

Water Quality Inventory Report for the Delaware River

A Status and Progress Report
Prepared under the Auspices of Section 305(b) of the
Federal Clean Water Act



Delaware River Basin Commission
West Trenton, New Jersey
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DELAWARE RIVER BASIN COMMISSION
WATER QUALITY INVENTORY REPORT FOR THE DELAWARE RIVER
-EXECUTIVE SUMMARY-

Delaware River and Bay comprise part of the boundary of four states: Delaware, New Jersey, New York and Pennsylvania. From Hancock, New York to the mouth of the Delaware Bay the Delaware River flows 330 miles, draining one percent of the U.S. land area. Over 10 percent of the Nation's population rely on the waters of the Delaware River Basin for potable and industrial water.

The non-tidal Delaware extending from Hancock, New York to Trenton, New Jersey is one of the Nation's premier recreational rivers. Thirty-nine percent of the non-tidal Delaware has been included in the National Wild and Scenic Rivers System and over one-half million visitors are estimated to have used the non-tidal river for recreation in 1983.

The tidal Delaware River Estuary extending from Trenton, New Jersey to Liston Point, Delaware flows through the Nation's fourth largest urban area: the Philadelphia-Camden metropolitan area. Including Trenton, New Jersey and Wilmington, Delaware, this area is one of the world's greatest concentrations of heavy industry, the second largest U.S. oil refining-petrochemical center and the world's largest freshwater port. Historically this section of the Delaware has also been one of the Nation's most grossly polluted rivers.

The 782 square mile Delaware Bay is 48 miles long and from 4 to 20 miles wide. The Bay is biologically productive and the home of commercially important fin and shell fish. Recreation and navigation are important as well.

The water quality of the Delaware River and Bay was assessed. Included in the assessment was nine miles of the West Branch, Delaware which forms the state boundary between New York and Pennsylvania. On a river mile basis, 49% of the Delaware River system was found to have excellent water quality; 32% had good water quality; 7% had good to fair water quality; 3% had fair water quality; 5% had fair to poor water quality and 4% had poor water quality. Ninety one percent of the river miles met the 1983 "swimmable" goal of the Federal Clean Water Act and 88% met the Act's "Fishable" water quality goal. Designated water uses, specified in the water quality standards of the four states and the Delaware River Basin Commission, were not met in 9% of the river miles. As may be expected, the middle portion of the Delaware Estuary in the Philadelphia-Camden area was found to have the worst water quality.

In urbanized areas point-sources of pollution are dominant. During rain events, however, non-point source impacts are noted. Elsewhere non-point sources are the major sources of pollution although at this time the available data do not suggest major water quality problems. The available data suggest that toxics found in the water column, sediments and fish warrant additional study.

The following table summarizes the findings of the water quality assessment by state:

	DE	NJ	NY	PA	Total
Total number of miles	79	253	86	260	339
Miles in Nat. Wild and Scenic R. Sys.	0	37	72	109	109
Miles supporting designated uses	79	224 ^{1/}	86	231 ^{1/}	310 ^{1/}
Miles not supporting designated uses	0	29	0	29	29
Miles of fishable water quality	68	213	86	231	299
Miles of non-fishable water quality	11	40	0	29	40
Miles of swimmable water quality	79	224	86	231	310
Miles of non-swimmable water quality	0	29	0	29	29

1/ In Zones 3 and 4 the following designated uses are not fully met: maintenance of resident fish, passage of anadromous fish and secondary contact recreation.

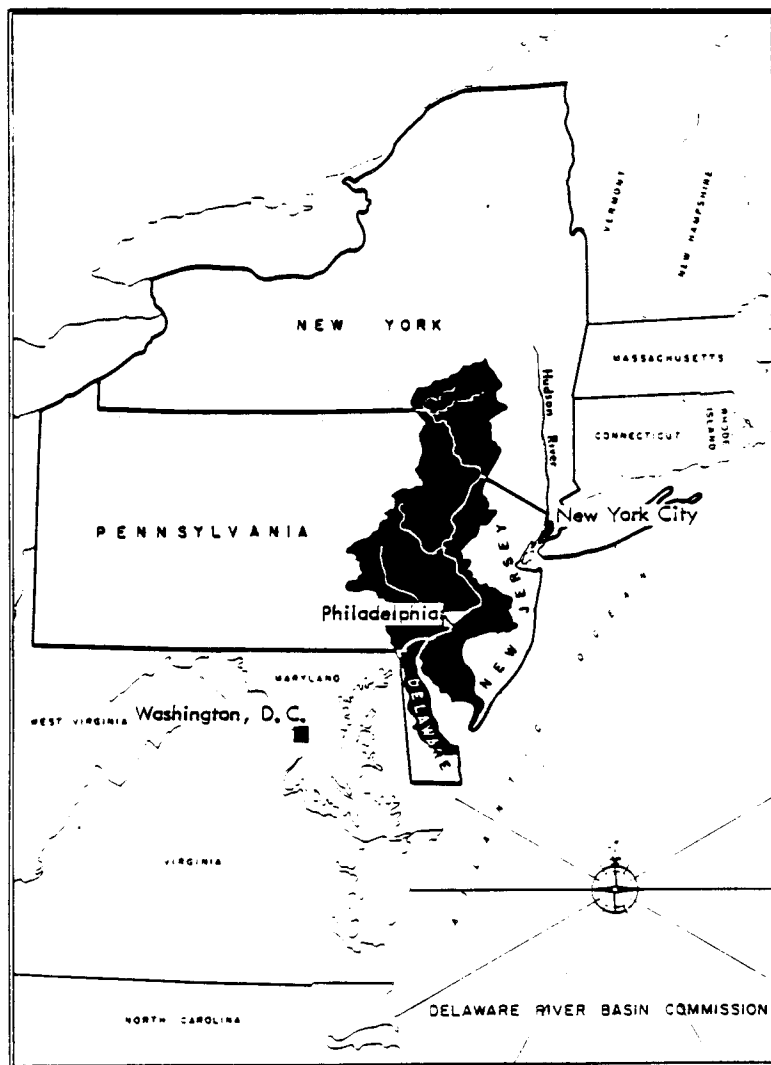


Figure 1. Location of Delaware River Basin.

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INTRODUCTION

Section 305(b) of the Federal Clean Water Act requires a biennial assessment of the water quality of the nation's rivers, streams and lakes. The required reports are prepared by state agencies and several interstate commissions with water pollution control responsibilities. From these reports the U. S. Environmental Protection Agency prepares a national report for the U. S. Congress. The report helps Congress determine how the Federal Act is working, whether new legislation is needed and what additional resources, if any, are needed. The 305(b) reports serve a similar function at the regional, state and local level.

Unlike state 305(b) reports, the Delaware River Basin Commission report is concerned with only one river - the Delaware. This 339 mile long river (including the Delaware Bay and nine miles of the West Branch, Delaware) is part of the boundary of four states: Delaware, New Jersey, New York and Pennsylvania. The DRBC 305(b) report is part of each Basin state's 305(b) submittal and is published as a separate document because of the public interest in Delaware River water quality.

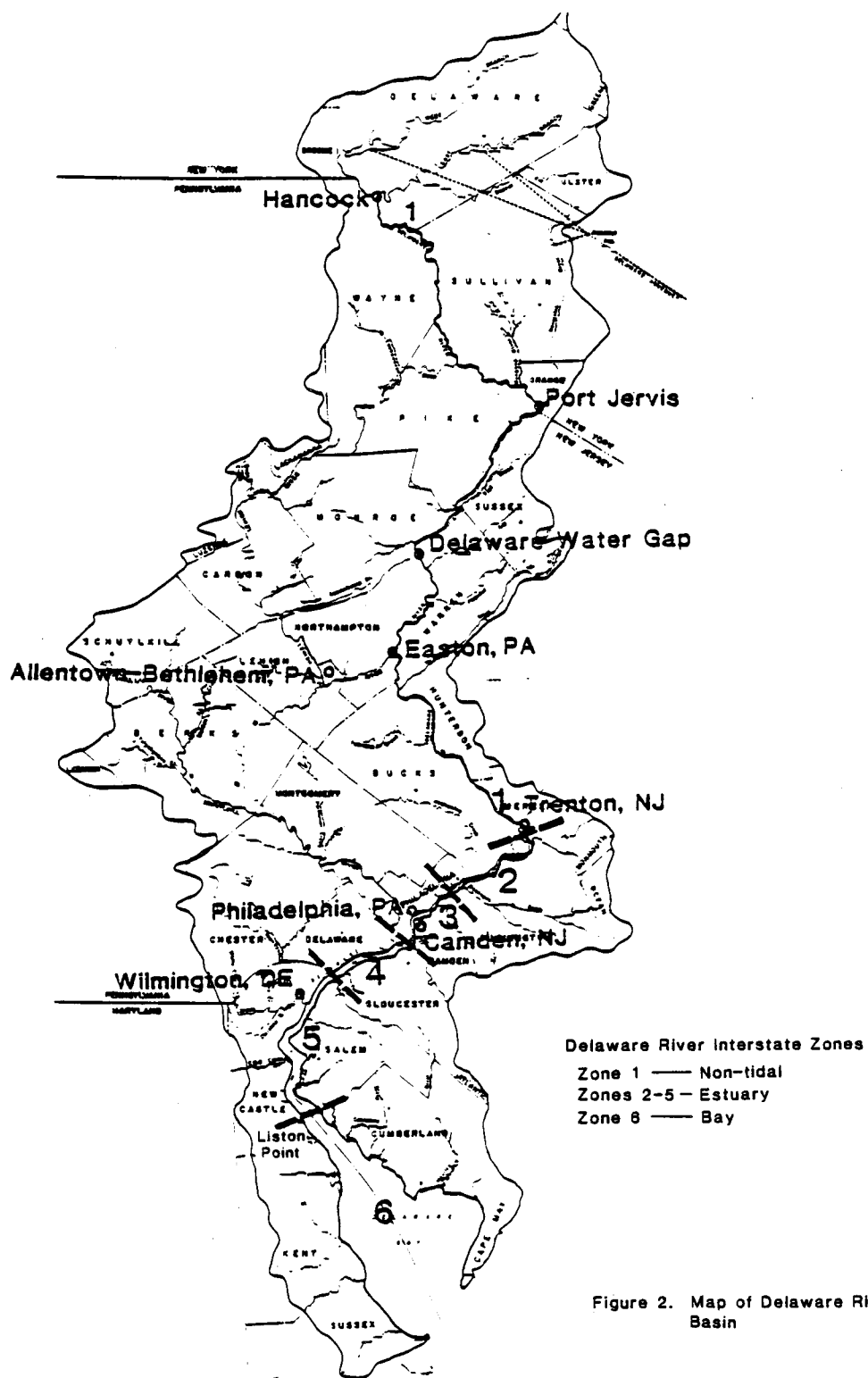
In March 1982 DRBC published a 305(b) report entitled "Cleaning Up the Delaware" The report marked the 20th anniversary of the Delaware River Basin Compact by summarizing the history of water pollution control in the Basin particularly emphasizing the gains made in the 1958 to 1981 period. The 1984 305(b) report describes the current status of water quality in the Delaware, the attainment of water quality standards and designated uses and changes in water quality and pollution control that have occurred since 1981. Similar information concerning tributaries of the Delaware River will be found in the Delaware, New Jersey, New York and Pennsylvania 305(b) reports.

Description of the Delaware River

The Delaware River Basin is a 13,500 square mile area including portions of Delaware, New Jersey, New York and Pennsylvania. The River itself is formed by the confluence of its East and West Branches near Hancock, New York, on the Pennsylvania-New York state border (Figure 2). For its first 77 miles the Delaware River flows southeast across the Appalachian Plateau, represented in the Delaware River Basin by the Pocono and Catskill Mountains. In this reach the Delaware drops half the elevation to sea level. The reach is characterized by rapids and pools contained in a steep-sided, narrow valley. Seventy-two miles of this reach of the Delaware has been included in the National Wild and Scenic Rivers system.

At Port Jervis, New York the Delaware River turns southwest and flows through the Minisink Valley to the Delaware Water Gap. This reach of river includes the Delaware Water Gap National Recreation Area and thirty-seven miles have been included in the National Wild and Scenic Rivers System.

At the Delaware Water Gap, the Delaware cuts through the Appalachian Ridge and flows 77 miles to Trenton, New Jersey. Enroute, the Delaware River passes through the Easton-Phillipsburg area. Here the Lehigh River, the Delaware's second largest tributary, flows into the Delaware River from Pennsylvania. Significant agriculture, urbanization, industry and other cultural influences are found between the Delaware Water Gap and Trenton.



The Delaware River becomes tidal at Trenton, New Jersey. The upper 86-miles of tidal river is the Delaware Estuary, which flows by Trenton, New Jersey; Philadelphia, Pennsylvania; Camden, New Jersey; and Wilmington, Delaware. This area is one of the world's greatest contrations of heavy industry and the Nation's second largest complex of oil refining and petrochemical plants. In this area the Delaware Estuary flows along the boundary between the Piedmont Plateau and the Atlantic Coastal Plain. Aquifers in the Coastal Plain are recharged in part from the river.

Delaware Bay begins at Liston Point, Delaware, 48 miles from the ocean. The Bay area is heavily farmed with many small towns catering to the fishing and resort industry. The Bay serves as a major shipping lane from the Atlantic Ocean to port facilities in the Philadelphia-Camden Area. Commercial fishing and shell fishing are important industries in the Bay.

Including its tidal portion the Delaware River drains one percent of the United States and is the 33rd largest U. S. river. Although a small river, over ten percent of the U. S. population rely on the Delaware River and its drainage area for municipal and industrial water. In addition thousands of people use the Delaware for recreation each year, making it one of the most heavily used recreational rivers in the nation.

As shown in Figure 2 the Delaware River is divided into six zones for water quality management purposes. These zones are as follows: Zone 1 is the entire non-tidal Delaware from Hancock, New York to Trenton, New Jersey, Zones 2 through 5 encompass the Delaware Estuary, a tidal, freshwater river and Zone 6 is the Delaware Bay.

The following sections describe the water quality of the Delaware River on a segment-by-segment basis beginning with the upstream reaches of the river. Presented are descriptions of each segment, designated uses, water quality standards, sources of pollution, and the status of water quality as reflected in the available data. Discussions of pollution sources follow these sections.

**NON-TIDAL DELAWARE
ZONE ONE
NEW JERSEY, NEW YORK, PENNSYLVANIA**

Description of Zone

The non-tidal segment shown in Figure 3. Included for water quality assessment purposes is the 9-miles of the West Branch, Delaware River that forms the boundary between Pennsylvania to the west and New York State. At Hancock, New York the West Branch unites with the East Branch to form the Delaware River. Both branches originate in the Catskill Mountains and drain rural areas characterized by woods, small towns and extensive dairy and poultry farming. On each are major impoundments built and operated by New York City: Cannonsville Reservoir on the West Branch and Pepacton Reservoir on the East Branch. Releases from Cannonsville impact the West Branch but in recent years releases from the reservoir have been modified to protect cold water fisheries.

The Delaware River from Hancock, New York (River Mile 331)^{2/} to Millrift, Pennsylvania (R.M. 258) was designated as the Upper Delaware Scenic and Recreational River and included in the National Wild and Scenic Rivers System by Congress in 1978. The scenic and recreational river is administrated by the National Park Service. In 1983 the National Park Service recorded 151,190 boaters (boats, canoes, rafts, tubes, etc.), almost 15,000 swimmers, over 9,000 fishermen plus other visitors.

The Upper Delaware is characterized by small towns, woodlands, open fields and farmland. The major population centers include Hancock (pop. 1700), Callicoon (pop. 800), Narrowsburg (pop. 500), and Barryville, New York (pop. 500); none of which have major industrial activity. The major tributaries to this Delaware River reach are the Lackawaxen River (Pennsylvania) and the Mongaup River (New York). Both rivers have major hydroelectric power generating facilities located in their drainage area.

Port Jervis, New York (pop. 9,000) and Matamoras, Pennsylvania (pop. 2,100) lie within the eight mile river reach above Milford, Pennsylvania which is not included in the National Wild and Scenic Rivers System. The Neversink River, whose watershed includes a New York City reservoir, enters the Delaware at the junction of the New York, Pennsylvania and New Jersey boundaries. New York City owns and operates the Port Jervis area sewage treatment plant.

From Milford, Pennsylvania to a point one mile downstream of the Delaware Water Gap, the Delaware runs through the Delaware Water Gap National Recreation Area, a 70,000 acre unit of the National Park System. Land acquisition for the recreation area has resulted in the removal of most homes, farms and commercial establishments that formerly existed in this reach of the river. In 1978 Congress designated the Delaware River in the Delaware Water Gap National Recreation Area as the Middle Delaware Scenic and Recreational River and added it to the National Wild and Scenic Rivers System. Milford, Pennsylvania (pop. 1,200) is the only town of any size located on this reach of the Delaware. Brodhead Creek, however, enters the Delaware just above the Delaware Water Gap. Located on Brodhead Creek nine miles above the confluence

^{2/} River miles are abbreviated R.M.

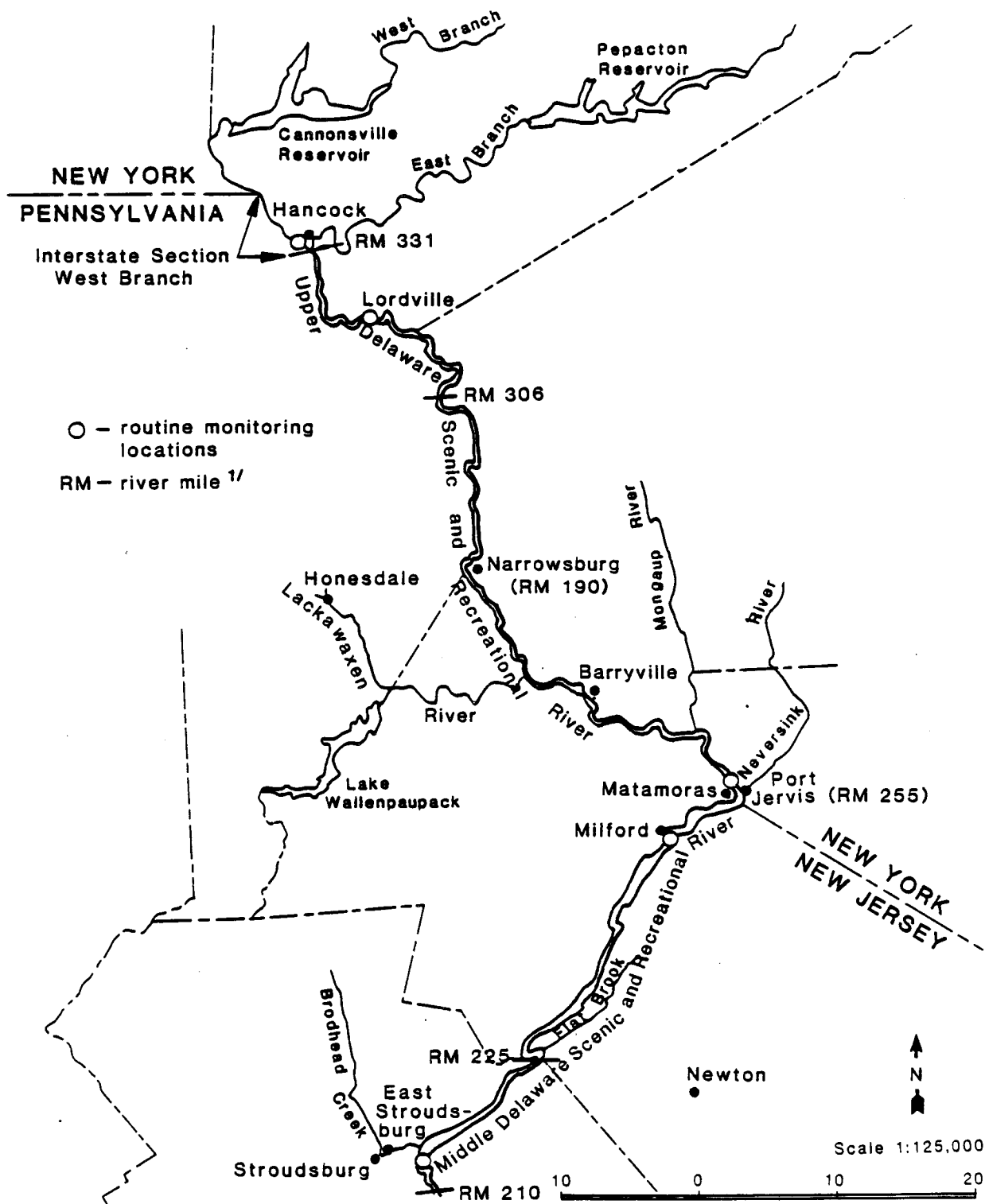


Figure 3. Non-Tidal Delaware River, Zone One and Environs (Northern Half)

^{1/} River Miles refer to the distance from the Atlantic Ocean.

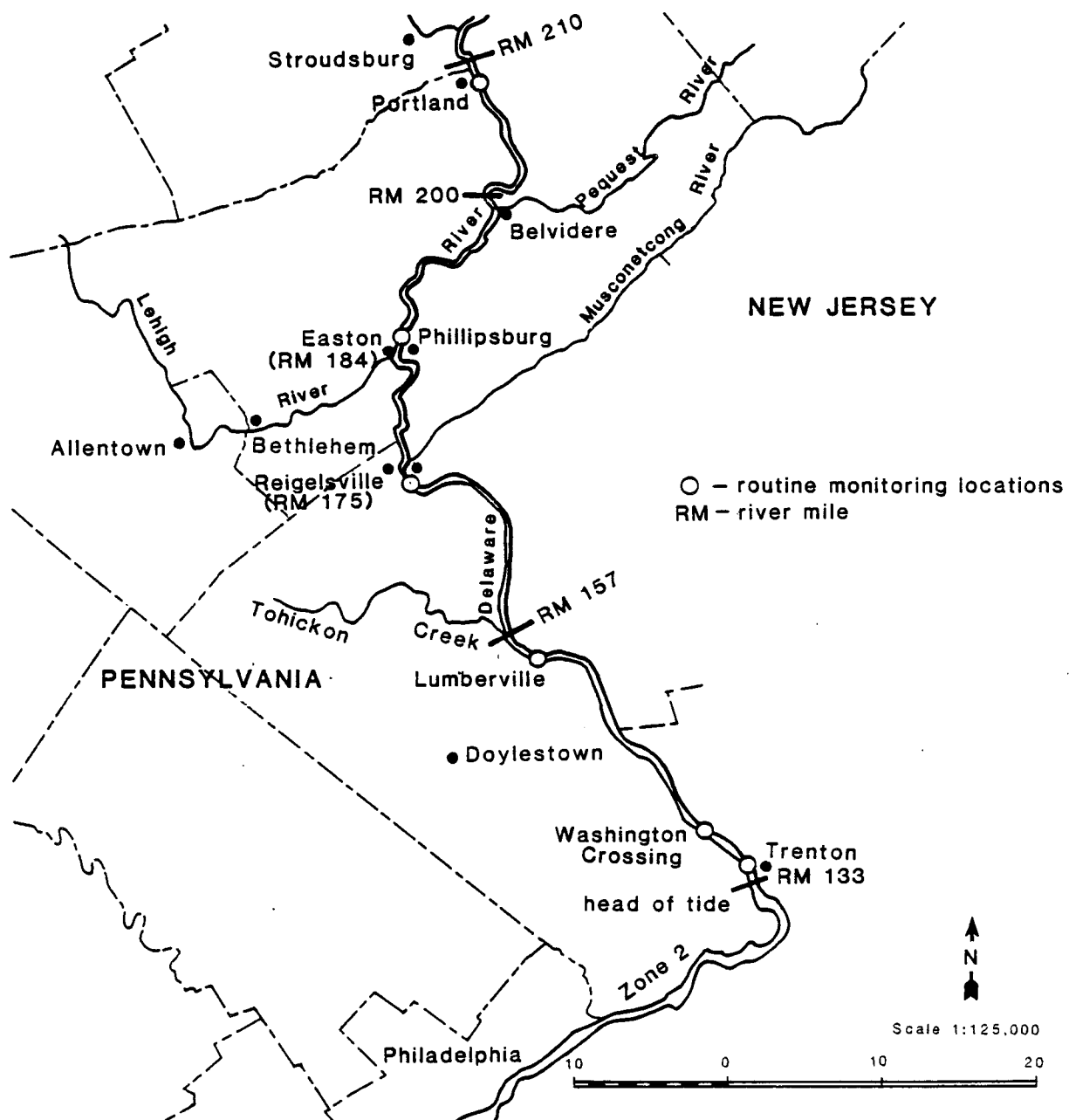


Figure 3 (cont'd). Non-Tidal Delaware River, Zone 1 and Environs (Southern Half)

are Stroudsburg (pop. 5,000) and East Stroudsburg, Pennsylvania (pop. 8,000). On other tributaries, particularly in Pennsylvania, are resorts, second home developments and various commercial establishments that may affect water quality.

The Middle Delaware is intensively used for various recreational activities. Two public bathing beaches are operated by the National Park Service; Milford Beach at Milford, Pennsylvania and Smithfield Beach, 6 miles above the Delaware Water Gap. In 1983 the National Park Service recorded 16,800 swimmers at their beaches. Swimming also occurs in non-designated areas. Boating (boats, canoeing, tubing) is the primary recreational activity in the Middle Delaware. Boating participation (including fishing boats) was in excess of 160,000 boaters in 1983, with approximately 70% involved in canoeing. Shore fishing was enjoyed by over 16,000 fishermen during the same year.

After passing through the Delaware Water Gap, the Delaware River flows 77 miles to the head of tide at Trenton, New Jersey. The adjacent terrain is gentler than upstream areas. Agriculture, industrial activity and small towns are located along the river. At R.M. 184 the Delaware passes through the Easton Pennsylvania/Phillipsburg, New Jersey urban area (pop. 43,000). Also influencing water quality in this reach of river is the Lehigh River which enters the Delaware at Easton. The Lehigh River drains a 1360 square mile area that includes former coal mining areas in the upper watershed, the intensely farmed Lehigh Valley, and the industrialized Allentown/Bethlehem metropolitan area. The Cities of Allentown and Bethlehem (pop. 200,000) are located along the Lehigh River beginning ten miles upstream from the confluence with the Delaware River. Other major population centers located along the Delaware River from the Delaware Water Gap to Trenton include Portland, Pennsylvania - Columbia, New Jersey (pop. 600); Belvidere, New Jersey (pop. 2,500); Riegelsville, Pennsylvania (pop. 1,000); Milford, New Jersey (pop. 1,400); Frenchtown, New Jersey (pop. 1,600); New Hope, Pennsylvania (pop. 1,500); and Lambertville, New Jersey (pop. 4,000). Most of these towns have one or more industrial plants.

The reach of Delaware River between the Delaware Water Gap and Trenton, New Jersey is also intensively used for water-based recreation. No estimates of usage are available. It is likely however, based on personal observation and the number of canoe/tube outfitters, that use is at least equal to either the Upper or Middle Delaware Scenic Rivers. If so, this would mean that the total recreational use of Zone One in 1983 approached or exceeded 1/2 million visitors. Most of this use occurred in the May-September period.

Zone One supports a wide variety of sport and forage fish, including various species of trout, pickerel, bass, walleye and others depending upon location. North of the Delaware Water Gap are found the most important spawning grounds of the American Shad, an anadromous fish. Shad populations were drastically reduced in the past due to pollution in the Delaware Estuary that prevented passage of migrating shad in the spring and fall months. A resurgence of shad has been noted as the Estuary becomes cleaner due to the upgrading of wastewater treatment. Additional migrating fish using Zone One for spawning are herring, the American eel and others. Small commercial fisheries are centered around the shad and eel migrations and sport fishing is of local economic significance.

Designated Water Uses

Water quality standards in Zone One call for the maintenance of water quality that supports the following designated uses:

1. Public water supplies after reasonable treatment,
2. Industrial water supplies after reasonable treatment,
3. Agricultural water supplies,
4. Maintenance and propagation of resident game fish and other aquatic life,
5. Spawning and nursery habitat for anadromous fish (except West Branch),
6. Passage of anadromous fish (Narrowsburg, New York - R.M. 289.9 to Trenton, New Jersey R.M. 133.4 only),
7. Maintenance and propagation of trout (West Branch and Delaware River from Hancock, New York - R.M. 330.7 to Narrowsburg, New York, R.M. 289.9 only),
8. Wildlife,
9. Recreation.

In addition to these protected uses the inclusion of the two sections of the Delaware River in the National Wild and Scenic Rivers system results in a special segment designation for these reaches. Protection of outstanding features (including water quality) is required by the policies of the Wild and Scenic Rivers Act (P.L. 90-542). The Upper Delaware Scenic and Recreational River has been adopted into the Delaware River Basin Commission Comprehensive Plan with the pledge that the Commission, New York and Pennsylvania would take measures to preserve the existing environmental values of the river corridor.

Water Quality Standards

Water quality standards for Zone One are promulgated by the Delaware River Basin Commission and the States of New Jersey, New York and Pennsylvania. Standards are developed cooperatively and, thus, are generally identical. These standards call for water quality meeting the following key criteria (not all criteria listed):

1. Dissolved oxygen - not to be less than 4.0 mg/l at any time, minimum 24-hour average not to be less than 5.0 mg/l. In the upper reaches where trout spawning is a protected use the dissolved oxygen is not be less than 7.0 mg/l when temperatures are suitable for spawning.
2. pH: between 6.0 and 8.5.
3. Fecal coliform: not to exceed 200/100 ml. as a geometric average (with sufficient number of samples taken).
4. Water temperature: not to exceed 5° F rise above ambient temperatures, after 87° F natural temperatures to prevail.

In addition to its water quality criteria, the Delaware River Basin Commission has adopted a nondegradation policy for interstate waters, particularly applicable to the upper reaches of Zone One. Where existing water quality is better than the established stream criteria, the existing, higher water quality level is to be maintained unless "necessary economic or social development" dictate otherwise.

Water Quality Monitoring

Routine water quality monitoring in Zone One is performed by the three states: New Jersey, New York and Pennsylvania; and the National Park Service - DWGNRA. The latter collects fecal coliform data during the summer months at its two Delaware River beaches and at the Kittatiny Point visitor center in the Delaware Water Gap. State sampling consists of quarterly or more frequent sampling at selected locations for a variety of routine chemical, bacterial and biological parameters.

The Delaware River Basin Commission conducts annual summer limnological studies in Zone One particularly north of the Delaware Water Gap to and including the West Branch. The program collects biological, bacteriological and chemical data. In recent years the program's thrust has been the assessment of impacts from reservoir releases in the West Branch, Delaware and the assessment of water quality and potential pollution sources in the two Delaware River scenic river segments. The Delaware River Basin Commission (DRBC) summer program is modified each year in response to perceived needs and special study subjects.

Other data available for assessing water quality are found in various reports prepared by government agencies and universities. These include a recently released New York State report assessing the thermal impacts of New York City reservoir releases on fisheries. This report presents data concerning fish in the West Branch and Upper Delaware (plus other tributaries) and data from continuously operated temperature monitors (Sheppard 1983). Shad tagging for migration-population assessment is conducted annually at Lambertville, New Jersey by the New Jersey, Department of Environmental Protection and the U. S. Fish and Wildlife Service (unpublished).

Status of Water Quality

Table 1 presents a summary of key parameters obtained from the eleven routine monitoring stations of the three states. Data obtained from the DRBC summer program as well as the National Park Service sampling program are published separately (DRBC 1981, 1982, 1983, 1984). The following conclusions are drawn from these data:

1. At most locations the data indicate water quality that meets or exceeds water quality standards. Delaware River Basin Commission summer program data and National Park Service data from the Delaware Water Gap National Recreation Area indicate that most of the Delaware River above the Delaware Water Gap has good to excellent water quality. Macroinvertebrate data collected in 1981-1983 in the lower West Branch and Upper and Middle Delaware indicate that stream health is excellent. In 1982 DRBC and NPS fecal coliform data indicated some minor risk concerning swimming at Smithfield Beach, however, studies in 1983 tend to discount that risk. Fecal coliform levels are observed to increase with rainfall suggesting possible non-point sources or in situ sources of bacteria.
2. Nutrients, nitrogen and phosphorous, increase in a downstream direction. This phenomenon has been observed in past water quality assessments.

Table 1
Summary of Zone One Water Quality, 1982 and 1983 as observed
by Routine State Monitoring Stations Zone 1

Parameter		West Branch at Hancock	Lordville RM 322	Port Jervis RM 255	Montague RM 246	Stroudsburg RM 212	Portland RM 207	Easton RM 184	Riegelsville RM 176	Lumberville RM 155	Wash. Crossing RM 142	Trenton RM 134
Dissolved Oxygen (mg/l)	Ave	9.6	9.7	9.7	11.4	9.9	11.0	10.9	10.9	10.6	10.7	10.4
	Max	10.5	11.6	12.6	14.8	16.2	14.6	14.2	13.6	14.6	13.8	13.6
	Min	8.5	7.8	7.6	7.9	4.7	8.1	8.8	7.4	8.4	8.0	7.0
	#	3	2	8	8	13	7	6	10	9	8	10
pH	Ave	6.5	6.6	7.2	7.3	7.0	7.3	7.6	7.4	7.6	7.8	7.9
	Max	7.2	7.2	7.7	7.9	8.1	7.8	8.6	8.0	8.7	8.2	8.5
	Min	5.9 ^{1/}	6.1	6.6	6.7	5.6	6.7	6.7	6.7	7.0	7.6	7.0
	#	19	6	10	10	14	8	8	11	9	8	10
Fecal Coliform (#/100ml)	Ave ^{2/}	76	87	33	22	409	32	46	142	128	71	25
	Max	180	100	1400	50	5000	140	490	2400	1300	340	460
	Min	50	75	84	20	25	20	20	8	20	20	4
	#	4	2	10	8	13	7	8	10	8	8	6
Total Phosphate (mg/l)	Ave	0.13	0.23	0.06	0.08	0.20	0.13	0.10	0.30	0.38	0.28	0.27
	Max	0.37	1.07	0.09	0.12	0.49	0.37	0.15	0.77	1.30	0.65	0.34
	Min	0.06	0.03	0.03	0.06	0.03	0.06	0.06	0.12	0.12	0.12	0.15
	#	19	6	10	9	17	6	8	10	8	8	7
Ammonia Nitrogen (mg/l)	Ave	0.02	0.003	0.02	0.14	0.05	0.12	0.11	0.19	0.13	0.13	0.11
	Max	0.09	0.02	0.04	0.22	0.12	0.20	0.26	0.35	0.24	0.25	0.25
	Min	0.01	0	0	0.05	0.01	0.05	0.05	0.09	0.07	0.03	0.02
	#	19	6	5	5	16	7	6	7	9	7	5
Nitrate & Nitrite Nitrogen (mg/l)	Ave	0.17	0.16	0.44	0.47	0.43	0.39	0.66	0.92	0.99	1.01	1.18
	Max	0.34	0.21	0.65	0.62	0.77	0.61	0.90	1.20	1.40	1.30	1.60
	Min	0.08	0.10	0.30	0.30	0.16	0.30	0.50	0.66	0.60	0.70	0.90
	#	19	6	10	10	17	7	8	11	8	8	7
Conducti- vity (micromho)	Ave	74	70	73	83	135	87	136	172	179	180	186
	Max	85	80	79	99.0	480	98	174	218	242	230	225
	Min	60	60	66	64.0	60	64	88	99	109	123	154
	#	19	5	10	9	17	8	8	11	9	8	10
Sampling		PA	PA	NY	NJ	PA	USGS	USGS	NJ	USGS	USGS	USGS

1/ lab pH - Field pH normally higher

2/ geometric mean

Nutrient levels in the Delaware River do not cause problems in the river per se. In recent years, however, indications of minor algal blooms have been noted around islands in the Delaware Water Gap. In 1980 the DRBC limnological program (DRBC 1981) noted that phytoplankton primary productivity increased in a downstream direction from Easton with the highest productivity in the Yardley, Pennsylvania - Trenton, New Jersey area. It was concluded that the latter location was autotrophic and thus an exporter of energy (biomass) to the upper portion of the tidal river. During the warmer months the City of Trenton water treatment plant must remove algae from the river water, a minor problem. Nutrients and the subsequent stimulation of plant activity results in minor violations of adopted pH standards. The only major problem with nutrients to date, however, is the stimulation of aquatic plant growth in the Delaware and Raritan Canal (New Jersey) which withdraws Delaware River water near Lumberville, Pennsylvania for water supply purposes. The canal is considered eutrophic with aquatic weeds and algae causing major water quality problems in the summer (Rutgers 1980).

3. The Delaware River in the vicinity of Stroudsburg, Pennsylvania (the Delaware Water Gap) appears to be slightly degraded. The data indicate that fecal coliform levels are occasionally higher than desired. In 1982 and 1983 69% of the fecal coliform values observed at the routine monitoring station in the Gap were greater than 200/100 ml. During the summer of 1982 two samples yielded values greater than 5000/100 ml. At this location dissolved oxygen values appear to be less than other Delaware River locations also indicating possible degradation.

The Delaware River Basin Commission and the National Park Service data support the conclusion that the Delaware River in the Delaware Water Gap is degraded to some extent. Limited data indicate that sources in the Brodhead Creek watershed and adjacent watersheds are likely contributors to the excessive bacterial levels. The data also indicate that rainfall runoff is a major factor in the high fecal coliform levels. Available fecal coliform and fecal streptococcus data (DRBC 1984) suggest animal sources of bacteria more so than human. A comparison of data from Pennsylvania's routine monitoring station with the DRBC/NPS Kittatinny Beach data indicates the possibility that higher values occur on the Pennsylvania side of the Gap than the New Jersey side.

4. Violations of fecal coliform standards appear to be occurring at the Riegelsville, Pennsylvania routine monitoring location.

At Riegelsville 70% of the 1982 and 1983 fecal coliform values (7 dates) were greater than 200/100 ml. On four dates fecal coliform to fecal streptococcus ratios are greater than 4 indicating that the high fecal coliform values on those dates were probably from domestic-human sources rather than animal. At Lumberville, 21 miles down river, 3 of eight values are greater than 200 (38%) and the fecal coliform/fecal streptococcus ratio is greater than 4 in one of the samples.

Fecal coliform data at Riegelsville appear to be from non-point sources. In 1982 and 1983 almost every sample taken was on rainy days or days following rain. A comparison of rainfall values with the observed fecal coliform level indicates that the magnitude of the observed bacteria level is related to the rainfall event. For example the highest fecal coliform level observed occurred during or after a rainstorm that dumped up to 2.5 inches of rain on upstream areas. While some of the fecal coliform-fecal streptococcus levels indicate possible human contamination, contact would have been minimal because of bad weather, or the lack of recreation activity (off-season).

5. Fish data and fishing activity demonstrate that the entire Zone One and lower West Branch support fish maintenance and propagation. In the West Branch the recent New York study (Sheppard 1983) concludes that changes in the modified operation of the New York City reservoir releases benefits the establishment of cold water fishery by reducing the number of days of thermal stress. Other information indicates that the clean-up in the Delaware Estuary has increased the number of American Shad successfully completing migratory trips to Zone One. Increases in the size of smallmouth bass have been reported recently with the presumption that this change is due to increased numbers of young shad, a primary food source.

**Overview of Delaware River Zone One Water Quality Including the
Interstate Portion of the West Branch, Delaware River**

	West Branch		Delaware River			Total
	NY	PA	NY	PA	NJ	
Total Number of Miles	9	9	77	197	120	206
Miles in Nat. Wild & Scenic R. System	0	0	72	109	37	109
Miles supporting designated uses	9	9	77	197	120	206
Miles not supporting designated uses	0	0	0	0	0	0
Miles of "fishable" water quality	9	9	77	197	120	206
Miles of "swimmable" water quality	9	9	77	197 ^{1/}	120 ^{1/}	206 ^{1/}
Miles improved since 1981	0	0	0	0	0	0
Miles degraded since 1981	0	0	0	0	0	0

- 1/ three miles in Delaware Water Gap (R.M. 213 to 210) and ten miles Easton, PA to below Riegelsville, N.J. considered marginally meeting the "swimmable" water quality goal. Exact status of latter reach requires field study.

**DELAWARE ESTUARY
ZONE 2
NEW JERSEY, PENNSYLVANIA**

Description of Zone

Zone 2 begins at the head of tide at Trenton, N.J. (R.M. 133) and extends down river twenty-five miles to a point midway between the mouth of Pennypack Creek, a small tributary that runs through the northeast portion of the City of Philadelphia and the Tacony-Palmyra Bridge (Figure 4). Although tidal, Zone 2 is a freshwater reach. In the Torresdale section of Philadelphia, the City withdraws approximately 200 million gallons of water per day for domestic and industrial use (after treatment).

Zone 2 is characterized by diversity. In the upstream portion of the zone are Trenton, New Jersey (pop. 92,000) and Morrisville, Pennsylvania (pop. 10,000). Various industries and urban and suburban development are major land uses. The largest tributary at the head of tide is the non-tidal Delaware River itself, having an average annual flow of 11,671 cfs and a 6780 square mile drainage area. Freshwater flow into the tidal Delaware River, however, varies seasonally and annually causing (along with other factors) changes in water quality.

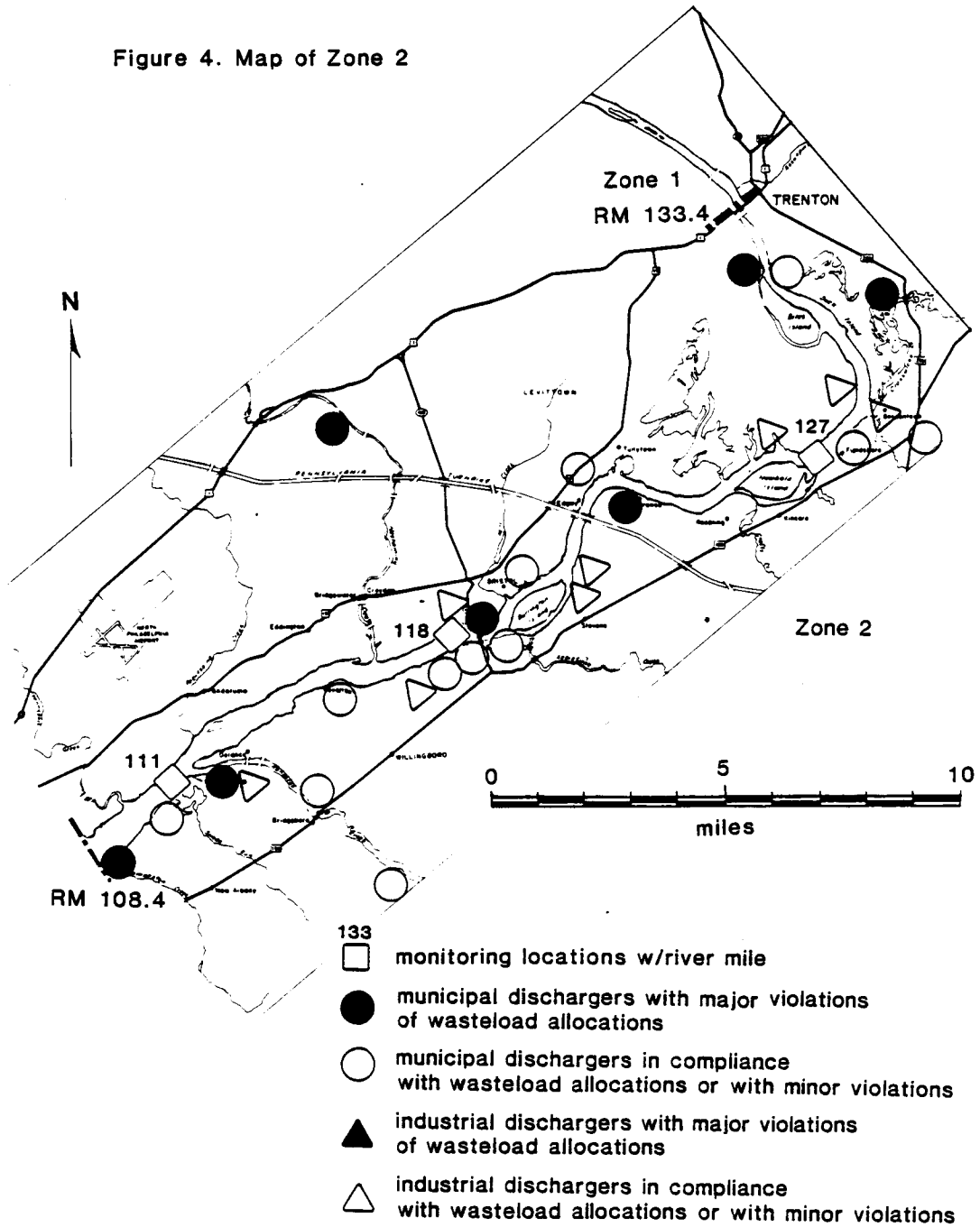
Below Trenton, Zone 2 is characterized by small towns such as Bordentown (pop. 4,500), Fieldsboro (pop. 600), Florence (pop. 9,000), and Burlington (pop. 10,000) in New Jersey and Bristol, (pop. 11,000) in Pennsylvania. Also present are freshwater wetlands, scattered large and small industrial plants, highway complexes and increasing suburbanization of the remaining farmlands. On the Pennsylvania side of Zone 2 is the U.S. Steel Fairless Works, a large integrated steel-making facility. In the lower reach of Zone 2 urbanization increases dramatically, with the last three miles of Zone 2 within the city limits of Philadelphia. Large suburban developments include Levittown in Bucks County, Pennsylvania and Willingboro in Burlington County, New Jersey.

The center channel of Zone 2 is maintained for navigation by dredging. The depth of the navigation channel varies from 40 feet in the lower reach to 35 feet near Trenton with a channel width of 300 to 400 feet. Major tributaries include Crosswicks Creek, Assiscunk Creek and Rancocas Creek in New Jersey and Neshaminy Creek, Poquessing Creek and Pennypack Creek in Pennsylvania. Water quality in each is highly influenced by wastewater discharges and urban-suburban development. New Jersey tributaries are tidal and, thus, in their lower reaches affected by inflow of Delaware River water.

Zone 2 is used, to a great degree, for recreation. Power boating, sailing and fishing are the predominant recreational uses. River sight-seeing boats operate out of Trenton and Philadelphia and at least two dozen marinas, boat yards and public boat ramps are operated. Swimming occurs in undesignated areas.

Fishing in Zone 2 is for a variety of fish species, both migratory and resident. Fish species using Zone 2 waters for spawning, nursery or passage include largemouth bass, walleye, alewife, herring, shad, yellow and white perch, striped bass, catfish, smallmouth bass and at least two dozen others. The short-nosed sturgeon, a federally-designated endangered species, is found

Figure 4. Map of Zone 2



in Zone 2. Rutgers University scientists (Courier-Post 1983) estimate that the short-nosed sturgeon population in the upper half of Zone 2 may number as many as 10,000.

Designated Water Uses

Water quality standards in Zone 2 call for the maintenance of water quality that supports the following uses:

1. Public water supplies after reasonable treatment
2. Industrial water supplies after reasonable treatment
3. Agricultural supplies
4. Maintenance and propagation of resident fish and other aquatic life
5. Passage of anadromous fish
6. Wildlife
7. Primary contact recreation in the upper 15.5 miles (R.M. 133.4 to R.M. 117.8)
8. Secondary contact recreation in the lower 9.5 miles (R.M. 117.8 to R.M. 108.4)
9. Navigation.

Water Quality Standards

Water quality standards for Zone 2 have been adopted cooperatively by the Delaware River Basin Commission and the States of New Jersey and Pennsylvania. Standards call for water quality meeting the following key criteria (not all criteria listed).

1. Dissolved oxygen: the 24-hour average concentration shall not be less than 5.0 mg/l. During shad migration (April 1 to June 15 and September 16 to December 31) the seasonal average shall not be less than 6.5 mg/l.
2. pH: between 6.5 and 8.5
3. Phenols: not to exceed 0.005 mg/l
4. Fecal coliform: not to exceed a geometric mean of 200 per 100 milliliters above R.M. 117.81 and a geometric mean of 770 per milliliters below R.M. 117.81 (with sufficient number of samples taken)
5. Alkalinity: between 20 and 100 mg/l.

Water Quality Monitoring

Routine water quality monitoring is conducted in Zone 2 by the Delaware River Basin Commission with the actual sampling (boat runs) being performed under contract by the State of Delaware Department of Natural Resources and Environmental Control. The DRBC "boat run" program samples 17 locations in the Delaware Estuary and Bay up to 18 times annually for thirty different parameters. Three Boat Run monitoring locations are located in Zone 2.

Status of Water Quality

Table 2 presents a summary of key parameters from the DRBC monitoring stations. The following conclusions are drawn from these data:

1. Dissolved oxygen standards appear to be attained for most dates and locations. On several dates at the Bristol and the Torresdale monitoring locations, however, it appears likely that the 24-hour average concentration of 5 mg/l was violated slightly. It is unlikely that the nature of these few violations caused any harm to aquatic life or other stream uses. Zone 2 summer dissolved oxygen values are included in the profile of Estuary dissolved oxygen shown in Figure 5.
2. Fecal coliform standards appear to be violated about 40% of the time at Fieldsboro. Most of these apparent violations occur in non summer months, however, and thus do not jeopardize recreational uses. Values in excess of 1000/100 ml occur during spring months and are likely related to rainfall runoff. Fecal coliform values, particularly summer values at Bristol and Torresdale, generally meet the applicable criteria which are less stringent than Fieldsboro. Bristol values meet the criteria for primary contact recreation suggesting that the river upstream from Bristol meets its more stringent water quality standards.
3. Alkalinity and pH standards were violated once each at Bristol and Torresdale. No problems are indicated by these slight and very infrequent violations.
4. Phenol concentrations are normally less than the adopted water quality standard at each of the three monitoring locations. Samples taken on May 5 and May 25, 1982 however, indicate a widespread violation.

Overview of Zone 2 Water Quality

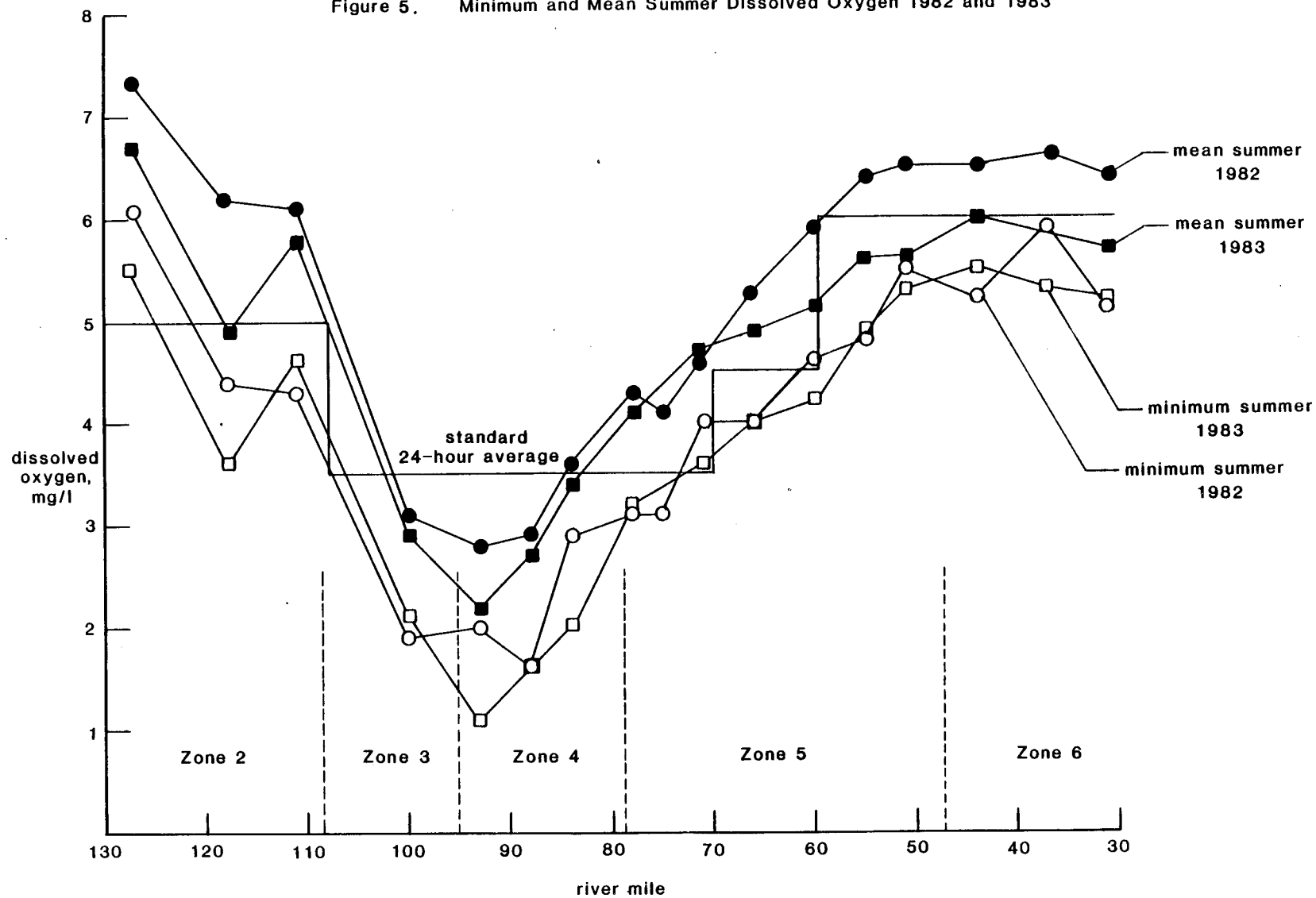
	NJ	PA	Total
Total Number of Miles	25	25	25
Miles supporting designated uses	25	25	25
Miles not supporting designated uses	0	0	0
Miles of "fishable" Water Quality	25	25	25
Miles of "swimmable" Water Quality	25	25	25
Miles improved since 1981	9	9	9
Miles degraded since 1981	0	0	0

Table 2
Summary of 1982 and 1983 Water Quality
Zone 2

Parameter		Fieldsboro RM 127	Bristol RM 118	Torresdale RM 111
Dissolved Oxygen (mg/l)	Ave	8.6	7.5	7.5
	Max	12.7	12.7	12.1
	Min	5.5	3.6	4.3
	#	35	35	35
Fecal Coliform (#/100ml)	Ave*	210	124	282
	Max	3600	1300	12000
	Min	30	20	20
	#	34	34	35
Total Phosphate (mg/l)	Ave	0.11	0.10	0.10
	Max	0.40	0.30	0.20
	Min	0.02	0.02	0.02
	#	32	32	32
Nitrate Nitrogen (mg/l)	Ave	1.1	1.1	1.1
	Max	2.0	1.9	1.9
	Min	0.6	0.2	0.6
	#	35	35	35
Ammonia Nitrogen (mg/l)	Ave	0.19	0.22	0.21
	Max	0.80	0.90	0.65
	Min	0.10	0.10	0.10
	#	35	35	35
pH	Ave	7.5	7.3	7.3
	Max	8.3	7.8	7.8
	Min	6.7	6.3	6.0
	#	34	35	35
Alkalinity (mg/l)	Ave	41.0	41.4	39.5
	Max	68	61	5.8
	Min	3	17	17
	#	35	35	35
Phenols (mg/l)	Ave	.005	0.006	0.006
	Max	.018	0.018	0.020
	Min	.002	0.005	0.005
	#	34	34	34
BOD ₅ (mg/l)	Ave	2.5	2.5	2.5
	Max	4.6	4.2	4.4
	Min	2.4	2.4	2.4
	#	35	35	35
Chlorophyll a	Ave	7.3	11	12
	Max	52	48	66
	Min	0	0	0
	#	34	35	35

* Geometric Mean

Figure 5. Minimum and Mean Summer Dissolved Oxygen 1982 and 1983



**DELAWARE ESTUARY
ZONES 3 AND 4
NEW JERSEY, PENNSYLVANIA**

Description of Zones

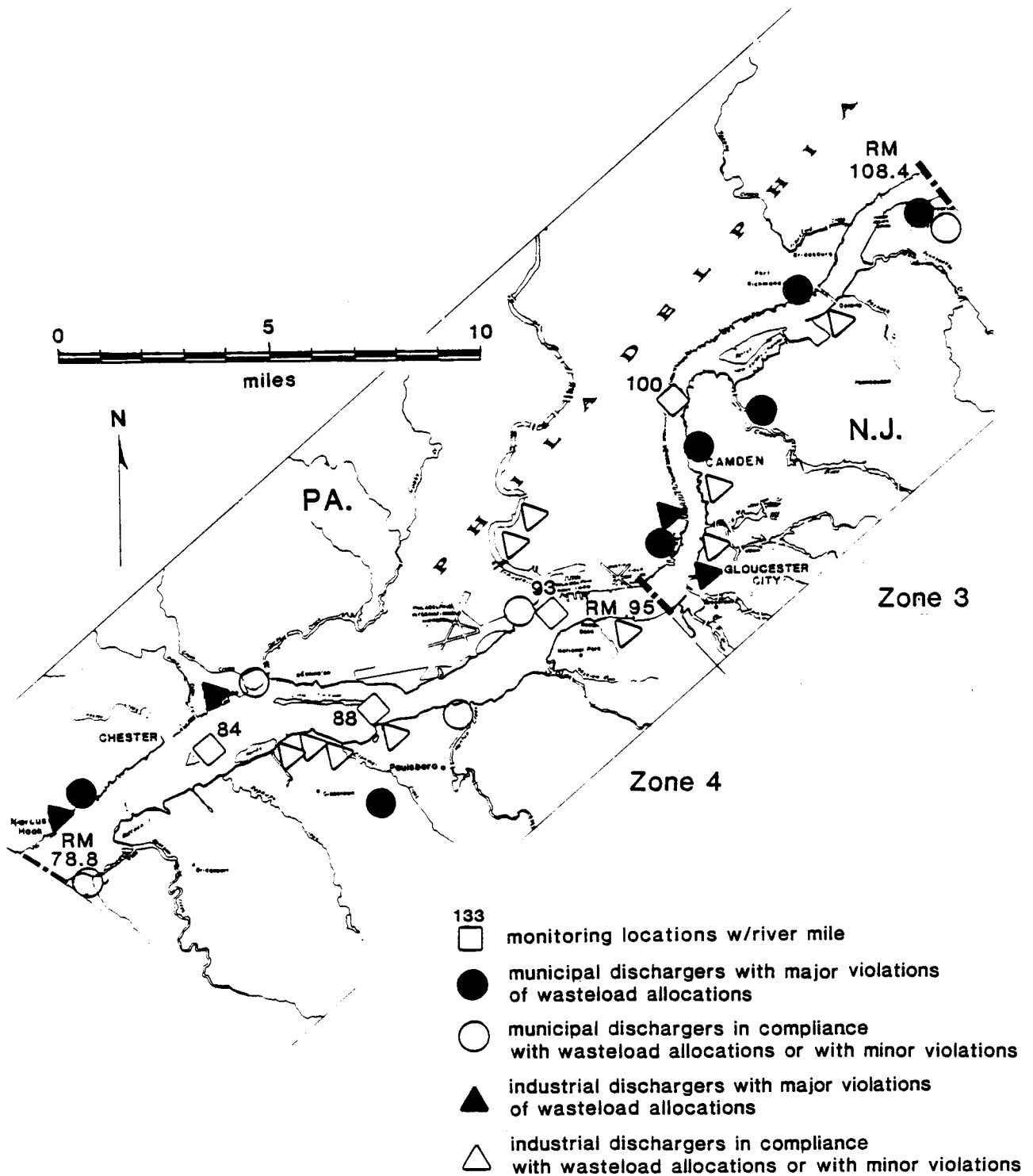
Zones 3 and 4 begin in Northeast Philadelphia and extend down to the Delaware-Pennsylvania-New Jersey stateline at Marcus Hook (Figure 6). The thirty mile reach (R.M. 108 to R.M. 79) has historically been one of the most polluted in the United States. In years past, massive amounts of untreated wastes entered the river in Zones 3 and 4 causing widespread septic conditions and noxious gases in adjacent land areas. Major improvements have been documented in recent years (DRBC 1982).

The Zones 3 and 4 reach of the Delaware Estuary flows through the fourth largest U.S. urban area, the Philadelphia-Camden metropolitan area. Over 4 million people reside in, or near these cities. In both cities and Gloucester City are found extensive networks of combined sewers that discharge untreated wastewater during rain and occasionally during dry periods. Manufacturing, although declining in importance, is still a major factor affecting water quality in the two zones. Major industries include paper-making, chemicals, oil-refining, shipbuilding, food processing, manufacturing and others. Ports along the Delaware are served by a dredged shipping channel forty feet deep. The Philadelphia area ports (including Zones 2 through 5) form the largest freshwater port in the world, the largest U.S. port in terms of international tonnage and the second largest U.S. port in total tonnage.

Major tributaries to Zones 3 and 4 are Pennsauken Creek, Cooper River, Big Timber Creek, Mantua Creek and Racoon Creek in New Jersey; and Frankford Creek, Schuylkill River and Darby Creek in Pennsylvania. The Schuylkill is the largest Delaware River tributary, draining 15% of the Delaware River Basin. The lower 8 miles of the Schuylkill is tidal with a dredged navigation channel and large oil refining and terminal facilities.

The intensive industrial and port development along Zones 3 and 4 preclude much recreational use of the river. Minor amounts of swimming occurs although the polluted water quality and strong tidal currents make such activity dangerous. Boating is the primary recreational activity during the warmer months. At least a dozen marinas are found in Zones 3 and 4 and tour boats are operated out of Philadelphia. In recent years both Philadelphia and Camden have developed recreation areas along the river making visual enjoyment of the river a recreational pursuit. Several waterfront restaurants have opened in recent years, a testimony to cleaner water. Fishing occurs in Zones 3 and 4 although its importance is diminished by pollution and lack of river access. A variety of fish can be found in Zones 3 and 4, but their numbers at any one location or time are uncertain. Important sport fishes include several that migrate through the zones, but do not use them for spawning or as an nursery area. Recent increases in the size of American Shad migrations into the upper Delaware River Basin are thought by some to be the direct result of improvements in the water quality of Zones 3 and 4. In the lower reach of Zone 4 is the Tinicum National Environmental Center which preserves a 1,200 acre freshwater tidal marsh.

Figure 6. Map of Zones 3 and 4



Industrial and domestic water supply are important considerations in both zones. The Delaware Estuary begins to become saline in Zone 4 and to a lesser extent Zone 3. This location varies both seasonally and annually depending upon the amount of freshwater inflow to the Estuary. During drought, salinity intrusion is of particular significance because saline water interferes with industrial processes. Another serious concern is the potential for saltwater intrusion into aquifers serving portions of the Camden metropolitan area. The Delaware River in Zone 4 recharges these aquifers as a result of excessive pumpage of ground water. Delaware River Basin Commission policies would limit the intrusion of saltwater into domestic wells by insuring that the amount of freshwater entering the Delaware Estuary adequately retards the movement of the "salt front" upriver. Freshwater releases from upper basin reservoirs are made when necessary in order to achieve adopted chloride and sodium standards in Zone 3.

Designated Water Uses

Water quality standards in Zones 3 and 4 call for the maintenance of water quality that supports the following uses:

1. Public water supplies after reasonable treatment (Zone 3 only)
2. Industrial water supplies after reasonable treatment
3. Agricultural water supplies (Zone 3 only)
4. Maintenance (but not propagation) of resident fish and other aquatic life
5. Passage of anadromous fish
6. Secondary contact recreation
7. Navigation.

Water Quality Standards

Water Quality standards for Zones 3 and 4 have been adopted cooperatively by the Delaware River Basin Commission and the States of New Jersey and Pennsylvania. Standards call for water quality meeting the following key criteria (not all listed):

1. Dissolved oxygen: the 24-hour average concentration shall not be less than 3.5 mg/l. During the shad migration season (April 1 to June 15 and September 16 to December 31) the seasonal average shall not be less than 6.5 mg/l.
2. pH: between 6.5 and 8.5
3. Phenols: not to exceed a maximum of 0.02 mg/l
4. Fecal coliforms: not to exceed a geometric mean of 770 per 100 ml. (with sufficient number of samples taken).
5. Alkalinity: between 20 and 120 mg/l
6. Chlorides: At River Mile 98 (one mile upstream from the Walt Whitman Bridge) 30-day average concentration should not exceed 180 mg/l
7. Sodium: at River Mile 98 the 30-day average should not exceed 100 mg/l.

Water Quality Monitoring

The DRBC Boat Run program, previously described, monitors four locations in Zones 3 and 4. These are Ben Franklin Bridge in Zone 3 (R.M. 100) and Navy

Yard (R.M. 93), Paulsboro (R.M. 88) and Eddystone (R.M. 84) in Zone 4. Data for Marcus Hook (See Zone 5 discussion) is also of use in assessing Zone 4 water quality.

Two U. S. Geological Survey automatic water quality monitors are located in Zones 3 and 4. These monitors obtain continuous information on dissolved oxygen concentrations, pH and specific conductivity at Philadelphia (R.M. 100) and Chester, Pennsylvania (R.M. 82). Water quality is also monitored routinely by the City of Philadelphia.

Status of Water Quality

Table 3 presents a summary of key parameters from the DRBC monitoring stations. The following conclusions are drawn from these data:

1. Dissolved oxygen standards are consistently violated during the summer at the Ben Franklin, Navy Yard and Paulsboro locations. At Eddystone dissolved oxygen concentrations recover with 60% of the 1982 and 1983 samples indicating the likelihood that dissolved oxygen standards are met. Most samples are greater than 3 mg/l a vast improvement over the water quality of past years. As shown in Figure 5 Zones 3 and 4 represent the bottom of the Estuary dissolved oxygen sag curve. At the sag curve bottom are found the lowest dissolved oxygen concentrations. Zone 3 and 4 summer dissolved oxygen values are indicated in the Estuary profile appearing in Figure 5, page 15.

Because of the frequency of sampling (24 times per day) minimum values recorded at the two U. S. Geological Survey monitors represent the lowest dissolved oxygen concentrations being experienced. During August 1982 the R.M. 100 monitor showed a 15-day period where daily minimum dissolved oxygen ranged from 0.3 mg/l to 0.9 mg/l. Downstream, at the R.M. 82 monitor, the minimum daily dissolved oxygen reached zero occasionally during July and August 1982. Changes in freshwater inflow and the timing of the minimums at both monitors indicate that each monitor was affected by the same influences and that each represented the bottom of the Estuary dissolved oxygen sag.

2. Fecal coliform standards are routinely violated at the Ben Franklin, Navy Yard and Paulsboro locations, although less frequently at the latter location. The available data indicate that fecal coliform standards at Eddystone are generally met.
3. Except for minor and infrequent pH values below 6.5, no other standards appear to be violated. Nutrients appear to be high enough to support algal blooms, but chlorophyll A concentrations remain low.
4. The attainment of the adopted water quality standards in Zones 3 and 4 will not result in fishable and swimmable water quality. Current DRBC and state standards, approved by the U.S. Environmental Protection Agency, are less than needed to support of fish propagation and primary contact recreation.

Table 3
Summary of 1982 and 1983 Water Quality
Zones 3 and 4

Parameter		Ben Franklin Cr. (RM 100)	Navy Yd. (RM 93)	Paulsboro (RM 88)	Eddystone (RM 84)
Dissolved Oxygen (mg/l)	Ave	5.4	5.0	5.2	5.7
	Max	12.7	12.0	12.4	11.2
	Min	1.9	1.1	1.6	2.0
	#	35	36	34	35
Fecal Coliform (#/100ml)	Ave	3253	2485	1381	384
	Max	15000	26000	34000	4500
	Min	220	230	100	20
	#	35	36	34	34
Total Phosphate (mg/l)	Ave	0.13	0.12	0.14	0.22
	Max	0.50	0.23	0.60	2.8
	Min	0.02	0.02	0.02	0.03
	#	32	30	29	32
Nitrate Nitrogen (mg/l)	Ave	1.2	1.4	1.6	1.7
	Max	1.9	2.4	2.7	2.9
	Min	0.8	0.8	0.8	0.9
	#	35	36	34	35
Ammonia Nitrogen (mg/l)	Ave	0.36	0.38	0.36	0.30
	Max	1.00	1.15	1.15	0.85
	Min	0.10	0.10	0.10	0.10
	#	35	36	34	34
pH	Ave	7.2	7.2	7.1	7.2
	Max	7.8	9.8	7.6	7.7
	Min	6.3	6.1	6.2	6.2
	#	35	36	35	35
Alkalinity (mg/l)	Ave	40	39	40	40
	Max	58	73	55	51
	Min	20	24	24	46
	#	35	36	34	35
Phenols	Ave	.005	0.006	0.006	.006
	Max	.018	0.022	0.018	.018
	Min	.005	0.005	0.005	.002
	#	34	35	32	34
BOD ₅	Ave	2.7	2.7	2.8	2.6
	Max	4.2	3.9	5.3	4.7
	Min	2.4	2.4	2.4	1.0
	#	35	36	33	35
Chlorophyll	Ave	15	15	14	14
	Max	49	57	49	61
	Min	0	0	0	0
	#	35	36	34	35

Overview of Zones 3 and 4 Water Quality

	Zone 3		Zone 4		Total
	NJ	PA	NJ	PA	
Total number of miles	13	13	16	16	29
Miles supporting designated uses ^{1/}	0	0	0	0	0
Miles not supporting designated uses	13	13	16	16	29
Miles of "fishable" water quality	0	0	0	0	0
Miles of "swimmable" water quality	0	0	0	0	0
Miles improved since 1981	0	0	0	0	0
Miles degraded since 1981	0	0	0	0	0

^{1/} Uses not fully met are maintenance of resident fish, passage of anadromous fish and secondary contact recreation. Uses considered met are water supply (public, industrial, agricultural) and navigation.

DELAWARE ESTUARY
ZONE 5
DELAWARE, NEW JERSEY

Description of Segment

Zone 5 extends from the juncture of the Pennsylvania-Delaware-New Jersey border at Marcus Hook (R.M. 79) to Liston Point, Delaware (R.M. 48.2), the officially-designated head of the Delaware Bay (Figure 7). From Marcus Hook to a point five and one-half miles upstream from Liston Point, the Delaware River is solely in the State of Delaware.

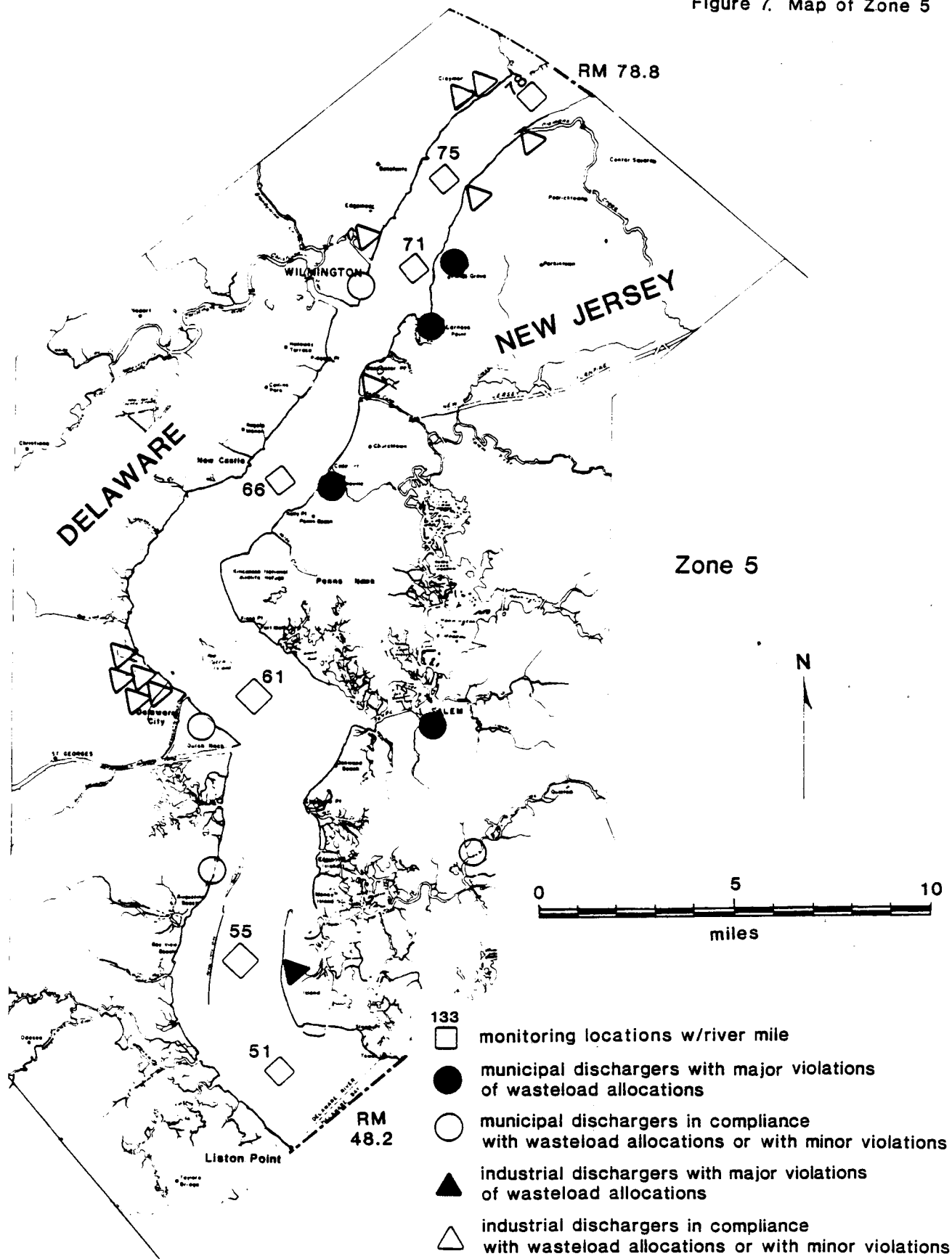
The only major urban area in Zone 5 is the City of Wilmington, Delaware and the surrounding suburban New Castle County (pop. 500,000). Wilmington is an commercial and industrial port city, the largest city in Delaware. In Wilmington and the surrounding area are inorganic and petro-chemical plants, oil refineries, steel-making and manufacturing of various types. A small portion of the City is served by combined sewers which discharge untreated sewage during major rainfalls. Among the electric generating stations in Zone 5 is the Salem Generating Station, a two unit nuclear plant on Artificial Island in New Jersey. When fully operated, this plant withdraws two billion gallons per day from Zone 5 for cooling purposes.

Zone 5 is also characterized by areas of brackish wetlands, small towns, significant farming and several large landfills including dredge spoils disposal areas. Major tributaries are Oldman's Creek, Salem Creek and Alloways Creek in New Jersey; and the Christina River, Brandywine Creek and Appoquinimink Creek in Delaware. Delaware City, Delaware is the eastern terminous of the Chesapeake and Delaware Canal. The shipping canal connects the Delaware with the Chesapeake Bay.

Water-related recreation in Zone 5 includes boating, sailing, fishing, limited swimming and activities related to waterfowl (hunting, etc.). Many marinas, boat access and fishing access areas are found in both New Jersey and Delaware and major portions of the wetlands adjacent to the Delaware have been preserved as fish and wildlife management areas (particularly in New Jersey). The Killocohook National Wildlife Refuge is located near Salem, New Jersey. Fort Delaware State Park is located in the center of the Delaware Estuary on Pea Patch Island.

The lower portion of Zone 5 supports an important sport and commercial fishery (see discussion under Zone 6). It serves as a route of passage for migratory fish such as shad, herring and eels and as a nursery for important marine fish. Year-round residents include catfish, white perch, brown bullhead and other forage fish. Native oyster populations found in the lower section of Zone 5 are part of a native population essential to the oyster industry in the region. There are, however, no designated shellfish-taking areas in Zone 5.

Figure 7. Map of Zone 5



Designated Water Uses

Water quality standards in Zone 5 call for the maintenance of water quality that supports the following uses:

1. Industrial water supplies after reasonable treatment
2. Maintenance of resident fish and other aquatic life
3. Propagation of resident fish below River Mile 70 (below the mouth of the Christina River)
4. Passage of anadromous fish
5. Wildlife
6. Secondary contact recreation from River Mile 79 (Marcus Hook) to River Mile 59 (near mouth of Chesapeake and Delaware Canal).
7. Primary contact recreation below River Mile 59
8. Navigation.

Water Quality Standards

Water quality standards for Zone 5 are promulgated by the Delaware River Basin Commission and the States of Delaware and New Jersey. These standards call for water quality meeting the following key criteria (not all listed):

1. Dissolved oxygen standards presume that Zone 5 represents the recovery leg of the Delaware Estuary dissolved oxygen sag curve. Standards call for a 24-hour average of 3.5 mg/l at River Mile 79, 4.5 mg/l at River Mile 70 and 6.0 mg/l at River Mile 59. The Estuary-wide shad migration standard of a 6.5 mg/l seasonal average also applies between April 1 - June 15 and September 16 - December 31
2. pH: Between 6.5 and 8.5
3. Phenols: not to exceed 0.01 mg/l
4. Fecal coliform standards require a log average concentration of 770 per 100ml between River Miles 78 and 59 and 200 per 100ml between River Miles 59 and 48 (with sufficient number of samples taken)
5. Alkalinity: between 20 and 120 mg/l.

Water Quality Monitoring

The DRBC boat run program monitors seven locations in Zone 5 spaced from 3 to 6 miles apart. Water quality data, including fisheries data, are also available from other organizations; in 1983 the University of Delaware, College of Marine Studies and the New Jersey Marine Sciences Consortium published a report on the lower Estuary and Delaware Bay presenting information collected since 1978 (Sharp 1983).

Status of Water Quality

Table 4 presents a summary of key parameters from the DRBC boat run program. The following conclusions are drawn from these data:

1. Dissolved oxygen standards are generally met in Zone 5. At upstream locations standards may be occasionally violated, but these violations are very infrequent and scattered throughout the year. The adopted standard in the upper sections of Zone 5 (R.M. 79 to RM 60) do not provide for fishable water quality. The available data, however,

Table 4
Summary of 1982 and 1983 Water Quality
Zone 5

Parameter		Marcus Hook RM 78	Oldmans RM 75	Cherry Is. RM 71	New Castle RM 66	Pea Patch RM 61	Ready Is. RM 55	Appoquinimink RM 51
Dissolved Oxygen (mg/l)	Ave	5.9	5.9	6.4	6.7	7.1	7.6	7.5
	Max	11.5	11.3	11.6	10.7	11.0	11.6	11.7
	Min	1.6	2.6	2.4	3.2	4.2	4.8	5.3
	#	35	35	35	36	36	34	32
Fecal Coliform (#/100ml)	Ave*	131	82	69	52	33	25	16
	Max	5100	3700	3900	3600	260	480	70
	Min	10	10	10	10	5	10	10
	#	35	32	35	34	35	36	31
Total Phosphate (mg/l)	Ave	0.13	0.14	0.12	0.16	0.13	0.13	0.12
	Max	0.20	0.21	0.25	1.0	0.30	0.45	0.30
	Min	0.02	0.10	0.02	0.02	0.02	0.01	0.02
	#	31	19	32	32	30	32	29
Nitrate nitrogen (mg/l)	Ave	1.9	1.9	1.9	1.8	1.8	1.6	1.4
	Max	2.9	2.7	2.7	2.7	2.4	2.2	1.9
	Min	1.0	1.1	1.1	0.07	1.1	0.8	0.6
	#	35	19	35	36	36	35	32
Ammonia Nitrogen (mg/l)	Ave	0.30	0.28	0.28	0.3	0.27	0.26	0.24
	Max	0.90	0.75	1.05	1.1	0.95	1.15	0.95
	Min	0.10	0.10	0.10	0.1	0.01	0.10	0.10
	#	35	19	35	36	36	35	32
pH	Ave	7.2	7.4	7.3	7.3	7.3	7.4	7.4
	Max	7.8	7.8	7.8	8.2	8.3	8.3	8.0
	Min	6.2	6.7	6.3	6.3	6.1	6.0	6.5
	#	35	24	35	36	36	34	31
Alkalinity	Ave	418	42	41	41	42	46	50
	Max	51	58	59	60	61	77	77
	Min	26	19	27	23	24	23	25
	#	35	19	35	36	36	35	32
Phenols	Ave	0.007	0.03	0.011	0.020	0.045	0.130	0.124
	Max	0.052	0.255	0.165	0.210	0.330	0.830	0.460
	Min	0.005	0.005	0.011	0.005	0.005	0.003	0.005
	#	34	18	34	33	34	33	31
BOD ₅	Ave	2.6	2.5	2.5	2.5	2.4	2.4	2.4
	Max	4.6	3.5	3.7	3.8	3.0	2.4	2.4
	Min	2.4	2.1	2.4	2.4	2.4	2.4	2.4
	#	35	20	35	35	36	35	32
Chlorophyll	Ave	10	9	8	9	7	6	5
	Max	24	21	41	34	21.0	21	15
	Min	0	0	0	0	0	0	0
	#	34	19	35	34	36	35	32

* Geometric Mean

suggest that at Marcus Hook fishable water quality is obtained about 50% of the time with higher percentages accrued at each successive downstream monitoring location until the New Castle station (84%) is reached.

The downstream two monitoring locations, Reedy Island and Appoquinimink, have a dissolved oxygen standard of 6.0 mg/l as a 24-hour average. Data for the summer of 1983 (Figure 5) indicate that this standard was probably not met during that critical season. Dissolved oxygen samples were greater than 5 mg/l, however, indicating generally good water quality. Zone 5 summer dissolved oxygen data are presented in Figure 5 on page 18.

2. Fecal coliform standards are met throughout Zone 5. The maximum observed values as shown in Table 4 were all observed on one of two days in April 1983. Between R.M. 79 and 59, DRBC standards provide for secondary contact recreation, a standard less than the swimmable water quality goal. Data for 1982 and 1983 indicate that bacterial concentrations in this reach met the more-stringent primary contact recreation standard, thus attaining the swimmable water quality goal.
3. pH standards were not violated in 1982. In 1983 pH values below standard were observed on one or two occasions at most Zone 5 locations. The pattern and dates of the pH violations suggest that pH was influenced by a point source discharge(s). On April 27, 1983 low pH values were observed between New Castle and Reedy Island. On July 20, 1983 the low pH values were observed from Marcus Hook to Pea Patch Island. Review of Zone 3 and 4 data indicate that the source of the July 1983 pH depression may have emanated as far upstream as Philadelphia. In no case did pH values fall below 6.0, thus, no harm occurred to aquatic life.
4. Phenol standards appear to be violated in Zone 5. At all locations the maximum phenol value observed in the 1982 and 1983 period exceeded the phenol standard. At locations downstream of Wilmington (Cherry Island) the mean of all samples violated the standard. Phenols are also observed to increase in a downstream direction, a pattern that includes the upper Delaware Bay monitoring locations (Zone 6).

Although there are sources of phenols in Zone 5 there is no logical reason why phenols should increase in a downstream direction to and including the Zone 6 locations. It was theorized, therefore, that the phenols test results reflected an interference due to chlorides (salinity). To test this hypothesis, regression analyses were conducted comparing phenol and chloride concentrations. When the means (1982-83 period) were compared, the coefficient of determination (R^2) was found to be 0.94, a high value suggesting that the two parameters are interrelated. It was concluded that the high phenols found in Zones 5 and 6 are due either to test interferences or, less likely, natural sources emanating from the Atlantic Ocean.

Overview of Zone 5 Water Quality

	Delaware	New Jersey ^{1/}	Total
Total number of miles	31	31	31
Miles supporting designated uses	31	31	31
Miles not supporting designated uses	0	0	0
Miles of "fishable" water quality	20	20	20 ^{2/}
Miles of "swimmable" water quality	31	31	31
Miles improved since 1981	0	0	0
Miles degraded since 1981	0	0	0

1/ 31 miles of New Jersey shoreline front on Zone 5. 25.1 miles of the Delaware Estuary in Zone 5 is solely in the State of Delaware.

2/ New Castle (R.M. 66) and downstream locations.

DELAWARE BAY
ZONE 6
DELAWARE, NEW JERSEY

Description of Segment

Zone 6 encompasses the Delaware Bay. A map of the Bay region appears in Figure 8. The Bay is a legally defined water body that is actually an estuary in oceanographic terms: a highly productive ecosystem where fresh and saline water intermix. The 782 square mile Delaware Bay is 48 miles long (center channel), and varies in width from 4 to 20 miles. The mouth of the Bay is located between Cape Henlopen, Delaware and Cape May, New Jersey. The center of the Bay is a major navigation channel for Philadelphia ports, maintained by dredging to a depth of 40 feet. The first 12 miles is a natural 55 feet deep channel.

The Delaware Bay region is a region of small towns, farmlands and salt marshes. Dover, Delaware (pop. 25,000) is the largest city in the region. Few towns are located directly on the Bay itself. Most, like Dover, are located upstream on tidal tributaries. Along the Bay itself are miles of salt marshes, many preserved as state wildlife management areas. The Prime Hook National Wildlife Refuge is a federal preserve located on the Delaware side of the Bay.

Near the mouth of Delaware Bay in both New Jersey and Delaware are major resort-beach areas located on the Bay (as well as the Atlantic Ocean). These areas experience increased populations in the summer season. Second-home and retirement villages are being developed in both areas. Also in the same region are designated anchorage areas for lightering. In these areas ships off-load part of their loads to barges in order to reduce their draft for travel up the relatively shallow Delaware River navigation channel. Crude oil heading for Delaware River refineries is the only cargo currently lightered. The refineries located in the Delaware Estuary and Bay area consume crude oil at an approximate rate of 900,000 to 1 million barrels per day, most of which is transported through the biologically sensitive Bay.

The Delaware Bay supports a variety of water-based recreation. Swimming beaches are scattered along the upper bay among the salt marshes and near the mouth of the Bay are miles of ocean-like beaches. Boating and sailing are also major recreation activities in the Bay and many marinas or boat access areas exist. Both shore and boats are used for fishing by individuals. Commercial sport fishing boats also operate.

Commercial fishing includes both shellfish and finfish. Oyster, blue crabs, lobsters (very limited), mussels (limited), and clams (limited) are shellfish of some commercial importance. Over 50,000 acres of the Delaware Bay are devoted to oyster culture and yields have improved since 1960 when the oyster harvest reached record low numbers due to early mismanagement and predation by the MSX oyster drill. Blue crab harvests are naturally variable and in good years can exceed 5 million pounds (Sharp 1983). Clams, mussels and lobster fishing are much less important.

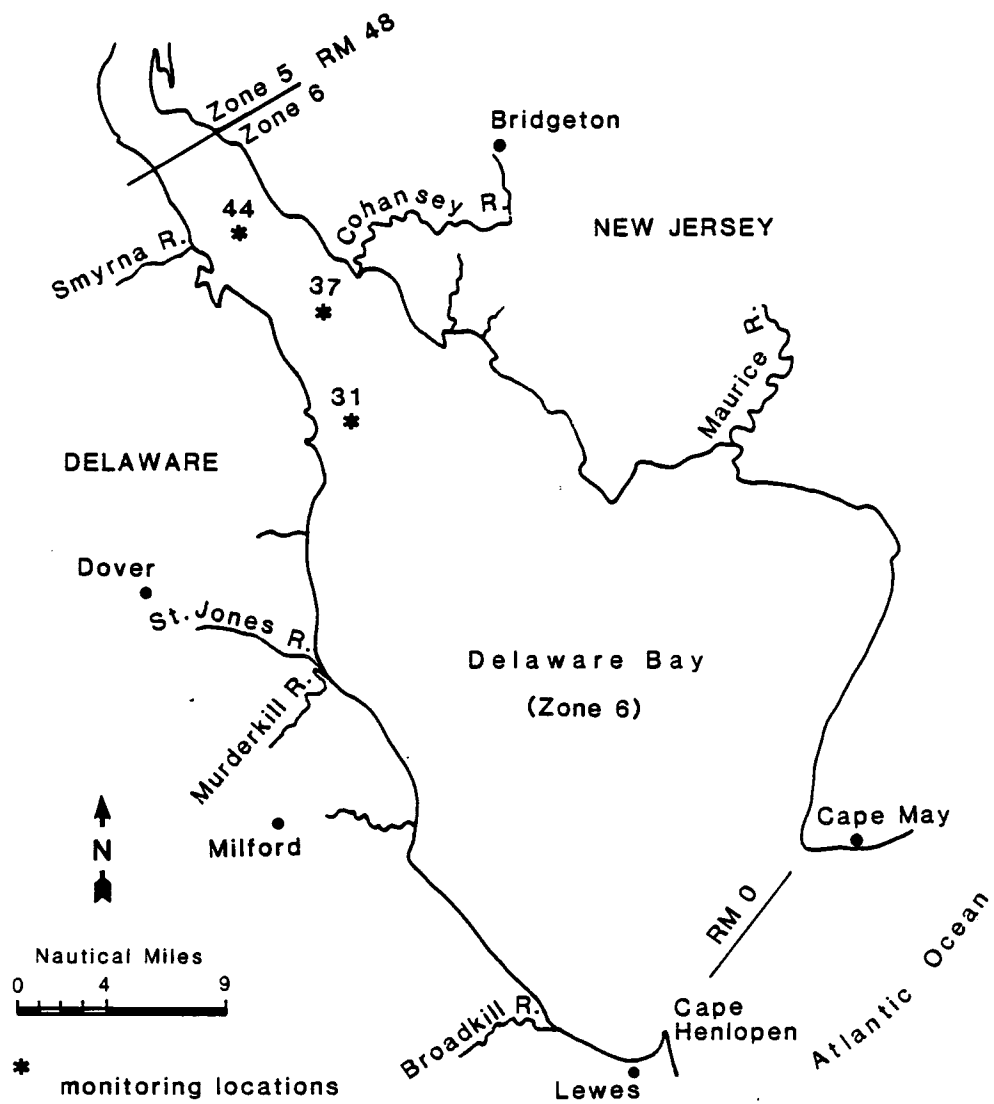


Figure 8. Map of the Delaware Bay Zone 6

Finfish of commercial or sport fishing importance include weakfish, bluefish, Atlantic menhaden, white perch, striped bass, summer flounder, spot, shad, Atlantic Sturgeon, alewife, the American eel and others. Some of these are more important as nearshore marine fish with the Delaware Bay serving as the spawning, feeding and nursery area. Others are transient visitors to the Bay or migrate through the Bay. Examples of the latter include the shad, eels and striped bass. Commercial fishing in the Bay has declined over the last 75 years due largely to overfishing within and without the Bay. A recent report, however, concludes that the Bay is "sufficiently healthy to maintain major fisheries" (Sharp 1983 p.18).

Designated Water Uses

Delaware Bay water quality standards call for the maintenance of water quality that supports the following designated uses:

1. Industrial water supplies after reasonable treatment
2. Maintenance and propagation of resident fish and aquatic life
3. Maintenance and propagation of shellfish
4. Passage of anadromous fish
5. Wildlife
6. Recreation
7. Navigation.

Water Quality Standards

Water quality standards for the Delaware Bay, Zone 6 have been adopted by the States of Delaware and New Jersey and the Delaware River Basin Commission. These standards require that the following criteria be met (not all listed):

1. Dissolved oxygen concentrations - a 24-hour average concentration not less than 6.0 mg/l
2. pH: between 6.5 and 8.5
3. Fecal coliform: a maximum geometric average of 200 per 100 milliliters
4. Alkalinity: between 20 and 120 mg/l
5. Phenols: maximum of 0.01 mg/l.

Water Quality Monitoring

The Delaware River Basin Commission Boat Run program, performed by the State of Delaware Department of Natural Resources and Environmental Resources conducts routine water quality monitoring at three locations in the upper portion of the Delaware Bay. These are at Smyrna (R.M. 44), Ship John (R.M. 37) and Mahon (R.M. 37), the latter the only boat run station not located in the center channel. The boat run program collects samples up to 18 times per year for analyses of 30 parameters.

In recent years additional data for other parts of Zone 6 have been collected by the University of Delaware and others as part of the Delaware Estuary Project. A report presenting the results of this work was released in July 1983 (Sharp 1983).

Status of Water Quality

Table 5 presents a summary of key parameters from the DRBC Boat Run program. The following conclusions are drawn from these data:

1. Dissolved oxygen standards in Zone 6 appear to be violated occasionally. In 1982 and 1983 one or more boat run measurements at each location were below the 24-hour average criterion of 6.0 mg/l suggesting the possibility that minor violations occurred. At no time however, were the concentrations of dissolved oxygen less than 5.0 mg/l; thus water quality was acceptable for aquatic life. Data from the previously mentioned Delaware Estuary Project indicate that dissolved oxygen concentrations downstream from the boat run locations are higher and everywhere greater than 90% saturation.
2. All fecal coliform samples taken by the boat run program (96 in all) were 60/100 ml or less indicating excellent sanitary water quality.
3. pH is generally acceptable in Zone 6. On October 5, 1983 each monitoring location experienced its minimum value for the 1982-1983 period suggesting a single source of pollution or, more probably, a biological phenomenon. Due to the season and timing of the boat run it is likely that the October 5, 1983 boat run monitored the nighttime low pH resulting from plant respiration in the absence of photosynthesis, a natural phenomenon caused by plant and animal carbon dioxide emissions. Diurnal variations in pH due to plant respiration were also noted by the Delaware Estuary Project.
4. Phenol standards appear to be violated. As described previously this appears to be related to test interferences caused by increasing salinity.

Overview of Zone 6 Water Quality

	Delaware	New Jersey	All
Total number of miles ^{1/}	48	48	48
Miles supporting designated uses	48	48	48
Miles not supporting designated uses	0	0	0
Miles of fishable water quality	48	48	48
Miles of swimmable water quality	48	48	48
Miles improved since 1981	0	0	0
Miles degraded since 1981	0	0	0

1/ miles refers to length of Zone 6.

Table 5
Summary of 1982 and 1983 Water Quality
Zone 6

Parameter		Smyrna (RM 44)	Ship John (RM 37)	Mahon (RM 31)
Dissolved Oxygen (mg/l)	Ave	7.7	7.6	7.6
	Max	12.1	11.9	12.8
	Min	5.2	5.3	5.1
	#	32	32	32
Fecal Coliform (#/100ml)	Ave*	12	12	11
	Max	60	60	60
	Min	10	10	10
	#	33	33	30
Total Phosphate (mg/l)	Ave	0.11	0.16	0.16
	Max	0.23	0.60	0.30
	Min	0.01	0.04	0.04
	#	30	29	29
Nitrate Nitrogen (mg/l)	Ave	1.2	1.0	0.7
	Max	1.9	2.0	1.0
	Min	0.4	0.6	0.3
	#	31	32	32
Ammonia Nitrogen (mg/l)	Ave	0.23	0.20	0.24
	Max	0.90	0.80	0.60
	Min	0.10	0.10	0.10
	#	32	32	32
pH	Ave	7.4	7.4	7.3
	Max	8.0	7.9	7.8
	Min	6.5	6.1	5.6
	#	31	31	31
Alkalinity (mg/l)	Ave	56	61	74
	Max	77	86	93
	Min	29	60	47
	#	32	32	32
Phenols (mg/l)	Ave	0.160	0.201	0.270
	Max	0.430	0.370	0.920
	Min	0.005	0.020	0.010
	#	31	31	31
BOD ₅ (mg/l)	Ave	2.4	2.4	2.5
	Max	2.4	2.4	3.4
	Min	2.4	2.4	2.4
	#	32	32	32
Chlorophyll a (mg/l)	Ave	4	7	19
	Max	13	29	55
	Min	0	0	0
	#	32	32	32

* Geometric mean

CAUSES OF NONSUPPORT OF DESIGNATED USES AND VIOLATIONS OF WATER QUALITY STANDARDS

There are two general sources of water pollutants. Point-sources are usually discharged from a pipe: the outfall from a wastewater treatment plant, a combined sewer that discharges during a rainstorm, a raw-sewage discharge from a "wildcat" sewer that serves one or more houses, an industrial plant floor drain or other similar discharges. Point sources by State and Federal law are required to have permits which limit the amount of pollutants contained in the effluent. In practice many of the small discharges such as floor drains and storm sewers are not yet permitted.

Non-point sources are sources of pollutants that are dispersed and diffuse. Examples of non-point sources include street washoff that enters streams in urban areas during rain; herbicides, fertilizers, manure and other agricultural "pollutants"; malfunctioning septic and other on-lot systems; leachate from landfills; erosion during construction activities; and many other sources. Non-point sources are generally related to land use and precipitation. Some non-point sources such as construction related soil erosion are regulated by state programs. Others are receiving increasing attention as more is learned about their causes and effects.

More is known about point-sources than non-point sources. Point sources have been regulated for many decades whereas non-point sources have only received major attention in the last ten years or so. Still there are many reaches of the Delaware River and Bay where water quality data are inadequate or not available. Without data it is not possible to assess water quality problems (if any) let alone the relative contributions of point and non-point sources. As an example, in the 25 miles between the Delaware Water Gap and Easton, Pennsylvania are two large thermal discharges, several municipal and industrial wastewater discharges and numerous potential non-point sources of pollutants. Yet there are little data available to assess water quality problems in this reach and relative contribution of various sources of water pollution are unknown.

The following sections present known information concerning point and non-point sources and their contribution to Delaware River water quality.

Zone One

Point Sources: There are at least three dozen wastewater treatment plants discharging to the Delaware River, or to nearby tributaries, in the 200 mile reach of river from Hancock, New York to Trenton, New Jersey. Most are small. Since 1981 a major accomplishment has been the completion of sewerage and treatment facilities for Hancock, New York. Prior to the completion, raw sewage including hospital wastes were discharged untreated. In recent years new treatment facilities have also been completed for other communities including Easton, Pennsylvania and Lambertville, New Jersey. Zone One is classified as Effluent-Limited in accordance with the Federal Clean Water Act. Wastewater treatment plants are required to achieve secondary treatment levels.

The three mile reach of the Delaware in the vicinity of the Delaware Water Gap is affected by point and non-point sources originating in nearby tributaries. These sources include raw sewage discharges in the vicinity of Delaware Water Gap Borough (Cherry Creek), point and non-point sources in the Brodhead Creek watershed, and a point source discharge from a resort complex. A regional wastewater treatment and interceptor system is planned to serve the lower Brodhead Creek watershed including Stroudsburg, East Stroudsburg and Delaware Water Gap Boroughs and the above mentioned resort. Construction of the system is to begin in 1984. It is anticipated that this regional system will eliminate the major point sources of pollution in the affected watersheds as well as some of the non-point sources (malfunctioning on-lot systems) and, thus, abate the problem noted in the Delaware River.

Non-Point Sources: Sources of non-point pollution in Zone One include malfunctioning septic tanks, agricultural runoff, urban runoff and others. The impact of these sources is subtle and does not appear to result in water quality standards violation. An exception is fecal coliform levels. Fecal coliform levels in the Delaware River from Port Jervis, New York to Trenton, New Jersey may increase dramatically when it rains. National Park Service 1983 bacterial data on tributaries in the Delaware Water Gap National Recreation Area indicate that under both dry and wet conditions bacterial levels appear to be related to the degree of development found in tributary watersheds. In most cases the increased level of fecal coliform does not indicate a major health problem because the bacteria levels are low and non-human in origin. Studies have also shown the possibility that natural sources of fecal coliform may be partly involved in the bacteria increases observed during rainfall. However, anthropogenic sources of fecal bacteria exist and will be a continuing concern.

The high fecal coliform values observed at Riegelsville appear to be non-point source related. Most of the ten values obtained in the 1982-83 period were taken on or following rainy days. A visual comparison of the amounts of the recorded rainfall and the magnitude of the observed fecal coliform levels indicates that the two are related. For example, the highest fecal coliform level, 2,400/100 ml, was observed in conjunction with a rainstorm that dumped up to 2.5 inches of rain on upstream areas. This was the most rain received on any of the sampled days. Fecal coliform-fecal streptococcus ratios for some sampling dates strongly suggest possible human contamination. The fact that rainfall appears to influence the level of bacteria, however, indicates that non-point sources may be the main cause of the observed water quality standards violations. The infrequent rainfall-biased sampling does not allow conclusions to be made concerning the magnitude of water quality problems at Riegelsville, if any. Data during dry periods, when recreation use of the river is more likely, are not available for Riegelsville.

Zones 2, 3, 4 and 5

The Delaware Estuary is impacted by both point and non-point sources of pollution. All four Estuary zones are classified as "water quality-limited in accordance with the Federal Clean Water Act. This classification means that wastewater dischargers must receive greater than secondary levels of treatment (as developed by a wasteload allocation program) and that water quality management should examine the abatement of non-point sources. The Estuary is

currently governed by a wasteload allocation program and an on-going study is examining both point and non-point source abatement needs for the future.

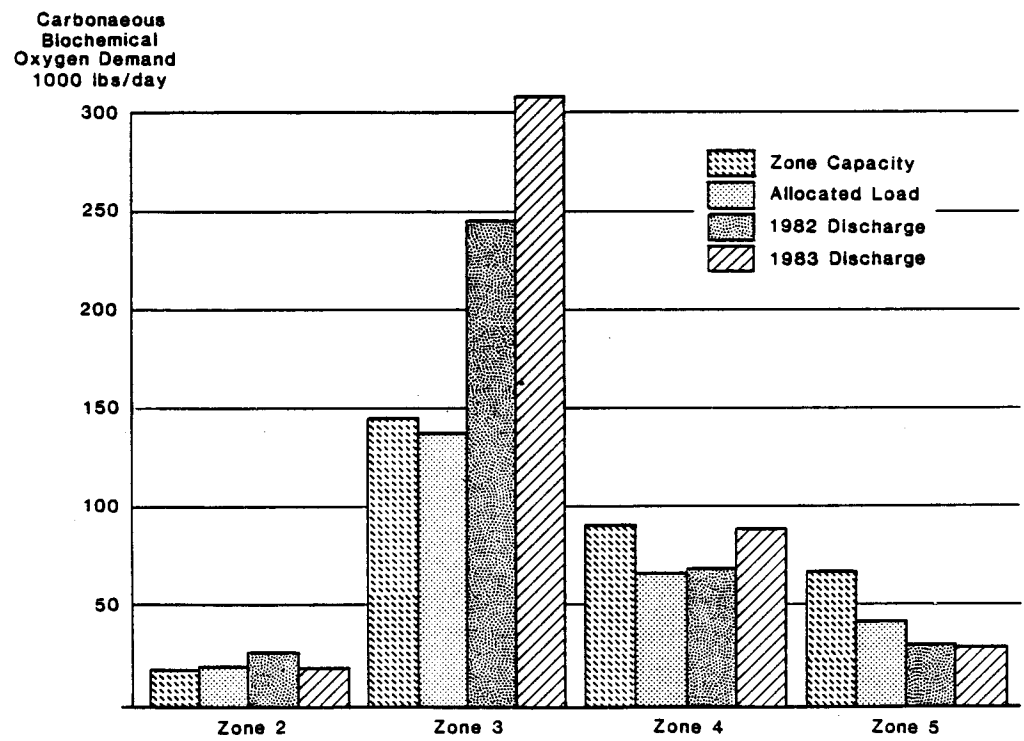
Point Sources: Much is known about point-sources since they have been the subject of water pollution abatement efforts for at least 40 years (DRBC 1982). In 1968 the Delaware River Basin Commission instituted an Estuary-wide wasteload allocation program which allocates permissible oxygen demanding waste discharges (carbonaceous biochemical oxygen demand or CBOD) in order to achieve water quality standards. Based on mathematical modeling studies the assimilative capacity in terms of pounds CBOD/day was determined for each zone. After setting aside a small reserve in each zone, allocations to individual dischargers were made based on the concept of equal waste reduction by all discharges in a zone. In 1968, allocations were issued to approximately 90 waste dischargers to the Delaware Estuary. Currently there are 77 active dischargers in the Estuary holding DRBC allocations. Five additional active dischargers have had their allocations withdrawn pending connection to regional systems not yet constructed. In addition five industrial dischargers have allocations, but recently suspended operations. The following table summarizes the DRBC wasteload allocation program. The difference between the zone assimilative capacities and the total allocated load represents the reserve set aside for future growth. As indicated Zone 2 is over allocated. This issue and future water quality strategies are currently the subject of on-going DRBC studies described later.

Zone	Assimilative Capacity	Allocated Load-1983	Required Zone Removal
2	18,600	19,901	88.5
3	144,800	137,542	86.0
4	91,000	67,089	89.25
5	67,600	42,574	87.5
Total	322,000 lbs/day	267,106 lbs/day	

Point sources of pollution at this time determine whether or not designated uses are being met in Zones 2-5. This is demonstrated by comparing Figure 9 which presents the exceedance of the zone allocated load by all the point sources in each zone with the previously presented water quality overviews for each zone:

- A. 100% of Zone 2 is meeting designated uses. Figure 9 indicates that by mid-1983 the total charge load to the Zone about equaled the allotted discharge load. The decrease from 1982 to 1983 is largely due to the completion of the Trenton, New Jersey wastewater treatment plant upgrading project and better treatment at another plant that was discharging above its limits in 1982. There are 4 municipal wastewater treatment plants in Zone 2 that are major violators of their permitted wasteload allocations.
- B. Zone 3 does not attain the Federal fishable and swimmable water quality goals and several of its designated uses. It is the most polluted section of the Delaware River. Figure 9 indicates that inadequately treated point source wastes are a major factor. The total load discharged exceeds the Zone's allocated discharge by a factor of about two. Wasteloads increased in 1983 at major municipal

Figure 9. Comparison of Wasteload Discharged with Total Load Allocated and the Zone Assimilative Capacity



wastewater treatment plants. This increase is possibly due to increased economic activity resulting from the diminution of the recent recession. The increased amount of wastes discharged to Zone 3 is reflected in the observed summer season dissolved oxygen concentrations (Figure 5). Concentrations in 1982 were better than 1983 due to the lesser amount of oxygen-demanding materials discharged.

There are 5 municipal and 2 industrial facilities considered to be major violators of their permitted discharge. Of these, two City of Philadelphia plants and two for the City of Camden, represent 96% of the allocated load to Zone 3 and 49% of the allocated load to the entire Estuary. All these plants are currently undergoing upgrading of treatment and, hopefully, will be meeting their allocations within the next two or three years. Water quality improvement should be noted if either of the two Philadelphia plants or the largest Camden plant come on-line with new facilities.

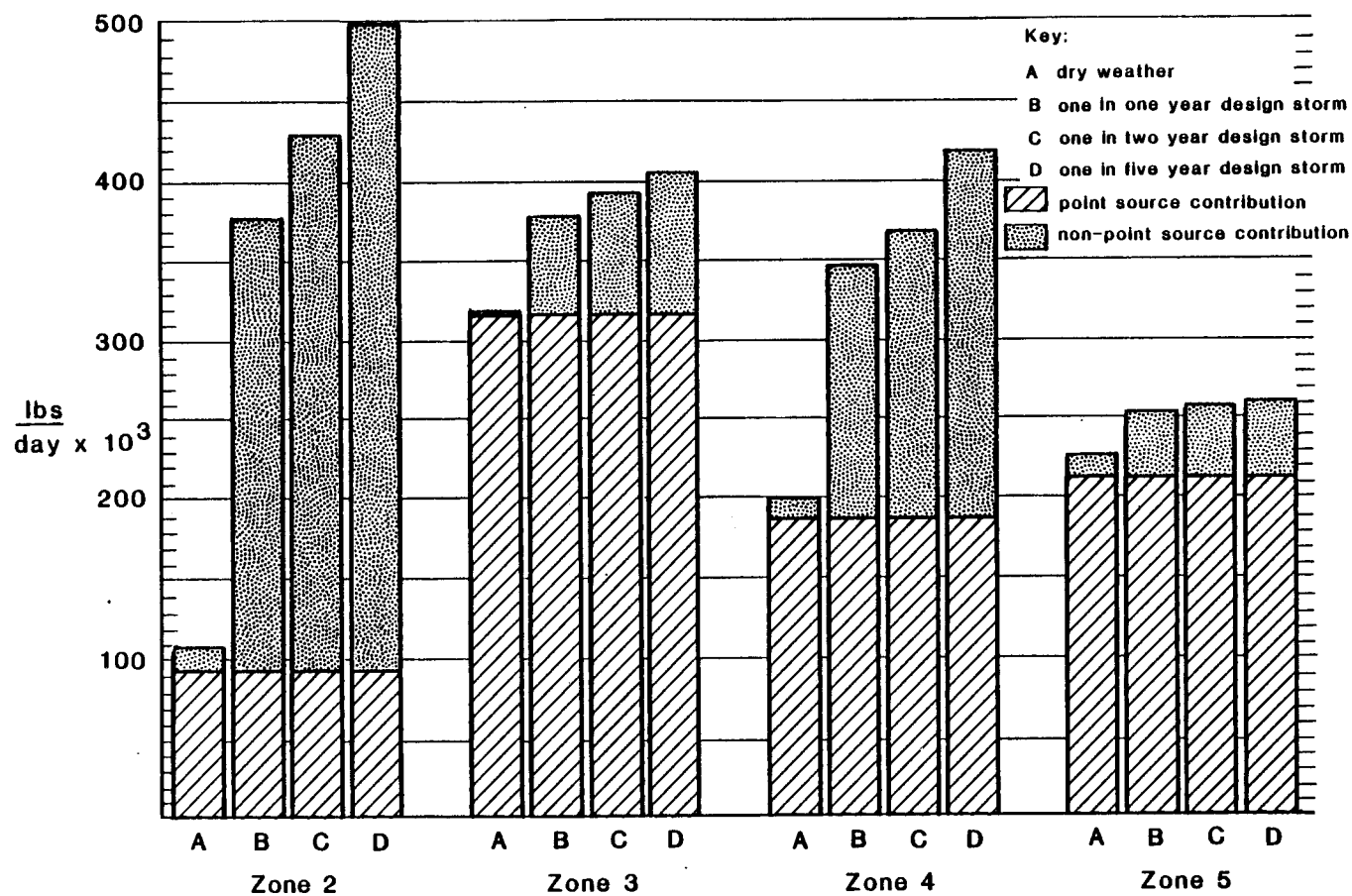
- C. Most of Zone 4 also does not support several of its designated uses nor meets the Federal fishable and swimmable goals. The area of non-attainment begins at the upper (Zone 3) end of Zone 4 and extends down river. The large point source wasteload discharged in Zone 3 impacts Zone 4 water quality possibly more so than the wasteloads discharged directly into Zone 4. Also, several large dischargers in Zone 4 are not in compliance with their wasteload allocations. The increase in discharge loads from 1982 to 1983 is also attributed to increased economic activity. Major violators of permitted allocations in Zone 4 include 1 municipal and 3 industrial facilities.
- D. Zone 5 not only attains its designated uses, but the upper section attains uses that are even higher. As Figure 9 indicates one reason is that the total wasteload discharged to Zone 5 is much less than the total allocated load. Thus, the water quality attained is better than projected when standards and designated uses were originally adopted. A minor increase in actual 1983 loads is also seen in Zone 5.

Four municipal and one industrial facility are considered major violators of their wasteload allocation permits. The largest treatment plant in Zone 5, the City of Wilmington wastewater treatment plant, discharges well below its wasteload allocation and is perhaps the most efficient large treatment plant along the Delaware River at this time.

Non-Point Sources: are a significant pollution load to tidal Delaware Estuary, Zones 2, 3, 4, and 5. These non-point sources can be divided into three categories: urban runoff, combined sewers and loads from tributaries and are primarily a wet-weather phenomenon, increasing with rainfall intensity.

The Delaware River Basin Commission is currently examining future abatement measures for the Delaware Estuary using a mathematical model developed by the U.S. EPA and others. Part of this effort involves the estimation of point versus non-point source contributions. The effort to date has yielded the load breakdown shown in Figure 10, which indicates the relative contribution

Figure 10. Relative Contributions of Point and Non-point Sources in the Delaware Estuary



of each type of pollution source to the total load (carbonaceous and nitrogenous oxygen demand) being discharged to each zone. The point sources shown assumes that all dischargers are meeting their DRBC allocation. Four conditions are presented (1) a dry weather, no-rain condition (2) a rainstorm of the size that occurs once a year (3) a once in every two year rain; and (4) a once in every five year rain. The three design rain storm differ in duration (from 13 to 27 hours) and intensity (2 to 3.3 inches). In most cases the resultant non-point source loads are discharged during the first 24-hours.

As would be expected point sources dominate during dry weather. As rainfall intensity increases the relative proportion of each zone's total load that is attributable to non-point sources also increases. In all cases the major portion of the non-point sources emanates from tributaries.

Zone 6

Point Sources: According to state 305(b) reports, the major impacts in Zone 6 from point sources are felt locally. Dischargers are scattered and small in comparison to the high volume of water represented by the Delaware Bay. Point sources do not appear to cause any significant harm to the attainment of designated uses in Zone 6. In past years the most significant point source impact on Zone 6 came from the high volume of oxygen demanding materials discharged above Zone 6 in Zones 3, 4 and 5.

Non-Point Sources: Specific data on non-point source impacts on Delaware Bay water quality are not available. The sources would be agricultural runoff, malfunctioning on-lot sewage disposal and the like, plus possibly non-point sources associated with commercial fishing such as oyster shucking, wastes etc..

TOXIC PARAMETERS

There are three types of toxic data depending upon where the toxic parameters are measured. These are water column data, data from bottom sediments and fish tissue data. The following discusses toxic parameters in the Delaware River and Bay for each type.

Water Column

Zone One is sampled for selected heavy metals on an occasional basis. Metals sampled include arsenic, cadmium, chromium, copper, lead, and several others. DRBC has adopted interpretive guidelines for eight metals and, in conjunction with the States and EPA is attempting to formulate new criteria to adopt as standards. Using the numeric guidelines (U.S. Fish and Wildlife Service 1983), potential criteria (DRBC-1983) and other information for guidance, it appears that no toxic water quality problems are evident in the water column of Zone One. Values for all samples parameters are extremely low; often less than the test sensitivity. Lead may be the exception in the lower section of Zone One, but natural sources there cannot be ruled out.

In Zones 2, 3, 4, 5 and the upper portion of Zone 6 the DRBC/Delaware DNREC boat run program samples several heavy metals that have human toxicity, such as lead, cadmium and arsenic. Metal concentrations in the water column are generally below DRBC's interpretive guidelines or criteria currently proposed.

Lead and cadmium can be considered borderline cases since a small percentage of values at some locations obtained in 1982 and 1983, were above the proposed criteria or the guidelines.

Data on some trace metals have been reported for the lower Estuary (Zone 5) and Delaware Bay (Sharpe 1983). Values were below toxicity levels and it was concluded that the concentrations were not exceptionally high when compared to either the Chesapeake Bay or Hudson River estuaries. While some elevations in concentrations were attributable to human activity, there were no indications of environmental deterioration.

Data for non-metallic toxic substances in the water column are generally not available. Studies have shown (including Sharp 1983) that phytoplankton and nitrification inhibition occur in the Estuary near Philadelphia. Although the reasons for these inhibitions are not known, toxicity from industrial chemical compounds is one of several possibilities. In May 1981 a survey by the Delaware Department of Natural Resources and Environmental Control found no presence of chlorinated pesticides in the water column of the Delaware Estuary or Bay. A repeat of the survey in April 1982 tested for both PCB and chlorinated pesticides without finding either.

Bottom Sediments

During the 1982-83 period bottom sediments were sampled once in Zone One at Trenton, New Jersey, and a variety of pesticides were found. Most values were below test sensitivity and others indicated low concentrations of the organic compounds. Indirect evidence of the lack of sediment toxicity is indicated by DRBC benthic macroinvertebrate samples. Samples taken in 1982 and 1983 in the

Delaware River at various locations upstream of the Delaware Water Gap show healthy, diverse macroinvertebrate populations.

Data concerning toxic compounds in the Delaware Estuary and Bay sediments have largely been acquired in the navigation channel for dredged spoils disposal analyses. A recent report (Corps 1984) summarized the results of various tests done in the 1979-83 period. Heavy metals, low concentrations of pesticides and a variety of organic compounds were found. Higher concentrations of most of the examined parameters were found in sediments in the reach of the Delaware River from Trenton to Philadelphia (Ben Franklin Bridge) than in the reach from Philadelphia to the sea. The report concluded that no serious pollution problems existed with respect to the sediments. Unfortunately there are very few data taken in sediments in near-shore areas. Concentrations of toxics in some of these sediments are known to be elevated due to their proximity to waste sources.

Sharp et. al. (1983) examined data for trace metals in the bottom sediments of the lower portion of Zone 5 - upper Delaware Bay area. Trace metals were attributed to three sources (a) riverine, largely natural sources (iron, manganese, lithium, potassium and aluminum) (b) marine sources (magnesium, strontium, calcium and sodium) and (c) pollution sources (chromium, copper, lead and mercury). As would be expected, pollution sources (i.e. human activity) increased in magnitude in an upstream direction. Pollution sources were considered a very high "factor influence" in the Bay area in the region centered around the mouth of the Cohansey River, New Jersey. That the researchers were able to differentiate trace metals in bottom sediments as to source does not mean that the metals were found at toxic levels.

A sediment sample taken by the Delaware Department of Natural Resources and Environmental Control in lower Zone 5 in 1982 showed no detectable concentrations of various pesticides and organic compounds. Metals were present in minute quantities.

Fish Tissue

Toxics in fish tissue are of concern because fish are caught and consumed by humans. Fish are the highest organisms in the Delaware River food chain and, thus, many toxic compounds are bioaccumulated. The accumulation of toxics in fish tissue can result in concentrations in the tissue that are higher than the surrounding environment.

Routine fish tissue sampling was initiated in 1979 by the four Delaware River Basin States as part of the EPA Basic Water Quality Monitoring Program. Up to ten locations are sampled each year from Port Jervis, New York in Zone One to the mouth of the Mahon River in Zone 6. Not all the data from this program are as yet available due to laboratory backlog and other problems. Limited fish tissue data are also available from a recently completed special study by the U.S. Department of the Interior, Fish and Wildlife Service (1983).

The toxics fish tissue data for Zone One locations are limited. In most cases measured parameters are not detectable. Several pesticides, herbicides and metals have been found in trace quantities; most are below applicable action

levels. In 1980 and 1981 some chlordane values at Trenton were a concern. Data collected since 1981 indicate lower levels. It must be emphasized that fish tissue analysis is complex and sufficient data have not been collected from which to draw scientifically valid conclusions.

Similar fish tissue data from the Delaware Estuary (Zones 2-5) indicate varying amounts of toxic compounds in fish flesh. Again chlordane appears to a concern. Small quantities of other parameters have also been found including DDT, Arsenic, PCB and others although in all samples the concentrations were below action levels.

Fish and oyster samples taken in the lower Estuary and Upper Delaware Bay indicate that concentrations of most measured toxics are below detectable limits. No potential toxic problems are evident.

Overview of the Toxics Problem

There is no doubt that toxic compounds are present in the Delaware River and Bay environment. The intense industrial activity and urbanization of the lower Delaware River Basin would suggest many potential sources of a wide variety of chemicals and chemical compounds. Even in relatively "clean" areas, toxic problems may occur. For example, near Narrowsburg, New York in the Upper Delaware Scenic and Recreational River area is a landfill that leaches toxic material. A study is underway to determine whether or not the leachate impacts Delaware River water quality. This and many other questions still exist concerning the sources and fates of toxic compounds in the Delaware River system.

The available data are limited. Few samples are taken at few locations for a limited number of parameters. The data analyzed to date suggests that few, if any, problems exist. However, this conclusion is only tentative until many more samples of Delaware River water, sediments and especially fish are made.

SPECIAL CONCERNS AND REMAINING PROBLEMS

The following discusses several areas of special significance that should be considered, along with previously mentioned concerns, as remaining problems.

1. Recreational use of the Delaware River is intense and increasing particularly in the non-tidal river. The increased use makes the maintenance of the sanitary water quality a key concern. An unanswered concern is the impact of the recreational use of the river on water quality itself.
2. In Zone 2 the allowable amount of oxygen demanding wastes discharged exceeds the previously-determined assimilative capacity of the zone, although standards are generally being attained. The reallocation of Zone 2 or the selection of alternative pollution control strategies is being studied by DRBC as part of an Estuary-wide modeling and planning program.
3. In Zones 3 and 4 sediment oxygen demand is a special concern. DRBC modeling studies indicate that SOD deposits exert a significant oxygen demand on the overlying water column. SOD rates measured in situ in Zones 3 and 4 are unusually high at some locations (DRBC 1983).
4. In Zones 3, 4 and part of Zone 5 adopted water quality standards are less than required to meet the Federal fishable and swimmable water quality goals. In 1979 a DRBC ad hoc task force of state and federal biologists defined fishable water quality in terms of dissolved oxygen levels that are not currently attainable. The pollution controls needed to attain these levels are being determined in the above-mentioned Estuary-wide program.
5. The attainment of designated uses and water quality standards usually requires that wastewater treatment plants be upgraded and operated to meet allowable wasteloads. When the latter does not occur, the benefits of upgrading are lost. Wastewater treatment plants that have completed their upgrading, usually with state and federal grant assistance, and still do not meet their effluent limitations should be the subject of increased attention.
6. Non-point sources and toxic substances will remain special concerns for the foreseeable future.

WATER QUALITY SUMMARY OF THE DELAWARE RIVER AND BAY

The following table presents a general assessment of Delaware River water quality in terms of excellent, good, fair or poor. These terms are defined as follows:

Excellent - no significant pollution problems. Water quality standards are violated very infrequently or not at all. Use of reach for effluent disposal is minimal or non-existent.

Good - Minor or localized pollution problems. Water quality standards are not violated in most samples or in major sections of the river reach. [Bacteria would be typical localized problem.] Wastewater dischargers to the reach generally meet applicable effluent requirements.

Fair - Frequent violations of one or more water quality standards on an annual or seasonal basis. Fish life limited to pollution-tolerant species or fish kills noted periodically. Bacteria levels sufficiently high to prevent safe swimming.

Poor - Regular violations of various water quality standards. Water quality unsuitable for fish survival at least part of the year. Very high bacterial levels present.

General Assessment and Attainment of Water Quality Goals

	No. of Miles	General Water Quality	Meets Swim- mable Goal	Meets Fish able Goal	Supports Designated Uses
West Branch Delaware Delaware River, Zone One	9	Good	yes	yes	yes
Hancock, N.Y. to Delaware Water Gap	118	Excellent	yes	yes	yes
Delaware Water Gap to Trenton, N.J.	79	Good	yes	yes	yes
Delaware Estuary Zone 2	25	Good to Fair	yes	yes	yes
Delaware Estuary Zone 3	13	Poor	No	No	No
Delaware Estuary Zone 4	16	Poor to Fair	No	No	No
Delaware Estuary Upper Zone 5	11	Fair	yes	No	yes
Delaware Estuary Lower Zone 5	20	Good	yes	yes	yes
Delaware Bay Zone 6	48	Excellent	yes	yes	yes

An overview of water quality by state is presented below. Total mileage includes nine miles of the West Branch, Delaware and includes the center line of the Delaware Bay.

State by State Water Quality Summary

	DE	NJ	NY	PA	Total	% of Total
Total number of miles	79	253	86	260	339	100 ^{1/}
Miles in Nat. Wild and Scenic R. Sys.	0	37	72	109	109	32
Miles supporting designated uses	79	224	86	231	310	91
Miles not supporting all designated uses	0	29	0	29	29	9 ^{1/}
Miles of fishable water quality	68	213	86	231	299	88
Miles of non-fishable water quality	11	40	0	29	40	12
Miles of swimmable water quality	79	224	86	231	310	91
Miles of non-swimmable water quality	0	29	0	29	29	9

1/ includes the interstate portion of the West Branch, Delaware River

2/ miles not supporting all designated uses are in Zones 3 and 4. Designated uses not being met fully there are maintenance of resident fish, passage of anadromous fish and secondary contact recreation.

CITED REFERENCES

1. Corps of Engineers "Delaware River Dredging Disposal Study Stage 2 Report Draft", Philadelphia, PA (January 1984)
2. Courier Post "Studies Show Dredging Safe for Sturgeon", by Tony Muldoon, Camden, N.J. (December 25, 1983)
3. Delaware River Basin Commission "Primary Productivity of the Nontidal Delaware River", July and August 1980, West Trenton, N.J. (June 1981)
4. Delaware River Basin Commission "Water Quality of the Upper Delaware Scenic and Recreational River: 1981 Survey", West Trenton, New Jersey (September 1981)
5. Delaware River Basin Commission "Cleaning Up the Delaware River", West Trenton, N.J. (March 1982)
6. Delaware River Basin Commission "Delaware River Water Quality in the Delaware Water Gap National Recreation Area", West Trenton, N.J. (February 1983)
7. Delaware River Basin Commission "Summary of Recommended Criteria", presented to the Water Quality Advisory Committee, West Trenton, N.J. (1983)
8. Delaware River Basin Commission "Report of Findings, Delaware Estuary Sediment Oxygen Demand Study Fall 1983", West Trenton, N.J. (December 1983)
9. Delaware River Basin Commission "Water Quality in the Delaware Water Gap National Recreation Area - 1983 and Recommended Monitoring Program", West Trenton, N.J. (February 1984)
10. Rutgers, The State University "Delaware and Raritan Canal Hydrologic, Hydraulic, Structural, Water Quality and Institutional Report", New Brunswick, N.H.J. (June 1980)
11. Sharp, Jonathan H. Editor "The Delaware Estuary: Research as Background for Estuarine Management and Development", prepared by the University of Delaware College of Marine Studies and New Jersey Marine Sciences Consortium for the Delaware River and Bay Authority, Lewes, DE (July 1983)
12. Sheppard, J. Douglas "New York Reservoir Releases Monitoring and Evaluation Program - Delaware River - Summary Report", New York Department of Environmental Conservation, Albany, N.Y. (September 1983)
13. U.S. Fish and Wildlife Service "Concentrations of Environmental Contaminants in Fish From Selected Waters in Pennsylvania", University Park, PA (1983)