (23). Another plant, Summit, has been proposed in New Castle County in Delaware on the Chesapeake and Delaware Canal, approximately two-thirds of the way towards the eastern end of the canal. This plant, as originally proposed, would use 2 cooling towers and have a total withdrawal rate of 42.5 cfs.

The oligohaline zone serves as a nursery area for many estuarine fish during much of the year. Some striped bass spawning occurs in portions of this zone in the spring. The three plants using oligohaline waters for cooling in the spring are Chalk Point on the Patuxent, Morgantown on the Potomac and Vienna on the Nanticoke. The salinity Chalk Point is often on the borderline between oligohaline and mesohaline in the spring and the Morgantown site drops to within the oligohaline range on the average only during spring of each year (2). Thus, impact at Chalk Point and Morgantown were discussed under mesohaline plants, with only Morgantown ichthyoplankton entrainment and impingement mentioned here.

Eight of the ten freshwater tidal plants become oligohaline during the summer-fall period (Table III-2).

- Entrainment

  Plankton entrainment data are not available for any of the present tidal freshwater plants. Studies elsewhere (see Mesohaline discussion above) indicate that entrainment losses of phytoplankton and zooplankton generally do not result in detectable nearfield depletions and thus would be unlikely to contribute to cumulative impact. However, at most of the present tidal fresh plants, cooling water withdrawal is large relative to freshwater and tidal flow (Table III-4), and localized effects on plankton may occur. Entrainment losses of ichthyoplankton could cause declines in fish populations utilizing discreet spawning areas. The Baltimore and Washington areas currently do not serve as important spawning ground for any anadromous species. The abundant species of these areas, such as white perch, are ubiquitous in the Bay (14). Losses of eggs and larvae at those plants are unlikely to cause Bay-wide declines in such ubiquitous stocks. Possum Point, however, is sited on the striped bass spawning grounds in the Potomac estuary. Recent work indicates that the plant entrains a maximum of about 2 percent of the bass larvae produced annually in the Potomac The exact significance of such a loss to adult fish is not currently known, but it can certainly not exceed 2 percent of the actual catch of fish spawned in the Potomac (23).

If a plant using cooling towers were constructed at Douglas Point (across the Potomac from Possum Point) it would be unlikely to alter local zooplankton and phytoplankton populations through entrainment because of the small volume of water utilized. It has been estimated that such a plant would entrain between 0.6 and 1.2 percent of the striped bass larvae produced there in any one year. Such a loss could cause no more than similar percentage decline in eventual production of adults (23). The strength of the year class is usually well established by the time the striped bass spawn become juveniles (3-5 months old) and is largely dependent on environmental conditions during that period (24). The Summit plant is located in an area of some striped bass spawning, although most of the spawning takes place towards the western end of the canal. It is estimated that between 1 and 2 pecent of the entrainable striped bass ichthyoplantkon that originate in the canal will be entrained by the Summit power plant (25). Possible plant design alternatives to reduce the entrainment are still being pursued.

Morgantown is located 20 km downstream of the center of the striped bass spawning area in the Potomac. Few eggs or larvae ($\leq$ .01 percent) are entrained (26) and consequently, no significant impact on the striped bass population occurs because of the operation of this plant. Vienna is in the midst of the spawning area in the Nanticoke. The plant has two distinct sections: units 5, 6, 7 (68 MW) using once-through cooling (withdrawal 3.6 m^3/sec) and unit 8 (162 MW) using a cooling tower (withdrawal 0.12 m^3/sec from discharge of units 5, 6, 7). The once-through units, now scheduled for retirement in 1987, will operate below 25% capacity factor (annual average) after 1980 (27). In addition, Delmarva has proposed a 400 MW expansion (1987 completion date) that will withdraw 0.36 m^3/sec for cooling and plant purposes. The present plant does entrain striped bass eggs and larvae (28), but the exact magnitude and consequences of the losses are not known. To estimate the loss, we may use two simple techniques (29) involving tidal volumes and known distributions of eggs and early larval stages. These results, for a withdrawal rate of 0.36 m^3/sec (about 10% capacity factor for units 5, 6, 7), give an entrainment estimate of 3-8% of the spawn in the river.* Spring capacity factors for the last 5 years have ranged between 23% (1977) to 79% (1974). The assumptions implicit in this simple calculation are probably not valid for losses greater than

* Implicit in this calculation are the following assumptions: 100% mortality, no recirculation, uniform entrainability for 90 days.

30%*. Nevertheless, they do show that entrainment losses at this site constitute a significant percentage of the Nanticoke spawn. Studies now underway to evaluate the impact of the new unit at Vienna will be used to establish the impact of the present units. A possible outcome of this study will be a capacity factor limitation at this site during the spawning and nursery season for striped bass.

The potential impact on the overall striped bass stock can be estimated by examining the contribution of each impacted area to total spawning in the Maryland part of the Chesapeake Bay and its tributaries. These contributions can be estimated from the commercial catch records for the months (March and April) just prior to spawning. This catch is assumed to be proportional to the presence of spawning adults and hence to the spawn. This data is summarized in Table III-7 which shows, for example, that Potomac River spawning constitutes about one fourth of total striped bass spawning in Maryland. Therefore, under our assumption, a 1 percent loss of striped bass larvae in the Potomac would translate to a 0.25 percent loss of the Maryland fisheries. The total potential loss can be assess from the size of the fishery affected. Table III-6 shows the annual commercial striped bass catch in Maryland (the average annual sports catch is roughly equal to the commercial catch (12)). Following the reasoning above, each 1 percent loss of the striped bass larvae in the Potomac is equivalent to a loss of about 8000 lbs of striped bass. This calculation neglects the relative decline in the Potomac catch for 1964 to 1972 (Table III-7) as well as the absolute decline in Maryland catch (Table III-6). In addition, the Bay stock is the principal contributor to a large fishery in the mid-Atlantic states and New England.

- Impingement

No impingement data are available for the the tidal-fresh plants. Since all except Possum Point are sited on waters of degraded water quality supporting limited fish populations, any impingement losses from these plants have little probability of influencing Bay resource yields. Because of the low velocity and volume of cooling water to be utilized at the proposed Douglas Point plant, magnitude of impingement there would be expected to be low and impact inconsequential (23).

It is interesting to note that the majority of white perch collected (3) in Morgantown impingement samples in 1975 (Table III-5) were taken during the single spring sampling period (March). At that time salinities are close to oligohaline. This species is more typically oligohaline than mesohaline. Thus, the data substantiates the validity of examining cumulative plant impact according to habitats defined by salinity regimes. As discussed earlier, white perch populations occur in virtually all tributary estuaries of the Bay, including areas of poor water quality. Morgantown impingement kills are not expected to modify Potomac River or Bay white perch populations. No impingement data is available from Vienna.

* Which would occur at a capacity factor of 37-100%.

Table III-7. Commercial catch of striped bass in March and April by region in the Maryland portion of the Chesapeake Bay, by percent

Year	Upper Bay above Sassafras River	Bay Bridge to Sassafras River	Chester River	Cove Point to Bay Bridge	Choptank River	Virginia to Cove Point	Patuxent River	Nanticoke River Wicomico River	Potomac River (including Virginia side)
1972	8.67	30.76	4.61	5.76	10.02	2.37	2.22	15.87	19.67
1971	10.13	27.24	2.39	5.66	10.58	0.85	4.07	13.15	25.87
1970	9.37	34.86	5.18	4.90	10.84	0.99	2.65	8.81	22.14
1969	17.17	33.66	1.63	4.18	9.24	0.86	3.27	8.27	21.67
1968	12.04	24.20	1.76	3.69	6.40	1.25	2.09	11.61	36.74
1967	9.54	29.58	1.36	3.31	7.00	0.82	2.18	11.45	34.75
1966	6.03	22.91	2.73	2.84	10.37	1.65	1.07	19.34	33.03
Averages	10.73	29.50	2.80	4.30	9.10	1.25	2.49	12.28	27.46

- Discharge and Habitat Modification

  The general degradation of water quality in the vicinity of the Baltimore and Washington plants (21) makes identification of plant discharge effects difficult. If water quality were to improve, thermal and biocide discharges of these plants would have the same potential for aquatic impact as plants in unpolluted areas. Thus, they require studies to determine appropriate measures to mitigate any adverse impact. (Studies at the Baltimore plants are now underway.) Possum Point cooling water enters the Potomac shortly after discharge. At the proposed Douglas Point plant, the discharge would consist of cooling tower blowdown, which could contain biocides and metals such as copper corroded from the plant cooling system, unless, as recommended, titanium tubing is used in the condenser and the blowdown is dechlorinated (30). Because of the low volume of discharge, any effects of these discharges would be restricted to the immediate area of the discharge point. Studies of the Vienna discharge during spring (31) revealed a small plume confined near the west bank. Over most of the region, larger temperature gradients resulted from differential solar heating than from the heated water discharge.

Riverine

The only Maryland steam electric stations located on rivers are R.P. Smith and Dickerson, both on the Potomac. Each utilizes, at times, a substantial portion of average river flow for cooling purposes (Table III-4). The plants are relatively old, of low to medium generating capacity, and located in areas inhabited by typical warm water "riverine" biological communities (32).

- Entrainment

  Riverine communities are not plankton-based. Entrainment losses of the sparse populations of plankton present have little influence on local ecosystems. No spawning of anadromous fish occurs near these plants. Most resident fish are nestbuilders having non-planktonic larvae. Significant ichthyoplankton entrainment would thus not occur. The juveniles tend to be shore oriented, not moving with the main flow of water (33).

- Impingement

  Data are now being gathered to provide the basis for an analysis of impingement effects.

- Discharge and Habitat Modification

  Temperature elevations in the discharge area are usually the only type of interaction of importance in assessing impact on riverine aquatic communities. Data delineating the size of the thermal plumes has been collected, but the results are not yet available. Studies to assess the significance of these elevations and to quantify their areal extent are underway at both plants.

The Conowingo Dam on the Susquehanna River is the only large hydroelectric generating station in Maryland. Large kills of anadromous clupeid fish (alewives, blueback, American and hickory shad) occurred at the base of the dam in the 1960's, and were accompanied by declines in the size of the annual runs of these species (34).

These springtime kills of spawning fish occurred when the turbines were shut off at night, and no water passed the dam site. The cause of the mortality was traced to a depletion of dissolved oxygen by fish massed at the foot of the dam during spawning runs (34). No kills have occurred in recent years since an agreement between the utility and the Maryland Department of Natural Resources went into effect, guaranteeing a continuous minimum flow of 5,000 cfs through the dam during the spawning season.

Runs of anadromous fish in the Susquehanna below the dam have continued to decline. However, since kills have not occurred in the dam, the decline cannot be directly attributed to these kills (34,35).

D. Regulatory Considerations

The question of which type of cooling system should be required for existing power plants in order to ensure acceptable aquatic effects has been the subject of several State and Federal Regulations. Under the Federal Water Pollution Control Act of 1972 (FWPCA), a goal of zero heat discharge was set by Congress. The original proposed EPA regulations under this Act (March 1974) included a requirement for all "base load" steam electric stations to install closed cycle cooling (see Chapter IV) by 1978/79. Exceptions were to be granted under section 316(a) if a utility could demonstrate that closed-cycle cooling was not needed to "assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the body of water..." The promulgated regulations have changed the deadline to 1981 for units constructed after 1970. However, the entire issue of federal regulation has been clouded by a 1976 court decision remanding several sections of the EPA regulations that affect Maryland power plants (36). In addition, the lack of final format for regulations, guidance manuals, and procedures has hindered initiation of studies. On the State level, the Water Resources Administration (WRA) has been delegated authority under the FWPCA to administer the National Pollutant Discharge Elimination System (NPDES). Under this system, once the State has established water quality standards that are at least as strict as Federal regulations, the State may, with EPA oversight, regulate all discharges within the State. Water Resources Regulation 08.05.04.13 places requirements on all steam electric stations over 25 MW expected to have in 1980 an annual capacity factor over 25 percent or a summer capacity factor over 40 percent. All discharges that do not satisfy a preliminary screening test based on the ratio of the size of the thermal plume to the cooling water body and the importance of spawning in the region must either: 1) install closed cycle cooling; 2) demonstrate that the standards are unnecessarily stringent and existing conditions preserve natural water quality; or 3) demonstrate that other limitations less costly than closed cyle cooling will preserve natural water quality. The first case (Morgantown) is presently scheduled for the spring of 1979.

All steam electric stations must, under section 316(b) of the FWPCA, demonstrate best practicable technology (to minimize impact) in their intake structure design. However, the EPA regulations for this section have also been remanded (36). Maryland Water Resources Regulation 08.05.04.13 requires evaluation of best practicable intake structure design by setting up a cost-benefit analysis approach for modifications. Here the potential conflict between Federal and State regulation is minimal.

E. Conclusions and Summary of Impact

Dividing the aquatic habitat into three general areas, we can draw the following conclusions:

- Mesohaline

  Because of the high reproduction rates of the plankton and good tidal mixing at the existing plants, depletion of plankton populations has not occurred. Spawning occurs throughout the Bay for the species of fish present here, so local depletions are insufficient to decrease Bay populations. Impingement totals are small compared to mortality due to other sources. In addition, efforts to reduce these totals are now underway at all three existing plants. Habitat modification effects, usually more subtle in nature, have minor, localized impacts as described in this chapter. Coupled together, the power plant monitoring studies show a low cumulative impact on the mesohaline environment.

- Tidal Fresh/Oligohaline

  The major area of concern within this region is the impact of cooling water withdrawals upon the nursery and spawning areas of striped bass and other anadromous species. Possum Point and Vienna have the highest potential for impact. New facilities planned for this region (Douglas Point, Summit, and Vienna) would increase withdrawals. Using Table III-7 as a guide for the relative importance of striped bass spawning areas, the present and future entrainment levels are summarized in Table III-8. As can be seen, the overall impact upon striped bass due to entrainment drops from an estimated 6.60 percent entrainment (upper bound) of the eggs and larvae spawning in Maryland portion of the Bay to an estimated 3.14 percent (upper bound). The addition of Douglas Point and Summit is more than off-set by the retirements of the once-through cooling units at Vienna. No impingement data is available at any of the present plants; however, degraded water quality at the Baltimore and Washington plants appears to have severely restricted fish populations in these waters. Similarly, habitat modification effects or depletion of plankton would be difficult to detect. Ongoing studies should help to quantify these effects at the Maryland plants. The proposed plants are expected to have no major impacts in the areas of impingement or habitat modification due to the small amount of water withdrawn.

Table III-8. Estimated upper limit impact on striped bass ichthyoplankton power plant entrainment

Power Plant	River	% of Md. Spawn in River	Present to 1980		1980 to 1987		After 1987[a]	
			% of River Population Entrained	% of Total Md. Spawn Entrained	% of River Population Entrained	% of Total Md. Spawn Entrained	% of River Population Entrained	% of Total Md. Spawn Entrained
Possum Pt.	Potomac	28	2	0.60	2	0.60	2	0.60
Morgantown	Potomac	28	0.01	<0.01	0.01	<0.01	0.01	<0.01
Vienna	Nanticoke	12	50[b]	6.00	25[c]	3.00	2.8[d] 8.0[e]	0.34 0.96
Douglas Pt.	Potomac	28	--				1.20	0.34
Summit	C&D Canal	30	--				3	0.90
TOTAL of Md. spawn entrained at all plants				6.60		3.60		3.14

(a) Assuming Douglas Point, Summit, and Vienna unit 9 come on line

(b) Assuming 50 percent capacity factor on once-through cooling units

(c) Assuming 25 percent capacity factor on once-through cooling units

(d) Assuming once-through units retired, Vienna 8 still on line

(e) Vienna unit 9

- Riverine

  No impact is expected from entrainment and impingement. Studies of possible habitat modification due to the discharge of heated effluent are now underway at both of the two existing plants in this region. These studies are expected to be completed during 1978.

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