SCREENING-LEVEL HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT FOR THE PASSAIC RIVER STUDY AREA

VOLUME IIB
APPENDICES

JULY 6, 1995

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EVALUATION OF AQUATIC AND TERRESTRIAL HABITATS WITHIN THE PASSAIC RIVER STUDY AREA

Introduction

The Passaic River Study Area (Figure 1), herein referred to as the Study Area, is located on the lower portion of the Passaic River, a major tributary of Newark Bay, which is situated within the Greater New York City Metropolitan Area. Specifically, the Study Area is defined as that portion of the Passaic River extending from the abandoned ConRail Railroad Bridge (located approximately 4,000 feet upriver from the red channel junction marker at the confluence of the Hackensack and Passaic Rivers) to a transect six miles (approximately 31,680 feet) upriver of this bridge. All or portions of the following five reaches, as defined by the Army Corps of Engineers, are encompassed within the Study Area: Point No Point Reach, Harrison Reach, Newark Reach, Kearny Reach, and Arlington Reach.

During the past two centuries, the Newark Bay Estuary, including the Passaic River, has been subject to multiple influences and changes due to the pressures exerted by rapidly expanding urban and industrial development in the region (Mytelka et al., 1973; Whipple et al., 1976; Wilber and Hunter, 1979a,b; Suszkowski et al., 1990). Degradation of water quality in the Passaic River was first noted during the Civil War (Brydon, 1974), and conditions deteriorated steadily for much of the first half of the 20th century (Mytelka et al., 1981). The problem of toxic chemicals in sediments throughout the Estuary has also been the focus of much concern in recent years (Meyerson et al., 1981; Bonnevie et al., 1992, 1993; Gillis et al., 1993; Crawford et al., 1994).

In addition to direct discharge of wastes to water and sediments in the Estuary, the industrial and urban activity within the region has severely reduced the natural habitats available for indigenous and migratory biota (Wallace et al., 1983; Squires and Barclay, 1990; Burger et al., 1993; Crawford et al., 1994). Geographical alterations to the Estuary since the 1800s (Figure 2) have resulted in the destruction of much of the necessary habitat (Squires and Barclay, 1990). Currently, approximately 75 percent of the original tidal marsh and wetland areas in the estuary have been filled or dredged, while the majority of those remaining have been significantly altered by a variety of human activities (Squires and Barclay, 1990). In addition, much effort has been directed towards stabilizing river banks, or redirecting water flow through the construction of dikes

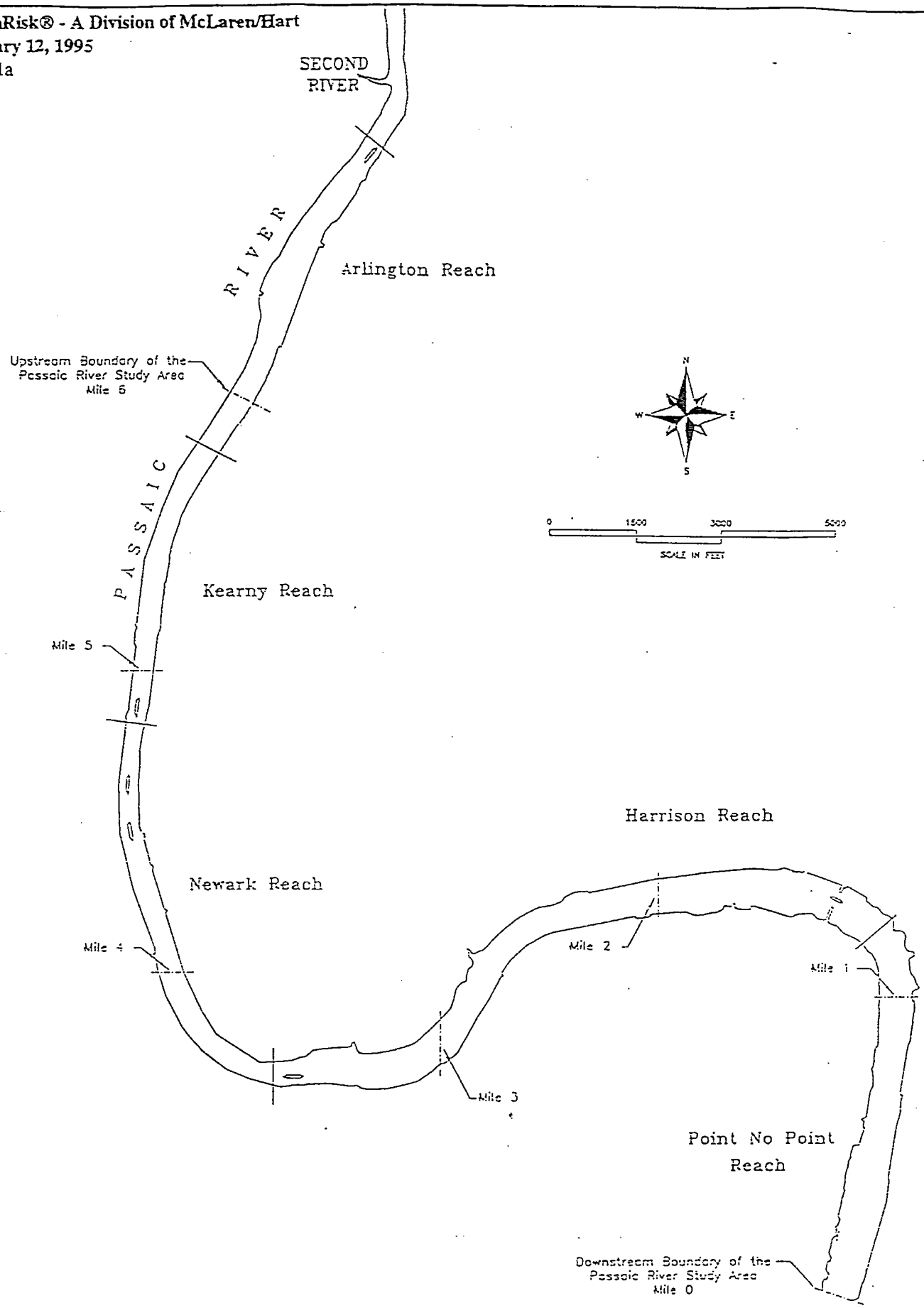


Figure 1. Passaic River Study Area

or dams, causing alterations in erosion and sedimentation patterns (Squires, 1992). Dredging activities and channel improvements, which began in 1874 (USACOE, 1988), have also continued the alteration of ecological conditions in the Passaic River and surrounding areas (Wallace et al., 1983; Burger et al., 1993).

The impacts of this industrial and urban expansion have been manifested in the ecological communities of the Estuary. For example, the Passaic River and Newark Bay were once considered prime fisheries for both finfish and shellfish (Brydon, 1974; Franz, 1982). However in recent years, only pollution tolerant species have been determined to be present (Princeton Aqua Science, 1982). Similarly, avian communities in the Estuary have significantly decreased over the last century (Burger et al., 1993; Parsons, 1993).

The objectives of this investigation were to (a) quantify and characterize the habitat currently available in the Study Area; and, (b) evaluate the quality of the available habitats with respect to their suitability as primary foraging or roosting areas for birds or mammals, or as nursery grounds for aquatic organisms. The results of this investigation are critical to our evaluation of the current and historical factors influencing the ecology of the Study Area.

Methods

A visual survey of the area was conducted by boat on August 9, 1994. The physical characteristics of the shoreline within each reach were recorded and a list of all species observed during the survey was generated. Hand net sweeps were conducted in areas where aquatic vegetation was identified. Baseline water quality parameters including dissolved oxygen, pH, salinity, and conductivity were also recorded on August 10 and 11, 1994, at six locations, representing each of the six miles within the Study Area (Figure 3). Coordinates for each of the six stations are presented in Table 1. Data were collected at the surface, mid-depth, and just above the bottom of the water column. A photographic record of the Study Area was constructed based on extensive photographs taken during the survey (Appendix A), as well as aerial photos of the Study Area taken in June, 1994 (Appendix B). In addition, the banks of the Study Area were videotaped at low and high tide.

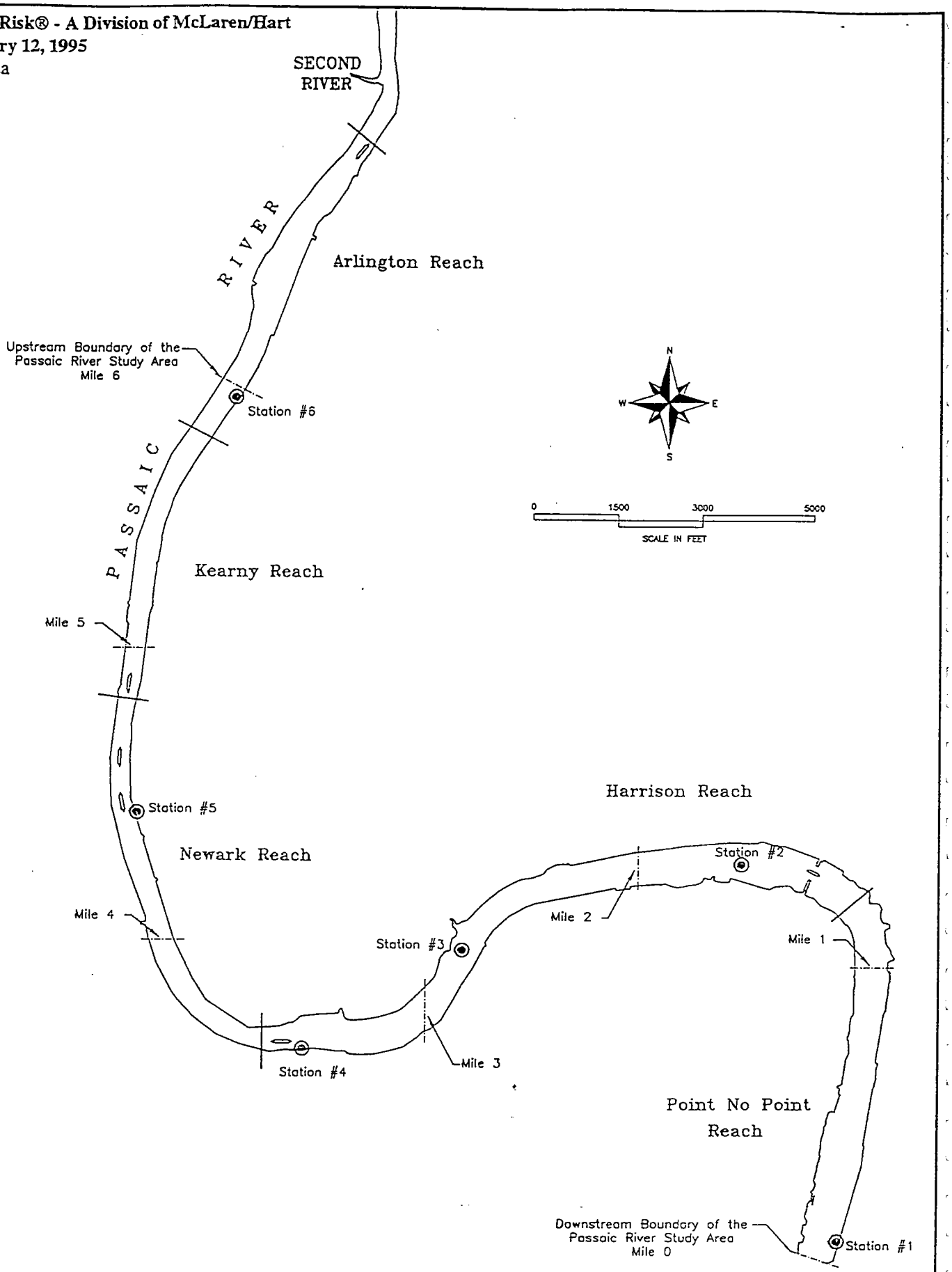


Figure 3. Passaic River Study Area Water Quality Sampling Stations

Table 1 Station Coordinates for Water Quality Sampling Stations

	Easting	Northing
Station 1	2151567	689018
Station 2	2149802	695691
Station 3	2144847	694160
Station 4	2141982	692396
Station 5	2138975	696559
Station 6	2140520	704213

a. Coordinates were determined utilizing a differential global positioning system (GPS). All positions are in NJ State plane coordinates.

The predominant shoreline features were identified within each of the reaches of the Study Area based on visual observations of the physical characteristics of the shoreline and review of aerial photos. These include wooden, metal, and stone bulkheads (i.e., Photos #8, #24 or #31), riprap (i.e., Photo #7), aquatic (i.e. marshy) vegetation (i.e., Photos #21 or #36), and a mixture of riprap and aquatic vegetation (i.e., Photo #25). The portion of each river bank, identified as left and right when facing upstream, occupied by each feature was estimated within the individual reaches, as well as the entire Study Area (Table 2). In addition to defining the composition of the river bank, the presence of mudflats and vegetation such as shrubs and trees (i.e., Photos #9 or #44) along the shoreline was determined (Table 3). The presence of vegetation and mudflats was not found to be linked to the presence of any particular shoreline feature; for example, mudflats were found in areas of aquatic vegetation, as well as in areas where the shoreline was predominantly comprised of bulkheads.

Based on these data, available ecological habitat areas in the Study Area were identified and individually evaluated for their suitability as primary foraging or roosting areas for birds or mammals, as well as nursery grounds for aquatic organisms.

Results

Visual Survey

Point No Point Reach (Photo #1-18)

The Point No Point Reach extends from the abandoned Conrail Railroad Bridge that delineates the lower portion of the Study Area to just downstream of the ConRail (Penn Central) Bridge (Station 67+00). This reach is the deepest portion of the Study Area, with water depths ranging from approximately 33 ft (MLW) at the downstream end to 21.1 ft (MLW) at the upstream end.

In total, 67 percent of the right bank and 60 percent of the left bank is comprised of bulkheads (Table 2). From the downstream river boundary of the Study Area to the Lincoln Highway Bridge (Photo #1-8), the shorelines of Point No Point Reach consist primarily of wooden and stone bulkheads created by several industrial facilities bordering these areas or riprap (Table 2).

Table 2. Shoreline features within the Passaic River Study Area

	Point No Point Reach				Harrison Reach				Newark Reach			
	Right Bank		Left Bank		Right Bank		Left Bank		Right Bank		Left Bank	
	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total
Bulkhead (Metal, stone, or wood)	4500	67%	4000	60%	3000	26%	6000	53%	6700	87%	4500	58%
Riprap	1500	22%	2550	38%	1000	9%	1250	11%	1000	13%	NO	NO
Mixed (a)	700	10%	NO	NO	2400	21%	3400	30%	NO	NO	3200	42%
Aquatic Vegetation	NO	NO	150	2%	5000	44%	750	7%	NO	NO	NO	NO
Total Shoreline (ft.)	6700		6700		11400		11400		7700		7700	

	Kearny Reach				Arlington Reach (b)				Cumulative Total for Study Area					
	Right Bank		Left Bank		Right Bank		Left Bank		Right Bank		Left Bank		Total Shoreline (c)	
	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total	Approx. ft	Percent of Total
Bulkhead (Metal, stone, or wood)	4200	81%	5200	100%	NO	NO	680	100%	18400	58%	20380	64%	38780	61%
Riprap	500	10%	NO	NO	NO	NO	NO	NO	4000	13%	3800	12%	7800	12%
Mixed (a)	NO	NO	NO	NO	680	100%	NO	NO	3780	12%	6600	21%	10380	16%
Aquatic Vegetation	500	10%	NO	NO	NO	NO	NO	NO	5500	17%	900	3%	6400	10%
Total Shoreline (ft.)	5200		5200		680		680		31680		31680		63360	

NO = Shoreline feature indicated was not observed in Reach.

a. Mixed refers to a mixture of rip-rap and aquatic vegetation.

b. Refers only to that portion of Arlington Reach included in the Passaic River Study Area.

c. Total Shoreline is equivalent to the sum of both right and left banks of the River.

Table 3. Estimated occurrence of shoreline vegetation and mudflats within the Passaic River Study Area

	Shoreline Vegetation (a)				Mudflats (b)			
	Right Bank		Left Bank		Right Bank		Left Bank	
	Approx. ft.	Percent of Total (c)	Approx. ft.	Percent of Total (c)	Approx. ft.	Percent of Total (c)	Approx. ft.	Percent of Total (c)
Point No Point Reach	1000	15%	1500	22%	NO	NO	1500	22%
Harrison Reach	5000	44%	3000	26%	4000	35%	2500	22%
Newark Reach	500	6%	1500	19%	750	10%	NO	NO
Kearny Reach	2000	38%	500	10%	1000	19%	1000	19%
Arlington Reach (d)	680	100%	500	74%	NO	NO	680	100%
Total For Study Area	9180	29%	7000	22%	5750	18%	5680	18%

NO=Not Observed

a. Shoreline vegetation refers to areas containing shrubs and trees. Large grassy areas may also be included. Areas of shoreline vegetation may co-occur with other features; for example, a stand of trees or shrubs may be present regardless of whether the bank is bulkhead, riprap, or aquatic vegetation. Therefore, these features are not included in estimate of total shoreline.

b. Mudflats refers to areas where mud substrate is exposed at low tide. Similar to shoreline vegetation, areas of mudflats may co-occur with other features, therefore, they are not included in estimate of total shoreline.

c. Represents the percent of the river bank in the indicated reach along which the feature occurs.

d. Refers only to that portion of Arlington Reach located within the Study Area.

Throughout much of this area, buildings and parking lots abut the river, with only narrow (i.e. <10 ft) strips of shoreline vegetation consisting primarily of grasses and woody shrubs. Upstream of the Lincoln Highway, the left bank of the river is somewhat less developed, however, it remains industrial in nature.

A stand of saltmarsh cordgrass (*Spartina alterniflora*) approximately 150 ft long and 10 ft wide was observed along Lawyer's Creek, a small tributary that drains into the Passaic River on the left bank approximately 3,000 ft from the upstream end of the reach near the General Pulaski Skyway Bridge (Photo #11). At low tide, a small, intertidal mudflat, encompassing approximately 1500 ft (i.e. 22 %) of the total shoreline can be observed. Designated as Area 1 (Aerial Photo #2), this stand encompasses approximately 0.03 acres.

Harrison Reach (Photo #19-44)

The Harrison Reach extends from approximately the ConRail (Penn Central) Bridge (Station 67+00) to just downstream of the Jackson St. Bridge (Station 181+00). Water depths range from 21.1 ft (MLW) at the downstream end of the Reach to approximately 19.2 (MLW) at the upstream end.

Much of the shoreline in Harrison Reach is comprised of bulkheads or riprap (Table 2). The left shoreline consists primarily of bulkheads bordered by several chemical facilities and inactive industrial properties. The remaining shoreline is predominately mixed. Aquatic vegetation is limited to a stand of *S. alterniflora* confined to a small area (Area 2) approximately 750 ft long near the Interstate 95 (NJ Turnpike) Bridge (Photo #21 & 23 and Aerial Photo #2), where a small ditch drains into the river. The *S. alterniflora* is limited to an area approximately 10 ft wide for a total of approximately 0.2 acres of aquatic vegetation. The aerial photo indicates a grassy area along the ditch, however, this area appears to be closely bordered by highway access ramps.

The banks of the right shoreline are relatively steep, consisting primarily of gravel riprap or wooden or stone bulkheads, and bordered by a passenger train yard and a train servicing depot. However, approximately 44 percent of the right shoreline (5000 ft) is comprised of aquatic vegetation (Table 2), representing the longest continuous stretch of *Spartina alterniflora* in the Study Area (Photo #36, #38, and #40). Throughout the majority of its length, this stand of *S. alterniflora* is confined to a very narrow area along the bank. However, a larger stand of *S.*

alterniflora and other aquatic vegetation was observed near a small ditch entering the River (Photo #36; Aerial Photo 3). One of the larger mudflats in the Study Area is also associated with this location. Designated as Area 3, this stand of aquatic vegetation approximately 10 ft wide, and extends for about 1500 feet, for a total area of 0.3 acres. Aerial photos (Aerial Photo #3) indicate the area is bordered by passenger rail tracks.

Strips of shoreline vegetation, although limited, appear more frequently than in Point No Point Reach, totalling approximately 44 percent of the right shoreline and 26 percent of the left (Table 3). The majority of these vegetated areas are comprised of narrow (<5 ft) strips of tall grasses or shrubs, however in a few areas there are woody perennials, such as *Phragmites* sp., *Artimesia* sp. (Photo #18), and narrow bands of trees including willows (*Salix* sp.), maples (*Acer* sp.), and Sumac (*Rhus* sp.) (Photo #41 and #43). These stands of trees appear to act as aesthetic borders between the river and adjacent highways and industrial facilities, and are frequently bisected by roadways or other development.

Newark Reach (Photo # 45-54)

The Newark Reach extends from just below the Jackson St. Bridge (Station 181+00) to the Clay St. Bridge (Station 258+00) and runs through the downtown section of the City of Newark. Channel depths in this reach range from 19.2 ft (MLW) at the downstream end to 18.7 ft (MLW) at the upstream end.

The majority of this reach is located within the downtown area of Newark, NJ (Photo #49-56). Most of the shoreline is comprised of bulkheads, with little shoreline vegetation (Table 2 and 3). The right shoreline is bordered by oil storage tanks, numerous small manufacturing facilities, and a former coal burning facility near the Jackson St. Bridge, while the left shoreline is bordered by a small park alongside Highway 52 (fenced on the river side) and parking lots. Along the left bank, approximately 42 percent of the shoreline was categorized as mixed (Table 2). Narrow strips of vegetation are present in some areas, consisting primarily of low shrubs or grasses. One small mudflat area, approximately 750 ft long, was observed along the right bank.

Kearny Reach (Photo # 55-60)

The Kearny Reach extends from approximately the Clay St. Bridge (Station 258+00) to Station 310+00 of the Study Area. Channel depths in this Reach range from 18.7 (MLW) at the downstream end to 17 ft (MLW) at the upstream end.

The Kearny Reach (Photo #57-60) is very heavily developed. The majority of the shoreline is comprised of bulkheads (Table 2). Shoreline vegetation is relatively limited, consisting primarily of grasses and woody shrubs (Table 3). The left shoreline consists primarily of stone bulkheads and is bordered by train tracks serviced by ConRail and Highway 22 (McCarter Freeway); much of this bank is predominated by large storage tanks (Photo #57 and #59). The right shoreline consists of wooden and stone bulkheads bordered by several small manufacturing facilities. Approximately 1000 ft of mudflats were observed along both shores (Table 3).

Arlington Reach (Photo #61-62)

Only a small portion of the Arlington Reach is in the Study Area. The Arlington Reach extends from Station 310+00 beyond the upstream extent of the Passaic River. The channel depth in the portion of the Reach located within the Study Area is 17 ft (MLW).

The right shoreline of the Arlington Reach consists of wooden and stone bulkheads bordered by several small manufacturing facilities and some private homes at the northern end of the Study Area. The left shore of the Arlington Reach consists primarily of parking lots. Toward the end of the Reach, the right bank is less developed with areas of shoreline vegetation including tree species such as willows (*Salix* sp.), maples (*Acer* sp.), and Sumac (*Rhus* sp.) (Photo #62; Aerial Photo #5). However, as noted for downstream reaches, these stands of trees are primarily narrow, aesthetic buffers occurring along highways or industrial properties.

Total Study Area

In total, 73 percent of the shoreline within the Study Area is comprised of either bulkheads or riprap (61 percent and 12 percent, respectively) (Table 2). Only about 10 percent (< 1 acre) of the shoreline in the Study Area contains aquatic vegetation, primarily concentrated in three areas. Area 1, located at the confluence of the Passaic River and Lawyer's Creek was estimated to contain 0.03 acres of aquatic vegetation. Located at a ditch entering the Passaic River near the Interstate 95 (NJ

Turnpike) Bridge, Area 2 was somewhat larger, estimated to contain 0.2 acres. The largest of the three areas, Area 3 is located near the upstream end of Harrison Reach (Station 140+00), and was estimated to be approximately 0.3 acres in size.

No terrestrial habitats were identified along the shorelines of the Study Area. Although shoreline vegetation is present (Table 3), it is primarily comprised of narrow buffer zones (< 20 feet in width) of trees, grasses, and woody shrubs occurring between the river and highways, parking lots, and industrial facilities. These areas are typically very fragmented, and are therefore unlikely to support significant populations of wildlife.

Water Quality Data

Water quality data are presented in Table 4. Dissolved oxygen (DO) levels were very low in the Study Area. In bottom waters, DO levels ranged from 2.2 mg/l near the upstream end of the Study Area, to 5.1 mg/l at Station 2. Surface water DO was nearly uniform throughout the Study Area, ranging from 4.6 mg/l to 5.8 mg/l. Water temperatures were nearly uniform throughout the water column and Study Area, ranging from 23.0°C to 25.0°C. Conductivity ranged from 80 µmho/cm^2 (x100) at Station 6 to 305 µmho/cm^2 (x100) at Station 5. At more downstream stations of the Study Area (i.e. Stations 1 through 4), salinity ranged from 13.5 ppth to 20.0 ppth. As would be expected, salinity tended to be lower in upstream locations, ranging from 6.0 ppth to 9.0 ppth at Station 6. Salinity and conductivity measured at Station 5 appear relatively high compared to other upstream stations (Table 4). It is important to note that measurements at this station were collected on August 10, using an instrument determined to be operating incorrectly. This instrument was replaced with a correctly operating meter which was used to collect data at the other stations on August 11.

Species Observed

A list of species observed during the survey is presented in Table 5. The only mammals in the Study Area were rats seen along the bulkheads and shorelines of the River. This is indicative of the urban nature of the area surrounding the Passaic River. Mammals that may be present in the areas adjacent to the Study Area are limited to those adapted to an urban environment, such as squirrels, rats, and other rodents. There are no apparent habitats suitable for aquatic or semi-aquatic mammals (i.e., muskrats, mink etc.) in the Study Area; the limited areas identified as

Table 4. Ambient water quality data for Passaic River Study Area, August 1994

Sampling Station	Date	Time	Approx. Tide Height (ft) (a)	Depth (ft)	Temperature (C)	Dissolved Oxygen (mg/l)	Salinity (ppth)	Conductivity (µmho/cm^2 x 100)
1	8/11/94	14:35	4.41	Surface	24.3	5.8	18.0	290
				10	23.5	5.4	19.5	259
				20	23.0	5.0	20.0	253
2	8/11/94	11:10	5.74	Surface	23.8	5.2	17.0	223
				8 (b)	23.8	5.1	18.0	233
3	8/11/94	14:25	4.75	Surface	24.5	4.9	16.0	215
				10	24.0	4.2	17.5	233
				20	24.0	4.2	18.8	248
4	8/11/94	14:16	4.75	Surface	24.5	4.6	13.5	183
				10	24.0	4.2	15.0	195
				20	24.0	3.8	16.3	215
5	8/10/94 (c)	13:15	5.74	Surface	24.3	-	21.2	290
				Bottom (b,d)	25.0	-	23.0	305
6	8/11/94	13:58	5.23	Surface	25.0	5.1	6.0	80
				10	24.0	3.0	8.5	120
				22	24.0	2.2	9.0	110

a. Represents tide height above mean low water. High tide during the two day survey was at approximately 11:35 (5.96 ft.) on 8/10/94 and at 12:26 (6.03 ft) on 8/11/94.

b. Data only collected at the surface and bottom.

c. Data for salinity and conductivity at Station 5 were collected using different instrumentation, and therefore may not be comparable to other stations.

d. Depth not recorded at Station 5

Table 5. Species observed in the Passaic River Study Area (a)

Species	Scientific Name
Fish and Aquatic Invertebrates	
Grass shrimp	*Palaemonetes pugio*
Amphipod	*Ampelisca sp.*
Blue Crab	*Callinectes sapidus*
Mummichog	*Fundulus heteroclitus*
Atlantic silverside	*Menidia menidia*
Carp	*Cyprinus carpio*
Oligocheates	*Oligocheata sp.*
Polychaetes	*Polychaeta sp.*
Birds	
Snowy egret	*Egretta thula*
Mallard	*Anas platyrhynchos*
Cormorant	*Phalacrocorax auritus*
Gulls	*Larus sp.*
Mammals	
Rat	*Rodentia sp.*
Vegetation	
Saltmarsh cordgrass	*Spartina alterniflora*
Common reed-grass	*Phragmites sp.*
Mugwort	*Artimesia sp.*
Maple	*Acer sp.*
Willows	*Salix sp.*
Sumac	*Rhus sp.*

(a) Includes only those species observed during August, 1994 survey

possible habitats in the Study Area are too small to support significant populations of these organisms. Similarly, no significant nesting areas for aquatic birds were identified within the Study Area. Only a few species of aquatic birds were observed (Table 5).

Hand net sweeps identified various aquatic species such as grass shrimp (*Palaemonetes pugio*), mummichog (*Fundulus heteroclitus*), Atlantic silversides (*Menidia menidia*), and blue crab (*Callinectes sapidus*) (Table 5). In addition, benthic invertebrates such as oligochaetes, polychaetes, and amphipods were observed. Carp (*Cyprinus carpio*) were also observed near the upstream boundary of the Study Area. No other large finfish were observed.

Discussion

Overall, there are limited existing terrestrial or wetland habitats within the Study Area. The majority of the shoreline consists of bulkheads (Table 2). The shoreline vegetation is generally limited to narrow buffer zones of woody perennials, such as *Phragmites* sp. or *Artimesia* sp., or narrow bands of trees including willows (*Salix* sp.), maples (*Acer* sp.), and Sumac (*Rhus* sp.), and is usually bordered by industrial facilities, highways, or parking lots. Land use along the banks is predominantly urban and industrial. There is little, if any suitable habitat in the Passaic River Study Area for aquatic birds or other terrestrial wildlife; the few potential areas are primarily aesthetic buffer zones fragmented by roads, buildings, and other types of industrial development. There are no apparent habitats suitable for aquatic or semi-aquatic mammals (i.e., muskrats, mink etc.) in the Study Area.

Estuarine habitats are widely recognized as among the most productive of marine environments; a healthy estuary can support dense and diverse populations of aquatic species (Levinton, 1982). Estuaries are particularly important as nurseries for juveniles of many fish and crustaceans; on the Atlantic Coast, the majority of commercially exploited fish species utilize estuaries as juvenile feeding grounds (Levinton, 1982; Boesch and Turner, 1984). One of the key components of an healthy estuary is the presence of salt marsh or other wetland areas (Levinton, 1982). It has been demonstrated that the populations of many commercial species of fish and shellfish in estuaries along the eastern coast of the United States are correlated with the ratio of marsh area to open water (Boesch and Turner, 1984). There are numerous explanations for this observation. For example, it has been suggested that many estuarine species rely on the presence of salt marsh plants, such as

S. alterniflora, and the associated microbiota and detritus as food sources (Levinton, 1982; Boesch and Turner, 1984). In addition, aquatic vegetation provides refuge for juveniles of many aquatic species, reducing predation and increasing the fitness of the species (Levinton, 1982; Boesch and Turner, 1984; Studholme, 1988). Increased yields of many fish and shellfish species have been observed in estuarine areas with abundant salt marsh vegetation (Boesch and Turner, 1984).

Based on the results of this survey, it is evident that the Study Area lacks sufficient salt marsh habitat to support a significant population of aquatic species. Three localized areas were identified as having conditions (i.e vegetation, exposed mudflats) suitable to provide cover for some aquatic organisms, however, combined they comprise less than one acre. Due to size limitations, it is unlikely that these areas would attract or support significant populations of resident or migratory finfish species (Boesch and Turner, 1984).

In addition to the lack of associated wetland habitats, the Passaic River is bordered by areas of intense urban and industrial development. For many years, myriad activities have resulted in pollution from municipal and industrial wastewaters, stormwater runoff, accidental spills, direct dumping of wastes, and atmospheric deposition (Olsen et al., 1984; HydroQual, 1991). The majority of the sewage generated in the region throughout the 1800s and the early part of this century was discharged directly into the estuary as untreated waste (Rod et al., 1989). In 1894, as much as one third of the total flow of the Passaic River was estimated to be untreated sewage (Brydon, 1974). Despite increased attempts to reduce direct discharges to the Estuary, a survey of outfalls in 1983 located more than 160 combined sewer overflow (CSO) discharges into the Kill van Kull, Newark Bay, Passaic River, and Hackensack River (ISC, 1988; Killiam, 1983). As a result, degraded water quality is a severely limiting factor in the Study Area. Impacted water quality parameters, such as depressed levels of DO, can adversely affect fish and benthic invertebrate communities by inhibiting growth, decreasing survival rates, and increasing competition (Stacey, 1990). Low DO concentrations have also been found to result in reduced species abundance and diversity (Boesch and Rosenburg, 1981; Keller and Squibb, 1992). In general, 5 mg/l is considered to be the minimum level for satisfying the oxygen requirements of most fish (Everhart and Youngs, 1981). In addition, more mobile and migratory species tend to avoid areas with DO concentrations below 3 mg/l (Keller and Squibb, 1992).

Despite reports of recent improvements in DO levels (Mytelka et al., 1981) in other portions of the Passaic River, it is evident from the data collected in this investigation that mid-summer DO levels within the Study Area still decline below those that are considered tolerable to most aquatic species. Dissolved oxygen concentrations measured during this survey were all at or below minimally acceptable levels (Table 4). This indicates that conditions may be stressful even for the pollution-tolerant species that inhabit the Study Area.

The NY/NJ Harbor Estuary and the NY Bight together form a diverse environment providing habitat for a variety of plants and animals (Studholme, 1988; USEPA, 1993). Significant coastal fish and wildlife habitats in the region include salt and fresh tidal marshes, shallow bays, barrier beaches, and dune systems. Approximately 180,000 acres of coastal wetlands (including salt and fresh tidal marsh) have been identified in the New Jersey portion of the NY/NJ Harbor Estuary (USEPA, 1993). The Hackensack Meadowlands, located within the NY/NJ Harbor Estuary approximately 10 miles east of the Passaic River, contains more than 8000 acres of marsh habitat (Squires and Barclay, 1990). Surveys of the Meadowlands have demonstrated that a wide range of ecological communities exist in the area (Bragin 1989). Approximately 750 acres of the Hackensack Meadowlands have been preserved in the Saw Mill Creek Fish and Wildlife Management Area (Festa and Toth, 1976). In contrast, the available habitat identified in the Study Area represents less than one hundredth of one percent (0.006 percent) of that available in the Hackensack Meadowlands.

Conclusions

The results of this survey indicate that land use throughout the Study Area is dominated by high-density commercial and industrial/commercial development. Essentially all of the wetlands that previously existed in the area have been eliminated, with more than 7,500 acres destroyed since 1940 (USACOE, 1988). For example, the left bank of the lower Passaic River (facing upstream), just upstream of the Interstate 95 (NJ Turnpike) Bridge was once primarily marshland, however, the area is now almost fully developed, consisting of active or abandoned commercial and industrial/commercial properties with little or no access to the river. The available habitat within the Study Area would not support significant populations of terrestrial species, and would only support a limited ranged of aquatic species. Substantial reductions of different habitats within the estuary (e.g., salt marsh, soft bottom substrate, and rocky intertidal) have eliminated or reduced

the resources that are necessary to sustain individual species, and have created more competition among the remaining species for less space. The loss of habitat typically results in deteriorating conditions for each individual in a population (Purves and Orians, 1983) and may have far-reaching implications on the entire ecosystem, as impacts are transferred throughout the food web.

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APPENDIX A

PHOTOGRAPHIC RECORD
OF
PASSAIC RIVER STUDY AREA

APPENDIX B

AERIAL PHOTOGRAPHS OF PASSAIC RIVER STUDY AREA

APPENDIX F

FINFISH AND BENTHIC INVERTEBRATE SURVEY OF THE PASSAIC RIVER STUDY AREA

FINFISH AND BENTHIC INVERTEBRATE SURVEY OF THE PASSAIC RIVER STUDY AREA

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FINFISH AND BENTHIC INVERTEBRATE SURVEY OF THE PASSAIC RIVER STUDY AREA

Introduction

The Passaic River Study Area (Figure 1), herein referred to as the Study Area, is located on the lower portion of the Passaic River, a major tributary of Newark Bay, which is situated within the Greater New York City Metropolitan Area. Specifically, the Study Area is defined as that portion of the Passaic River extending from the abandoned ConRail Railroad Bridge (located approximately 4,000 feet upriver from the red channel junction marker at the confluence of the Hackensack and Passaic Rivers) to a transect six miles (approximately 31,680 feet) upriver of this bridge. All or portions of the following five reaches, as defined by the U.S. Army Corps of Engineers, are encompassed within the Study Area: Point No Point Reach, Harrison Reach, Newark Reach, Kearny Reach, and Arlington Reach.

During the past two centuries, the Newark Bay Estuary, including the Passaic River, has been subject to multiple influences and changes due to the pressures exerted by rapidly expanding urban and industrial development in the region (Mytelka et al., 1973; Whipple et al., 1976; Wilber and Hunter, 1979a,b; Suszkowski et al., 1990). Degradation of water quality in the Passaic River was first noted during the Civil War (Brydon, 1974), and conditions deteriorated steadily for much of the first half of the 20th century (Mytelka et al., 1981). The problem of toxic chemicals in sediments throughout the Estuary has also been the focus of much concern in recent years (Meyerson et al., 1981; Bonnevie et al., 1992, 1993; Gillis et al., 1993).

Despite the extensive efforts to characterize the distributions of contaminants in sediments of the Passaic River, there has been little emphasis on characterizing the ecological communities that are potentially exposed to contaminated sediments. A recent evaluation of ecological conditions in the Newark Bay Estuary found that only limited information is available regarding the characteristics of fish and benthic invertebrate populations inhabiting or utilizing the tidal Passaic River (Crawford et al., 1994). Available data for the Newark Bay region suggest that benthic community diversity is very low (USACOE, 1980; Princeton Aqua Science, 1982; Cristini, 1990; Cerrato and Bokuniewicz, 1986; Cerrato, 1986). Finfish data for the lower Passaic River indicate that non-commercial species, such as the common mummichog (*Fundulus heteroclitus*), sunfish (*Lepomis*

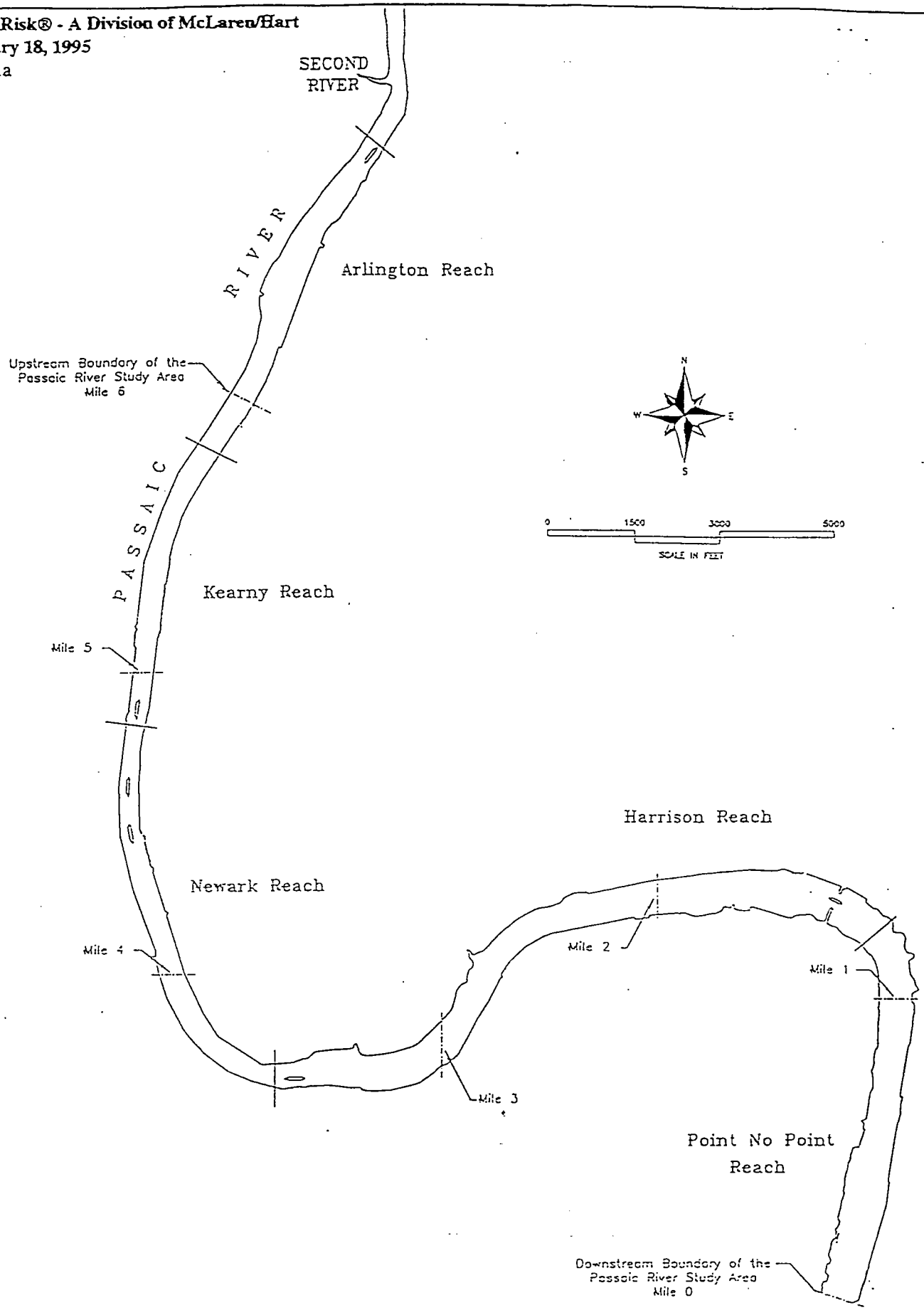


Figure 1. Passaic River Study Area

sp.), and minnow (*Notropis* sp.), are the predominant species present (Princeton Aqua Science, 1982).

The purpose of this investigation was to conduct finfish and benthic invertebrate surveys in the Study Area as part of an ongoing effort to characterize the ecological communities present. The surveys were conducted during the summer growing season, when the diversity and abundance of organisms are expected to be the greatest.

Methods

The finfish and benthic invertebrate surveys were conducted concurrently on August 10 and 11, 1994. All sampling was conducted by boat. Sampling stations were located within each river mile of the Study Area (Figure 2), and were selected based on the presence of mud flats and shoreline vegetation, in an attempt to sample areas most likely to contain the highest diversity and abundance of organisms. To that end, no sampling stations were located in previously dredged navigation channels. Coordinates for each of the stations are presented in Table 1.

Four replicate bulk sediment samples were collected utilizing a Petite Ponar Grab Sampler at each of the 6 stations within the Study Area. Three of the replicates were collected for the purpose of characterizing the benthic invertebrate communities, while the fourth was used to determine the corresponding grain size of the sediments. A photographic record of each benthic sampling station is presented in Appendix A. In an effort to quantitatively evaluate resident finfish populations, gill nets were deployed at three locations representing the upstream boundary (Station 6), downstream boundary (Station 1), and approximate midpoint (Station 3) of the Study Area. Dip net sweeps and minnow traps were also employed at various locations to obtain additional, qualitative information on the species present. In addition, baseline water quality parameters, including dissolved oxygen, pH, salinity, and conductivity, were recorded at each benthic sampling station.

Benthic Invertebrate Population Surveys

The three replicate samples designated for benthic invertebrate community analysis were passed through a standard 500 micron mesh sieve. Retained organisms and detrital material from each replicate sample were placed in appropriately labeled zip-lock bags and preserved in 70% ethyl alcohol.

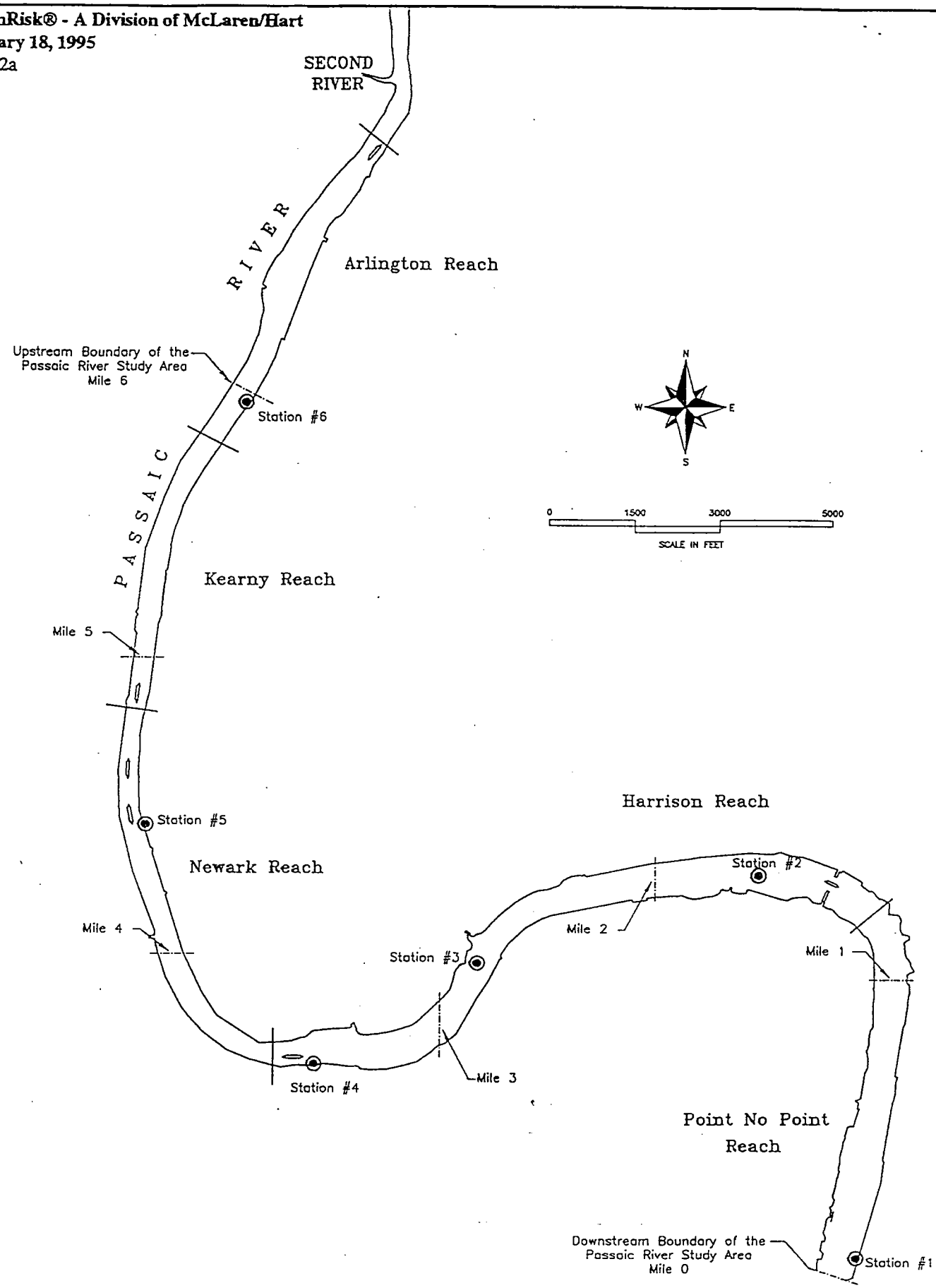


Figure 2. Passaic River Study Area Benthic Sampling Stations

Table 1 Station coordinates for water quality sampling stations

	Easting	Northing
Station 1	2151567	689018
Station 2	2149802	695691
Station 3	2144847	694160
Station 4	2141982	692396
Station 5	2138975	696559
Station 6	2140520	704213

a. Coordinates were determined utilizing a differential global positioning system (GPS). All positions are in NJ State plane coordinates.

Samples were shipped to RMC Environmental Services, Inc. in Spring City, PA for processing. Each sample was sorted to separate biota from detrital material. Organisms were then sorted by phylum, and identified to the lowest practical taxon (i.e. genus or species), given their condition and degree of maturity, using standard marine/estuarine invertebrate identification keys (Bousfield, 1973; Gosner, 1980; Brinkhurst, 1986; Epler, 1992).

Species diversity and abundance was evaluated using the Shannon-Weaver Diversity Index (H′), which is described by Equation 1:

$$H' = -\sum [(n_i/N) * \ln(n_i/N)] \quad (1)$$

where,

- H' = Shannon-Weaver Diversity Index;
- n_i = Mean number of individuals per square meter for a particular species; and,
- N = Total number of individuals per square meter.

The Shannon-Weaver Diversity Index, H′, measures both species richness (i.e. the number of species in a sample) and the distribution of individuals among species (Cerrato, 1986). The higher the value of H′, the more diverse the assemblage. In general, the H′ value will be high if a consistent number of individuals are present from a large number of species (i.e., the total number of organisms (N) are distributed relatively evenly amongst a large number of species). Lower H′ values can be due to either (a) a low number of individuals from any number of species (i.e., both n_i and N are small numbers), or (b) a large number of individuals from only a few species (i.e., n_i is very high for only a few species and very low for others). Either of these scenarios would infer that diversity and/or abundance of the invertebrate community are low; hence the low H′ value.

Grain Size

The fourth replicate sample collected at each sampling station was retained for grain size analysis. These samples were placed in separate, labeled zip-lock bags and shipped to RMC Environmental Services, Inc. in Spring City, PA for processing. Grain size analyses were conducted by Lesny and Kitlinski Associates of Camp Hill, PA.

Fish Population Surveys

Two monofilament, experimental gill nets were constructed for use in this survey. Each net was comprised of six 6 x 24 ft. panels with mesh sizes of 1.5 in, 2.0 in., 2.5 in., 3.0 in., 3.5 in., and 4.0 in. respectively, and equipped with lead weights and floats designed to hold the net vertically in the water column (i.e., after deployment, the top of the net was suspended approximately six feet above the sediment surface). The nets were deployed perpendicular to the river flow according to methods described in Nielsen and Johnson (1983). A total of five deployments were conducted, two each at Stations 1 and 3, and one at Station 6. The first deployments at Stations 1 and 3, as well as the deployment at Station 6, were daytime sets lasting about 4 to 8 hours. The second deployments at Stations 1 and 3 were overnight sets lasting at least one semidiurnal tidal cycle. Upon retrieval of the nets, the size, sex, and species of each organism collected were recorded, and those that had survived were released.

In an effort to obtain qualitative information regarding smaller finfish species and aquatic invertebrates, dip net sweeps were conducted in vegetated areas along the river banks. In addition, baited minnow traps were placed overnight at Stations 3 and 5.

Water Quality Data

Water quality parameters such as dissolved oxygen (DO), salinity, temperature, and conductivity were recorded at various depths at each of the six sampling stations. Data were collected at the surface, mid-depth, and just above the bottom of the water column.

Results

Benthic Invertebrate Population Survey

Results of the benthic invertebrate survey for the Study Area are summarized in Table 2 and Figure 3. The raw data for each replicate analysis, prepared by RMC Environmental Services, Inc., are presented in Appendix B. Species richness (number of taxa) was low at all stations, ranging from 4 taxa at Station 2 to 9 taxa at Station 6, with an arithmetic mean of 6.8. The highest number of individuals per square meter were found at Stations 5 and 6; however this is attributable to the relatively large numbers of one species (*Limnodrilus hoffmeisteri*) found only at these stations.

Table 2. Benthic macroinvertebrate data from the Passaic River Study Area, August 1994

Taxon	Mean Number of Individuals (n) per square meter (a,b)					
	Station 01	Station 02	Station 03	Station 04	Station 05	Station 06
Annelida						
Oligochaeta						
Limnodrilus hoffmeisteri					14840.6	4695.7
Tubificidae	14.5	1130.4	159.4	173.9		
Polychaeta						
Eteone heteropoda	29.0					
Scolecolepides viridis	14.5		159.4	260.9	14.5	14.5
Scoloplos sp.	14.5					
Streblospio benedicti	1985.5	130.4	289.9		72.5	
Hypaniola grayi			942.0		304.3	202.9
Laeonereis culveri			202.9			
Arthropoda						
Crustacea						
Leucon americanus	58.0	173.9		14.5		14.5
Rhithropanopeus harrisii		14.5	43.5	144.9	72.5	14.5
Cyathura polita			318.8	29.0	130.4	130.4
Edotea triloba					58.0	72.5
Gammaridae						43.5
Insecta						
Procladius sp.						29.0
Mollusca						
Bivalvia						
Veneroida	14.5		29.0			
Mytilopsis leucophaeata				14.5		
Total No. of Individuals/sq. meter (N)	**2130.4**	**1449.3**	**2144.9**	**637.7**	**15492.8**	**5217.4**
Total No. of Taxa	**7**	**4**	**8**	**6**	**7**	**9**
Shannon-Weaver Diversity (H') (c)	**0.358**	**0.711**	**1.66**	**1.37**	**0.236**	**0.491**

a. Mean No. of individuals/sq. meter based on data for 3 replicate Ponar Grab samples at each station. Calculated based on known area sampled by Petite Ponar Grab.
b. All calculated values are expressed in significant figures.
c. $H' = -\Sigma [(n/N)*\ln(n/N)]$

The results of the Shannon-Weaver Diversity Index are also presented in Table 2. H´ values ranged from 0.236 at Station 5 to 1.66 at Station 3. The highest H´ values occur at Stations 3 and 4 (1.66 and 1.37, respectively), while those for the remaining stations were significantly lower (0.236 to 0.711).

The species assemblage at all stations was dominated by polychaete worms (primarily *Streblospio benedicti* and *Hypaniola grayi*) and oligochaete worms (primarily *Limnodrilus hoffmeisteri* and Tubificidae sp.). In general, polychaetes were the dominant species at stations located in the more downstream (i.e. saline) portion of the Study Area (i.e. Stations 1 through 4), while more upstream (i.e. brackish water) stations were dominated by oligochaetes. Station 2, in which oligochaetes comprised 78 percent of the organisms present, is the only exception to this trend. At Stations 5 and 6, approximately 96 and 90 percent, respectively, of the individuals present are comprised of one oligochaete, *Limnodrilus hoffmeisteri*. Other species observed at most stations included the crustaceans *Cyathura polita*, *Rhithropanopeus harrisii*, and *Leucon americanus*. Insects and mollusks were observed infrequently and in relatively low numbers throughout the Study Area (Figure 3).

In addition to the organisms identified in the invertebrate survey, the dip net sweeps provided a qualitative evaluation of the species present in the vegetated shoreline areas of the River. Grass shrimp (*Palaemonetes pugio*) and the amphipod, *Ampelisca abdita*, were observed in the dip nets sweeps. Large numbers of amphipods and mud crabs (*Rhithropanopeus harrisii*) were also observed in leaf litter inadvertently collected in the gill nets.

Blue crabs (*Callinectes sapidus*) were collected in all but two of the gill net deployments (Table 3); no organisms were collected in the nets set at Station 6, or in the overnight set at Station 3 due to the large amounts of trash and debris that became entangled in the nets. Male crabs ranged in size from 5.5 to 17.5 cm in carapace width (horn to horn), with an arithmetic mean width of 14 cm (n=23). Females ranged in size from 10.0 to 14.0 cm with an arithmetic mean width of 11.8 cm (n=12).

Fish Population Survey

Fish species collected through the dip net sweeps and in the minnow traps were mummichogs (*Fundulus* sp.) and atlantic silversides (*Menidia menidia*). No finfish species were collected in

Table 3. Summary of gill net deployments and results (a)

Sampling Location	Net Deployment Date	Net Deployment Time	Net Retrieval Date	Net Retrieval Time	Male Blue Crabs No. of Individuals	Male Blue Crabs Carapace width (cm) Arithmetic Mean	Male Blue Crabs Carapace width (cm) Range	Female Blue Crabs No. of Individuals	Female Blue Crabs Carapace width (cm) Arithmetic Mean	Female Blue Crabs Carapace width (cm) Range
Station 1	8/10/94	9:20	8/10/94	16:30	8	14.1	12.0 - 16.8	4	12.4	11.0 - 14.0
Station 1	8/10/94	16:45	8/11/94	8:45	14	13.8	5.5 - 17.5	4	11.6	11.5 - 12.0
Station 3	8/10/94	9:55	8/10/94	15:30	1	15.5 (b)	15.5 (b)	4	11.4	10.0 - 12.0
Station 3	8/10/94	16:05	8/11/94	10:30	0	NA (c)	NA	0	NA	NA
Station 6	8/11/94	10:00	8/11/94	13:50	0	NA	NA	0	NA	NA
				Total	23	14	5.5 - 17.5	12	11.8	10.0 - 14.0

a. Blue crabs were the only species caught in the gill nets.
b. Arithmetic mean and range based on one individual.
c. NA - Not applicable. Nets were destroyed by trash and debris in the River, therefore, no organisms were collected.

the gill nets. Carp were observed near Station 6, confirming the presence of larger finfish in the upper reaches of the Study Area.

Grain Size

The percent grain size distributions are summarized in Table 4, and the grain size distribution curves are presented in Appendix C. In general, samples tended to be predominantly comprised of fine grained materials (i.e. silts and clays). Only samples from Stations 3 and 4 contained 50 percent or more coarse grained (i.e. sand) materials.

Water Quality Data

Water quality data are presented in Table 5. Dissolved oxygen (DO) levels were very low in the Study Area. In bottom waters, DO levels ranged from 2.2 mg/l near the upstream end of the Study Area, to 5.1 mg/l at Station 2. Surface water DO was nearly uniform throughout the Study Area, ranging from 4.6 mg/l to 5.8 mg/l. Water temperatures were nearly uniform throughout the water column and Study Area, ranging from 23.0°C to 25.0°C. Conductivity ranged from 80 μmho/cm^2 (x100) at Station 6 to 305 μmho/cm^2 (x100) at Station 5. At more downstream stations of the Study Area (i.e. Stations 1 through 4), salinity ranged from 13.5 ppth to 20.0 ppth. As would be expected, salinity tended to be lower in upstream locations, ranging from 6.0 ppth to 9.0 ppth at Station 6. Salinity and conductivity measured at Station 5 appear relatively high compared to other upstream stations (Table 5). It is important to note that measurements at this station were collected on August 10, using an instrument determined to be operating incorrectly. This instrument was replaced with a correctly operating meter which was used to collect data at the other stations on August 11.

Discussion

As depicted in Figure 3, polychaetes and oligocheates are the dominant benthic invertebrate species found throughout the Study Area, together comprising 68 to 98 percent of all organisms observed at each station. In general, polychaetes are more abundant at more saline downstream locations and oligochaetes are more abundant in upstream (brackish water) locations. Station 2, in which oligochaetes comprised 78 percent of the organisms present, is the only exception to this trend. Aquatic oligochaetes and polychaetes are closely related annelid worms. In general, oligochaetes occur mainly in fresh- to brackish-water environments, while polychaetes inhabit mainly saline

Table 4. Grain size distribution (%)

Station	Clay	Silt	Sand	Gravel
Station 1	25	73	2.0	0.0
Station 2	10	70	20	0.0
Station 3	10	35	55	0.0
Station 4	8.0	22	50	20
Station 5	12	68	20	0.0
Station 6	5.0	40	43	12

Clay - grain size less than 0.004 millimeters
Silt - grain size between 0.004 and 0.0625 millimeters
Sand - grain size between 0.0625 and 2 millimeters
Gravel - grain size between 2 and 256 millimeters

Table 5. Ambient water quality data for Passaic River Study Area, August 1994

Sampling Station	Date	Time	Approx. Tide Height (ft) (a)	Depth (ft)	Temperature (C)	Dissolved Oxygen (mg/l)	Salinity (ppth)	Conductivity (µmho/cm^2 x 100)
1	8/11/94	14:35	4.41	Surface	24.3	5.8	18.0	290
				10	23.5	5.4	19.5	259
				20	23.0	5.0	20.0	253
2	8/11/94	11:10	5.74	Surface	23.8	5.2	17.0	223
				8 (b)	23.8	5.1	18.0	233
3	8/11/94	14:25	4.75	Surface	24.5	4.9	16.0	215
				10	24.0	4.2	17.5	233
				20	24.0	4.2	18.8	248
4	8/11/94	14:16	4.75	Surface	24.5	4.6	13.5	183
				10	24.0	4.2	15.0	195
				20	24.0	3.8	16.3	215
5	8/10/94 (c)	13:15	5.74	Surface	24.3	-	21.2	290
				Bottom (d)	25.0	-	23.0	305
6	8/11/94	13:58	5.23	Surface	25.0	5.1	6.0	80
				10	24.0	3.0	8.5	120
				22	24.0	2.2	9.0	110

a. Represents tide height above mean low water. High tide during the two day survey was at approximately 11:35 (5.96 ft.) on 8/10/94 and at 12:26 (6.03 ft) on 8/11/94.

b. Data only collected at the surface and bottom at Station 2.

c. Data for salinity and conductivity at Station 5 were collected using different instrumentation, and therefore may not be comparable to other stations.

d. Depth not recorded at Station 5

environments (Gosner, 1980). In polyhaline estuarine environments, such as the Study Area, there is some overlap between these organisms as they are both at the extreme limits of their salinity ranges.

The results of this investigation are consistent with the existing data on benthic invertebrates for the Passaic River. In 1981, benthic samples were collected at several locations on the Passaic River, two of which were located within the Study Area (Princeton Aqua Science, 1982). Results for those locations within the Study Area either contained no organisms, or were dominated by oligochaete worms (*Limnodrilus* sp.), one of the species commonly identified in this investigation. An earlier study in the Passaic River found only eight benthic species, three of which were oligocheates (USACOE, 1987). Similarly, Cerrato (1986) found that the polychaete *Streblospio benedicti* was one of the most abundant species in the Newark Bay Estuary.

Values for the Shannon-Weaver Diversity Index, H', ranged from 0.236 to 1.66, indicating that the biological diversity of the benthic invertebrate community within the Study Area is low. Diversity values below 2 are generally considered to be indicative of pollution stress (Stainken, 1984). Indeed, the majority of the species observed during this survey are frequently associated with polluted or degraded environments (Cerrato, 1986).

There are factors other than pollution, particularly in an estuarine environment, that reduce diversity, including changes in grain size, salinity, and temperature (Cerrato, 1986; Cristini, 1990). For example, species preferences for varying substrate types (i.e. sandy versus muddy) can influence species distribution. Changes in grain size were observed among the sampling locations in the Study Area (Table 4; Appendix C). Grain sizes at Stations 3 and 4 were much more evenly distributed among fine and coarse grained material than at other stations; it is interesting to note that these Stations were also found to have the highest Shannon-Weaver Diversity Index values. In general, samples at other stations were composed predominantly of fine grained materials (i.e. silts or clays). Salinity gradients can also influence species distribution. It is likely that changes in salinity between upstream and downstream sampling locations (Table 5) contribute to the observed shift in dominance from oligochaetes to polychaetes at these stations, as previously discussed.

Based on the data collected in the survey, mummichogs (*Fundulus heteroclitus*) appear to be one of the dominant finfish species present in the Study Area. Based on visual observations, carp are also abundant in the upper reach (mile 6) of the Study Area. The identification of mummichog and carp as dominant species is consistent with the results of earlier surveys (Princeton Aqua Science, 1982; Belton et al., 1985; USACOE, 1987). Both of these species are frequently associated with polluted or degraded environments.

Sediments in the Study Area are known to be contaminated with a wide variety of chemicals (Olsen et al., 1984; Belton et al., 1985; Pruell et al., 1990; Bopp et al., 1991; Rappe et al., 1991; Squibb et al., 1991; Bonnevie et al., 1992, 1993, 1994; Gillis et al., 1993; Huntley et al., 1993; Wenning et al., 1994). Furthermore, it is clear that degraded water quality, likely due to significant, continuing municipal and industrial discharges (ISC, 1988; Killiam, 1983), is also a severely limiting factor to biological diversity in the Study Area. Impacted water quality parameters, such as depressed levels of DO, can adversely fish and benthic communities by inhibiting growth, decreasing survival rates, and increasing competition (Stacey, 1990). Low DO concentrations have also been found to result in reduced species abundance and diversity (Boesch and Rosenburg, 1981; Keller and Squibb, 1992). In general, 5 mg/l is considered to be the minimum level for satisfying the oxygen requirements of most fish (Everhart and Youngs, 1981). In addition, more mobile and migratory species tend to avoid areas with DO concentrations below 3 mg/l (Keller and Squibb, 1992).

Despite reports of recent improvements in DO levels in other portions of the Passaic River (Mytelka et al., 1981), the data collected in this investigation suggest that mid-summer DO levels within the Study Area are below those that are considered tolerable to most aquatic species. Dissolved oxygen concentrations measured during this survey were all at or below minimally acceptable levels (Table 5). This indicates that conditions may be stressful even for the pollution-tolerant species that inhabit the Study Area.

In addition to direct discharge of wastes to water and sediments in the Estuary, the industrial and urban activity within the region has severely reduced the natural habitats available for indigenous and migratory biota (Wallace et al., 1983; Squires and Barclay, 1990; Burger et al., 1993; Crawford et al., 1994). Currently, approximately 75 percent of the original tidal marsh and wetland areas in the estuary have been filled or dredged, while the majority of those remaining

have been significantly altered by a variety of human activities (Squires and Barclay, 1990). In addition, much effort has been directed towards stabilizing river banks, or redirecting water flow through the construction of dikes or dams, causing alterations in erosion and sedimentation patterns (Squires, 1992). Dredging activities and channel improvements, which began in 1874 (USACOE, 1988), have also continued the alteration of ecological conditions in the Passaic River and surrounding areas (Wallace et al., 1983; Burger et al., 1993).

Conclusions

Overall, the results of this investigation are consistent with the limited historical data for the area. Various aquatic species such as grass shrimp (*Palaemonetes pugio*), mummichog (*Fundulus heteroclitus*), Atlantic silversides (*Menidia menidia*), and blue crab (*Callinectes sapidus*) were identified. The benthic invertebrate communities in the Study Area were found to be comprised predominantly of pollution-tolerant oligochaetes and polychaetes. Calculated indices of diversity and abundance were low, probably as a result of degraded water quality and the presence of a wide range of sediment contaminants. Variations in salinity were believed to be responsible for the observed shift from polychaetes to oligochaetes in more upstream sampling locations.

The fact that no large finfish were caught in this investigation is due to a combination of the low abundance and diversity of finfish in the Study Area and the site-specific problems encountered in fishing with gill nets. The latter were attributed to the large amount of trash and debris in the Passaic River that diminished the effectiveness of the first three net deployments and destroyed the nets during the last two deployments.

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APPENDIX A

PHOTOGRAPHIC RECORD
OF
BENTHIC SAMPLING STATIONS

Appendix B

Benthic Invertebrate Data

Benthic Macroinvertebrates collected from the Passaic River Estuary.

Location and Cell No. : S01 Collection Date : 08/11/94 Sampler : Petite Ponar Grab

Taxon	Replicate No. 1 No. of Indiv.	Replicate No. 2 No. of Indiv.	Replicate No. 3 No. of Indiv.	Mean Number per Sq Meter (Standard Error)
Annelida				
Oligochaeta				
Tubificidae	1	0	0	14.5 (14.5)
Polychaeta				
Eteone heteropoda	0	1	1	29.0 (14.5)
Scolecolepides viridis	0	0	1	14.5 (14.5)
Scoloplos sp.	1	0	0	14.5 (14.5)
Streblospio benedicti	13	72	52	1985.5 (753.2)
Arthropoda				
Crustacea				
Leucon americanus	0	2	2	58.0 (29.0)
Mollusca				
Bivalvia				
Veneroida	1	0	0	14.5 (14.5)
Total	16	75	56	2130.4 (756.0)

Benthic Macroinvertebrates collected from the Passaic River Estuary.

Location and Cell No. : S02 Collection Date : 08/11/94 Sampler : Petite Ponar Grab

Taxon	Replicate No. 1 No. of Indiv.	Replicate No. 2 No. of Indiv.	Replicate No. 3 No. of Indiv.	Mean Number per Sq Meter (Standard Error)
Annelida				
Oligochaeta				
Tubificidae	26	44	8	1130.4 (451.8)
Polychaeta				
Streblospio benedicti	6	3	0	130.4 (75.3)
Arthropoda				
Crustacea				
Leucon americanus	3	9	0	173.9 (115.0)
Rithropanopeus harrisii	1	0	0	14.5 (14.5)
Total	36	56	8	1449.3 (605.2)

Benthic Macroinvertebrates collected from the Passaic River Estuary.

Location and Cell No. : S03 Collection Date : 08/10/94 Sampler : Petite Ponar Grab

Taxon	Replicate No. 1 No. of Indiv.	Replicate No. 2 No. of Indiv.	Replicate No. 3 No. of Indiv.	Mean Number per Sq Meter (Standard Error)
Annelida				
Oligochaeta				
Tubificidae	0	0	11	159.4 (159.4)
Polychaeta				
Hypaniola grayi	65	0	0	942.0 (942.0)
Laeonereis culveri	8	5	1	202.9 (88.2)
Scolecolepides viridis	1	9	1	159.4 (115.9)
Streblospio benedicti	0	0	20	289.9 (289.9)
Arthropoda				
Crustacea				
Cyathura polita	13	4	5	318.8 (123.8)
Rithropanopeus harrisii	0	3	0	43.5 (43.5)
Mollusca				
Bivalvia				
Veneroida	2	0	0	29.0 (29.0)
Total	89	21	38	2144.9 (888.3)

Benthic Macroinvertebrates collected from the Passaic River Estuary.

Location and Cell No. : S04 Collection Date : 08/10/94 Sampler : Petite Ponar Grab

Taxon	Replicate No. 1 No. of Indiv.	Replicate No. 2 No. of Indiv.	Replicate No. 3 No. of Indiv.	Mean Number per Sq Meter (Standard Error)
Annelida				
Oligochaeta				
Tubificidae	6	0	6	173.9 (87.0)
Polychaeta				
Scolecolepides viridis	14	2	2	260.9 (173.9)
Arthropoda				
Crustacea				
Cyathura polita	2	0	0	29.0 (29.0)
Leucon americanus	0	0	1	14.5 (14.5)
Rithropanopeus harrisii	2	6	2	144.9 (58.0)
Mollusca				
Bivalvia				
Mytilopsis leucophaeata	0	1	0	14.5 (14.5)
Total	24	9	11	637.7 (204.4)

Benthic Macroinvertebrates collected from the Passaic River Estuary.

Location and Cell No. : S05 Collection Date : 08/10/94 Sampler : Petite Ponar Grab

Taxon	Replicate No. 1 No. of Indiv.	Replicate No. 2 No. of Indiv.	Replicate No. 3 No. of Indiv.	Mean Number per Sq Meter (Standard Error)
Annelida				
Oligochaeta				
Limnodrilus hoffmeisteri	517	294	213	14840.6 (3951.8)
Polychaeta				
Hypaniola grayi	10	4	7	304.3 (75.3)
Scolecolepides viridis	0	0	1	14.5 (14.5)
Streblospio benedicti	5	0	0	72.5 (72.5)
Arthropoda				
Crustacea				
Cyathura polita	3	2	4	130.4 (25.1)
Edotea triloba	3	0	1	58.0 (38.3)
Rithropanopeus harrisii	0	0	5	72.5 (72.5)
Total	538	300	231	15492.8 (4043.1)

Benthic Macroinvertebrates collected from the Passaic River Estuary.

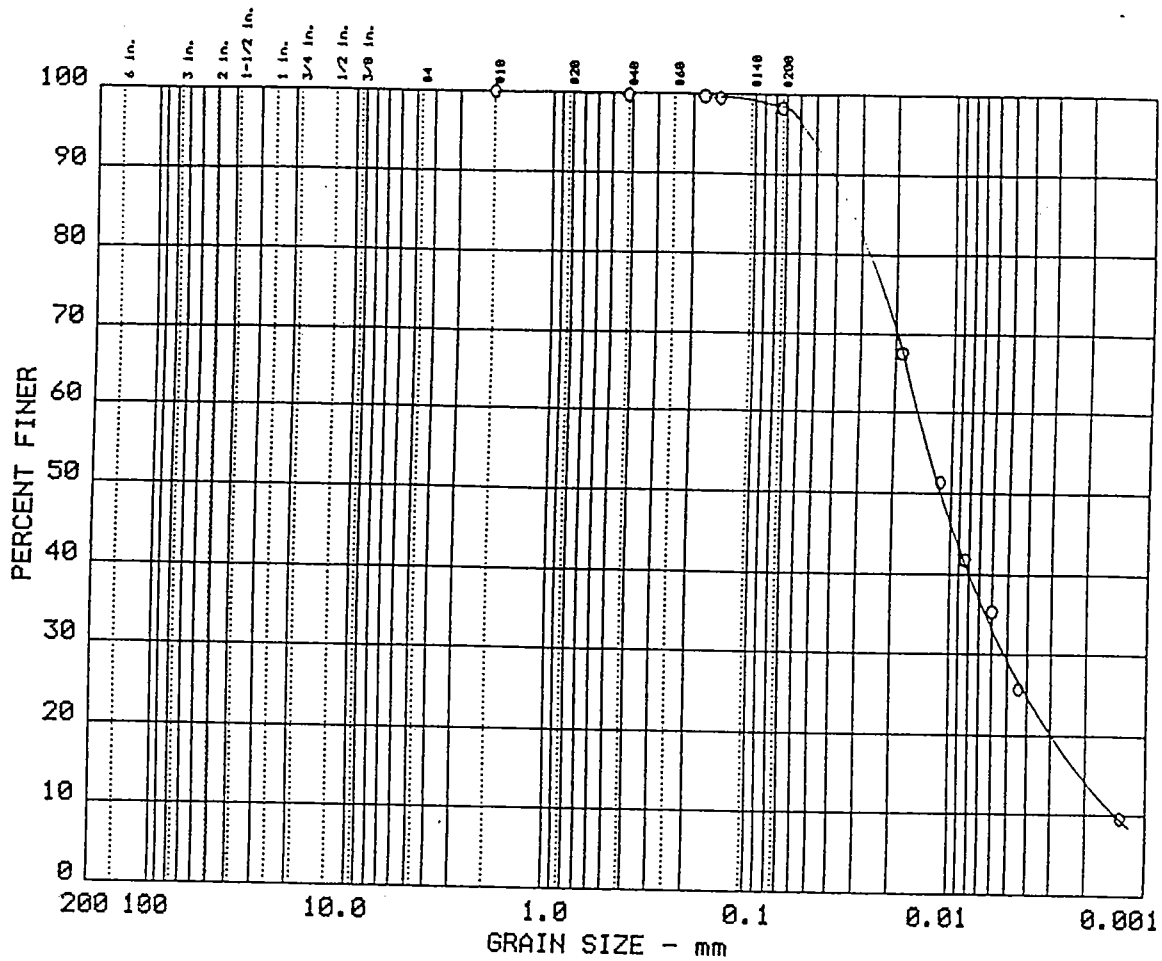
Location and Cell No. : S06 Collection Date : 08/10/94 Sampler : Petite Ponar Grab

Taxon	Replicate No. 1 No. of Indiv.	Replicate No. 2 No. of Indiv.	Replicate No. 3 No. of Indiv.	Mean Number per Sq Meter (Standard Error)
Annelida				
Oligochaeta				
Limnodrilus hoffmeisteri	85	19	220	4695.7 (2571.8)
Polychaeta				
Hypaniola grayi	5	4	5	202.9 (14.5)
Scolecolepides viridis	0	0	1	14.5 (14.5)
Arthropoda				
Crustacea				
Cyathura polita	4	4	1	130.4 (43.5)
Edotea triloba	1	1	3	72.5 (29.0)
Gammaridae	0	1	2	43.5 (25.1)
Leucon americanus	0	0	1	14.5 (14.5)
Rithropanopeus harrisii	0	1	0	14.5 (14.5)
Insecta				
Procladius sp.	0	0	2	29.0 (29.0)
Total	95	30	235	5217.4 (2629.7)

APPENDIX C

GRAIN SIZE ANALYSIS DATA

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
O					

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O										

	MATERIAL DESCRIPTION	USCS	AASHTO
O			

Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER
O Location: S01

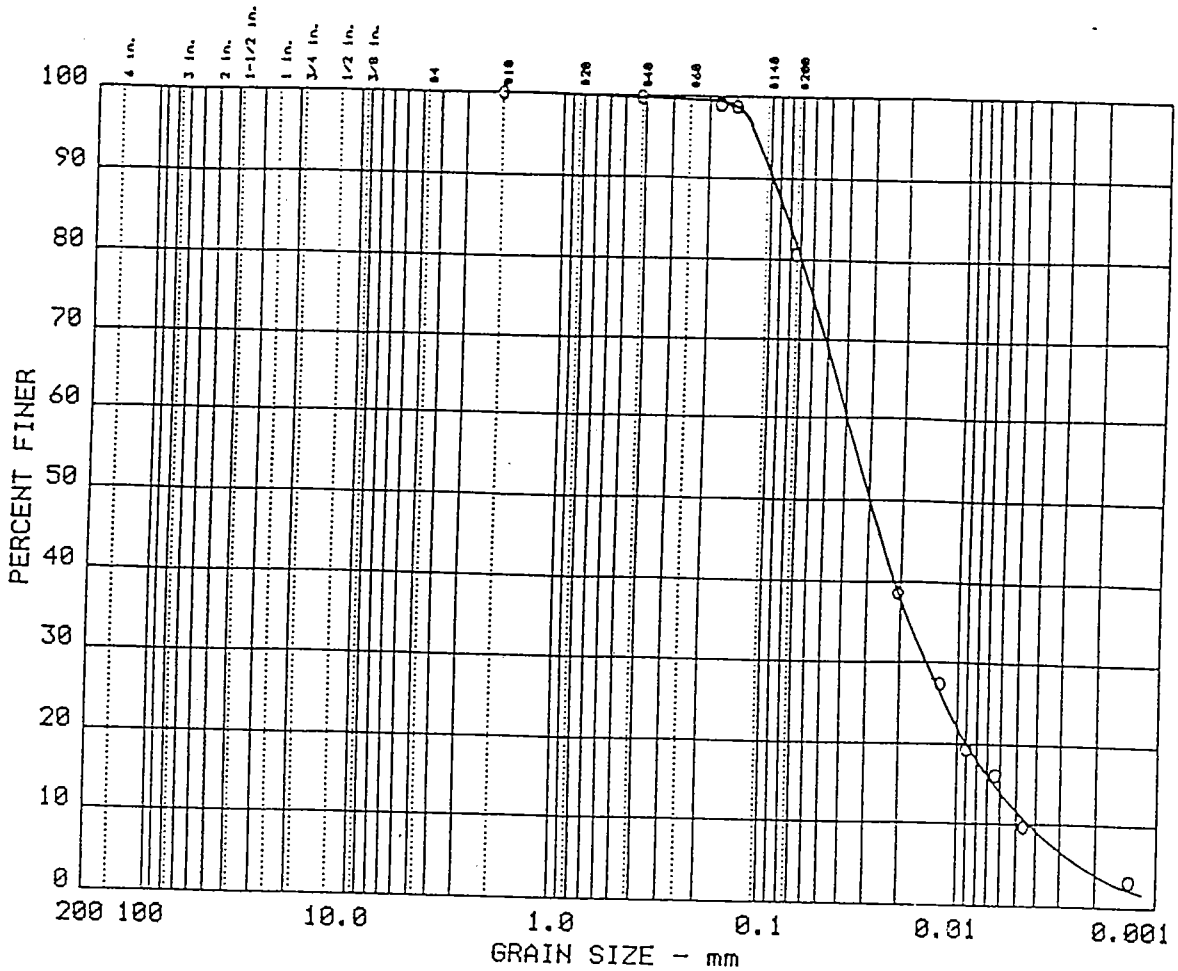
Date: 9-06-1994

LESNY & KITLINSKI ASSOCIATES

Remarks:

Figure No.

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
O					

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O										

	MATERIAL DESCRIPTION	USCS	AASHTO
O			

Project No.: 94-08-1265
Project: RMC PROJECTS NO. 04972/03 PASSAIC RIVER
O Location: S02

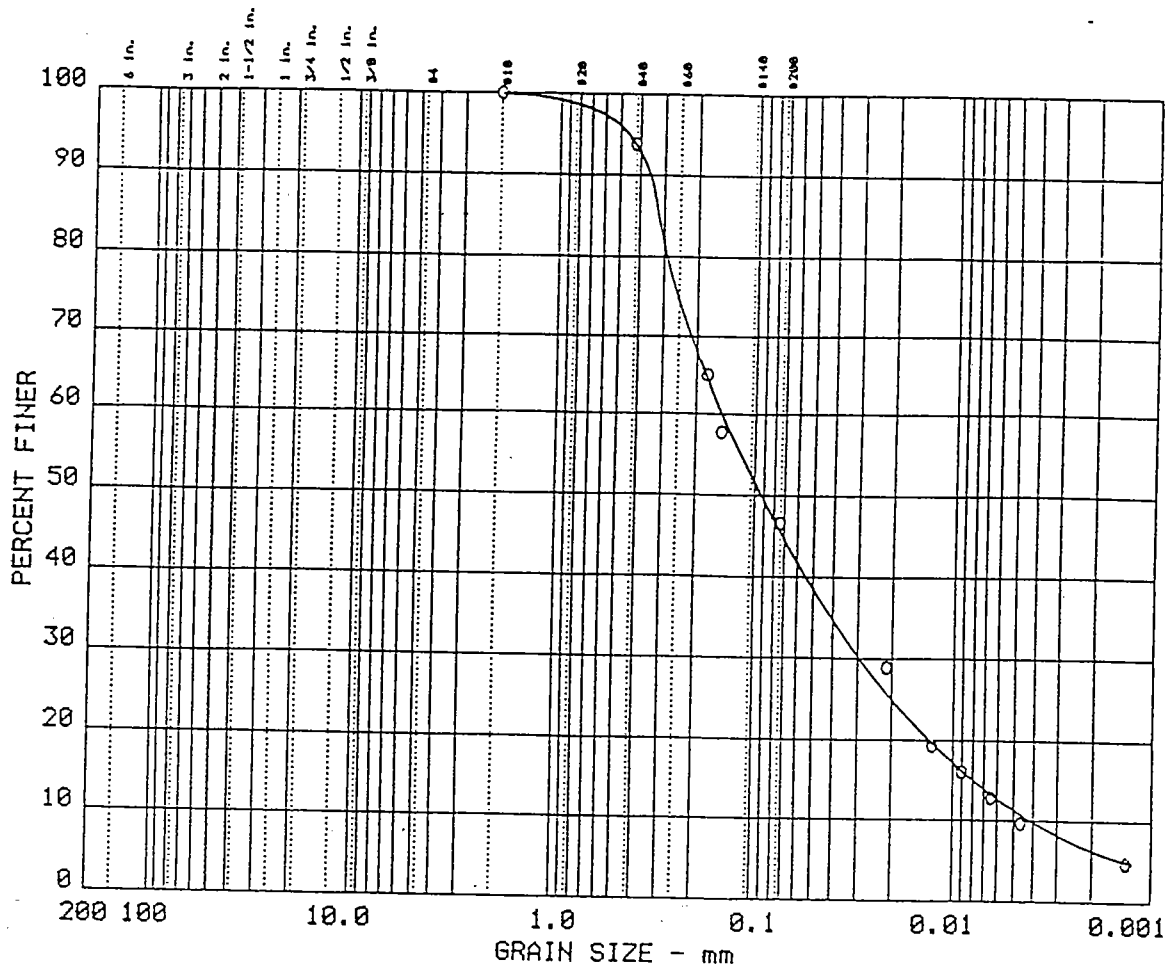
Date: 9-06-94

Remarks:

LESNY & KITLINSKI ASSOCIATES

Figure No.

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75_	% GRAVEL	% SAND	% SILT	% CLAY
O					

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O										

MATERIAL DESCRIPTION	USCS	AASHTO
O		

Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER
O Location: S03

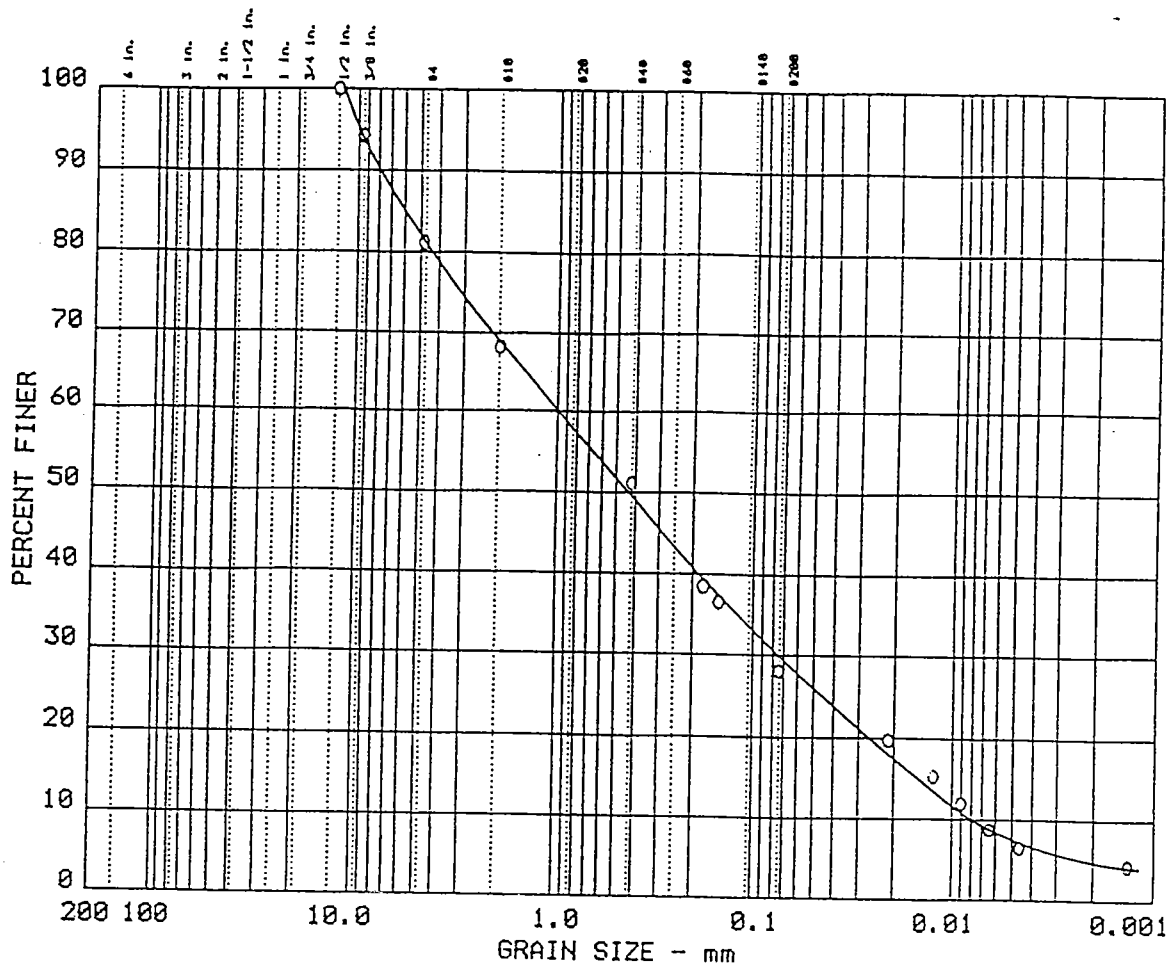
Date: 9-06-1994

LESNY & KITLINSKI ASSOCIATES

Remarks:

Figure No.

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
O					

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O										

MATERIAL DESCRIPTION	USCS	AASHTO
O		

Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER
O Location: S04

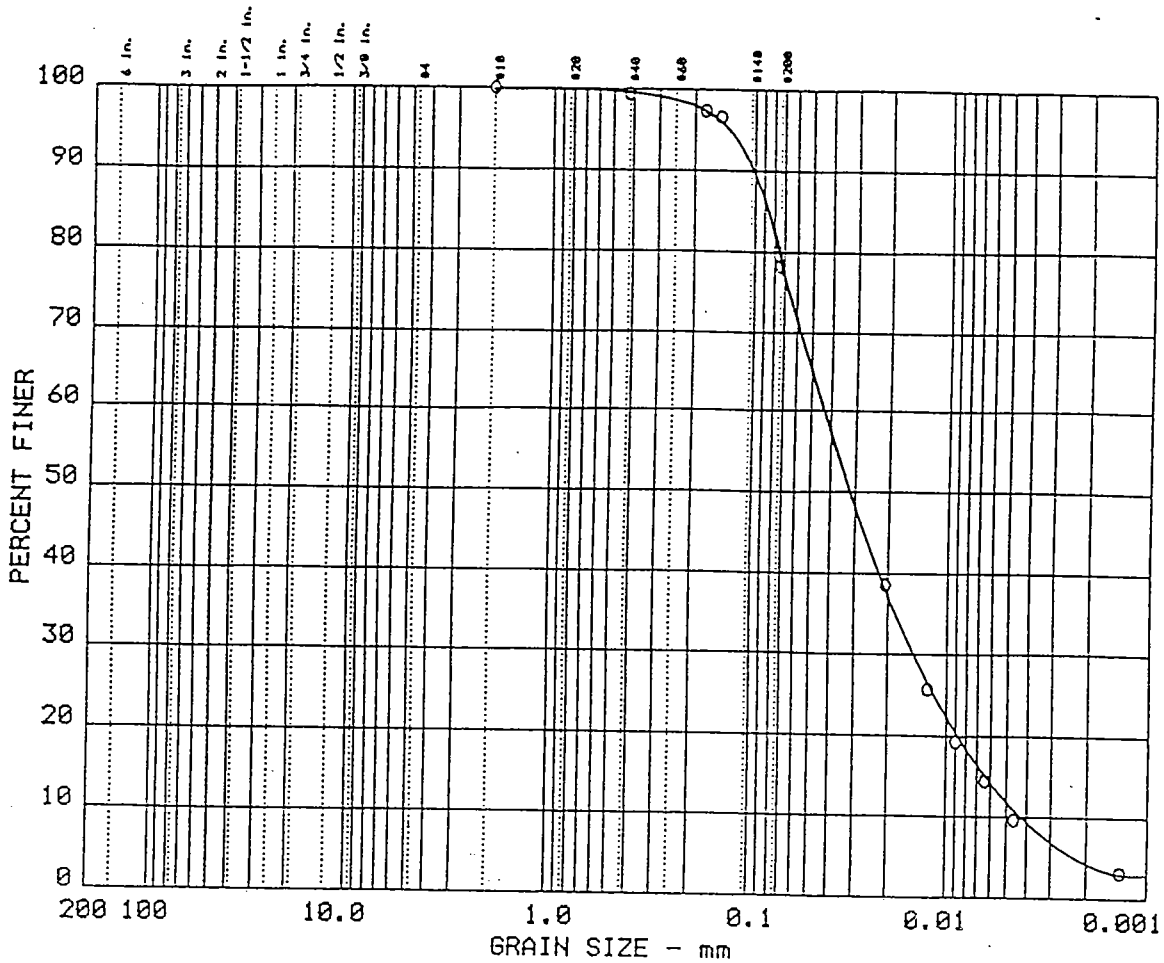
Date: 9-06-1994

LESNY & KITLINSKI ASSOCIATES

Remarks:

Figure No.

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75	% GRAVEL	% SAND	% SILT	% CLAY
O					

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O										

	MATERIAL DESCRIPTION	USCS	AASHTO
O			

Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER
O Location: S05

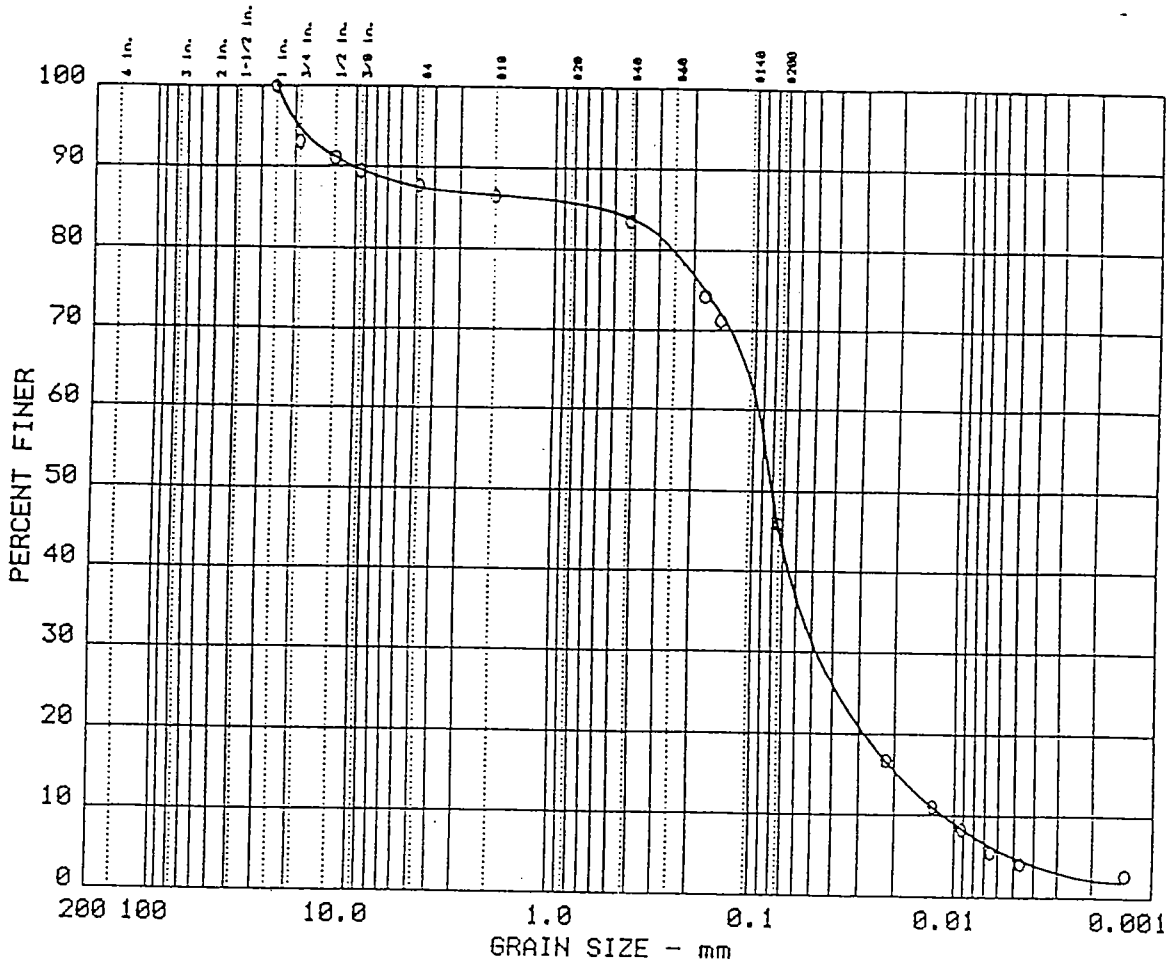
Date: 9-06-1994

LESNY & KITLINSKI ASSOCIATES

Remarks:

Figure No.

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
O					

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O										

	MATERIAL DESCRIPTION	USCS	AASHTO
O			

Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER
O Location: S06

Date: 9-06-1994

LESNY & KITLINSKI ASSOCIATES

Remarks:

Figure No.

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 8

Date: 9-06-1994
Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER

Sample Data

Location of Sample: S01
Sample Description:
USCS Class: Liquid limit:
AASHTO Class: Plasticity index:

Notes

Remarks:

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 50.00
Tare = 0.00
Dry sample weight = 50.00
Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 10	0.00	0.00	100.0
# 40	0.10	0.00	99.8
# 80	0.05	0.00	99.7
# 100	0.10	0.00	99.5
# 200	0.60	0.00	98.3

Hydrometer Analysis Data

eparation sieve is number 10
ercent -# 10 based on complete sample= 100.0
eight of hydrometer sample: 50
alculated biased weight= 50.00
able of composite correction values:
Temp, deg C: 22.2
Comp. corr: - 4.0
eniscus correction only= 0
pecific gravity of solids= 2.65
pecific gravity correction factor= 1.000
ydrometer type: 151H Effective depth L= 16.294964 - 0.2645 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
5.0	22.2	1.0250	1.0210	0.0133	25.0	9.7	0.0185	67.5
15.0	22.2	1.0200	1.0160	0.0133	20.0	11.0	0.0114	51.4
30.0	22.2	1.0170	1.0130	0.0133	17.0	11.8	0.0083	41.8
60.0	22.2	1.0150	1.0110	0.0133	15.0	12.3	0.0060	35.3
120.0	22.2	1.0120	1.0080	0.0133	12.0	13.1	0.0044	25.7
1440.0	22.2	1.0070	1.0030	0.0133	7.0	14.4	0.0013	9.6

GRAIN SIZE DISTRIBUTION TEST DATA — Test No.: 6

Date: 9-06-94
Project No.: 94-08-1265
Project: RMC PROJECTS NO. 04972/03 PASSAIC RIVER

Sample Data

Location of Sample: S02
Sample Description:
USCS Class: Liquid limit:
AASHTO Class: Plasticity index:

Notes

Remarks:

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 50.00
Tare = 0.00
Dry sample weight = 50.00
Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 10	0.00	0.00	100.0
# 40	0.10	0.00	99.8
# 80	0.40	0.00	99.0
# 100	0.10	0.00	98.8
# 200	9.10	0.00	80.6

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Table of composite correction values:
Temp, deg C: 22.2
Comp. corr: - 4.0
Meniscus correction only= 0
Specific gravity of solids= 2.65
Specific gravity correction factor= 1.000
Hydrometer type: 151H Effective depth L= 16.294964 - 0.2645 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
5.0	22.2	1.0160	1.0120	0.0133	16.0	12.1	0.0206	38.5
15.0	22.2	1.0125	1.0085	0.0133	12.5	13.0	0.0124	27.3
30.0	22.2	1.0100	1.0060	0.0133	10.0	13.6	0.0090	19.3
60.0	22.2	1.0090	1.0050	0.0133	9.0	13.9	0.0064	16.1
120.0	22.2	1.0070	1.0030	0.0133	7.0	14.4	0.0046	9.6
1440.0	22.2	1.0050	1.0010	0.0133	5.0	15.0	0.0014	3.2

GRAIN SIZE DISTRIBUTION TEST DATA — Test No.: 12

Date: 9-06-1994
Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER

Sample Data

Location of Sample: S03
Sample Description:
USCS Class: Liquid limit:
AASHTO Class: Plasticity index:

Notes

Remarks:

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	50.00
Tare =	0.00
Dry sample weight =	50.00

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 10	0.00	0.00	100.0
# 40	3.10	0.00	93.8
# 80	14.40	0.00	65.0
# 100	3.60	0.00	57.8
# 200	5.60	0.00	46.6

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Table of composite correction values:
Temp, deg C: 22.2
Comp. corr: - 4.0
Meniscus correction only= 0
Specific gravity of solids= 2.65
Specific gravity correction factor= 1.000
Hydrometer type: 151H Effective depth L= 16.294964 - 0.2645 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
5.0	22.2	1.0130	1.0090	0.0133	13.0	12.9	0.0213	28.9
15.0	22.2	1.0100	1.0060	0.0133	10.0	13.6	0.0127	19.3
30.0	22.2	1.0090	1.0050	0.0133	9.0	13.9	0.0091	16.1
60.0	22.2	1.0080	1.0040	0.0133	8.0	14.2	0.0065	12.8
120.0	22.2	1.0070	1.0030	0.0133	7.0	14.4	0.0046	9.6
1440.0	22.2	1.0055	1.0015	0.0133	5.5	14.8	0.0013	4.8

GRAIN SIZE DISTRIBUTION TEST DATA — Test No.: 9

Date: 9-06-1994
Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER

Sample Data

Location of Sample: S04
Sample Description:
USCS Class: Liquid limit:
AASHTO Class: Plasticity index:

Notes

Remarks:

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 121.30
Tare = 0.00
Dry sample weight = 121.30
Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
0.5 inches	0.00	0.00	100.0
0.375 inches	7.00	0.00	94.2
# 4	15.80	0.00	81.2
# 10	15.90	0.00	68.1
# 40	12.40	0.00	51.2
# 80	9.40	0.00	38.4
# 100	1.40	0.00	36.5
# 200	6.20	0.00	28.1

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 68.1
Weight of hydrometer sample: 50
Calculated biased weight= 73.43
Table of composite correction values:
Temp, deg C: 22.2
Comp. corr: - 4.0
Meniscus correction only= 0
Specific gravity of solids= 2.65
Specific gravity correction factor= 1.000
Hydrometer type: 151H Effective depth L= 16.294964 - 0.2645 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
5.0	22.2	1.0130	1.0090	0.0133	13.0	12.9	0.0213	19.7
15.0	22.2	1.0110	1.0070	0.0133	11.0	13.4	0.0126	15.3
30.0	22.2	1.0095	1.0055	0.0133	9.5	13.8	0.0090	12.0
60.0	22.2	1.0080	1.0040	0.0133	8.0	14.2	0.0065	8.7
120.0	22.2	1.0070	1.0030	0.0133	7.0	14.4	0.0046	6.6
1440.0	22.2	1.0060	1.0020	0.0133	6.0	14.7	0.0013	4.4

GRAIN SIZE DISTRIBUTION TEST DATA — Test No.: 10

Date: 9-06-1994
Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER

Sample Data

Location of Sample: S05
Sample Description:
USCS Class: Liquid limit:
AASHTO Class: Plasticity index:

Notes

Remarks:

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 50.00
Tare = 0.00
Dry sample weight = 50.00
Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 10	0.00	0.00	100.0
# 40	0.30	0.00	99.4
# 80	1.00	0.00	97.4
# 100	0.40	0.00	96.6
# 200	9.10	0.00	78.4

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Table of composite correction values:
Temp, deg C: 22.2
Comp. corr: - 4.0
Meniscus correction only= 0
Specific gravity of solids= 2.65
Specific gravity correction factor= 1.000
Hydrometer type: 151H Effective depth L= 16.294964 - 0.2645 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
5.0	22.2	1.0160	1.0120	0.0133	16.0	12.1	0.0206	38.5
15.0	22.2	1.0120	1.0080	0.0133	12.0	13.1	0.0124	25.7
30.0	22.2	1.0100	1.0060	0.0133	10.0	13.6	0.0090	19.3
60.0	22.2	1.0085	1.0045	0.0133	8.5	14.0	0.0064	14.5
120.0	22.2	1.0070	1.0030	0.0133	7.0	14.4	0.0046	9.6
1440.0	22.2	1.0050	1.0010	0.0133	5.0	15.0	0.0014	3.2

Date: 9-06-1994
Project No.: 94-08-1265
Project: RMC PROJECT NO. 04972/03 PASSAIC RIVER

Sample Data

Location of Sample: S06
Sample Description:
USCS Class: Liquid limit:
AASHTO Class: Plasticity index:

Notes

Remarks:

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 149.30
Tare = 0.00
Dry sample weight = 149.30
Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
1 inches	0.00	0.00	100.0
0.75 inches	10.40	0.00	93.0
0.5 inches	3.00	0.00	91.0
0.375 inches	2.40	0.00	89.4
# 4	2.60	0.00	87.7
# 10	1.80	0.00	86.5
# 40	1.70	0.00	83.5
# 80	5.40	0.00	74.2
# 100	1.80	0.00	71.1
# 200	14.60	0.00	45.8

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 86.5
Weight of hydrometer sample: 50
Calculated biased weight= 57.82
Table of composite correction values:
Temp, deg C: 22.2
Comp. corr: - 4.0
Meniscus correction only= 0
Specific gravity of solids= 2.65
Specific gravity correction factor= 1.000
Hydrometer type: 151H Effective depth L= 16.294964 - 0.2645 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
5.0	22.2	1.0100	1.0060	0.0133	10.0	13.6	0.0220	16.7
15.0	22.2	1.0080	1.0040	0.0133	8.0	14.2	0.0129	11.1
30.0	22.2	1.0070	1.0030	0.0133	7.0	14.4	0.0092	8.3
60.0	22.2	1.0060	1.0020	0.0133	6.0	14.7	0.0066	5.6
120.0	22.2	1.0055	1.0015	0.0133	5.5	14.8	0.0047	4.2
1440.0	22.2	1.0050	1.0010	0.0133	5.0	15.0	0.0014	2.8