United States
Environmental
Protection Agency

Office of Water
AWPD (WH-553)
Washington, DC 20460

EPA 841-F-92-001
August 1992

EPA

Water Quality Progress Reports
Water Quality Program Highlights

Water Quality Progress Reports	Water Quality Program Highlights
Horse Creek, South Carolina .... January 1985	New York State's Wasteload Allocation Procedure .... April 1986
Lower Fox River, Wisconsin ...... June 1985	The Deleware River Cooperative Monitoring Program .... July 1986
Flint River, Michigan .... August 1985	Arkansas' Ecoregion Program . September 1986
Housatonic River, Connecticut ... January 1986	EPA's National Dioxin Study . November 1986
Upper Potomac Estuary Washington, DC, Virginia, and Maryland .... March 1986	The Massachusetts Fish Toxics Monitoring Program .... January 1987
Upper Trinity River, Texas .... July 1986	Maine's Biologically Based Water Quality Standards .... April 1988
Tillamook Bay, Oregon .... August 1986	Minnesota's Nonpoint Source Assessment Program .... May 1988
Passaic River, New Jersey ..... October 1986	Ohio EPA's Use of Biological Survey Information .... May 1990
Koshkonong Creek, Wisconsin .. February 1987	Multimedia Toxics Study of the Calcasieu River Estuary, Louisiana .... March 1991
Whitewood Creek, South Dakota ... June 1987	Eutrophication Management in North Carolina .... May 1991
Duwamish River, Washington ..... April 1991	Florida's Method for Assessing Metals Contamination in Estuarine Sediments .... June 1991

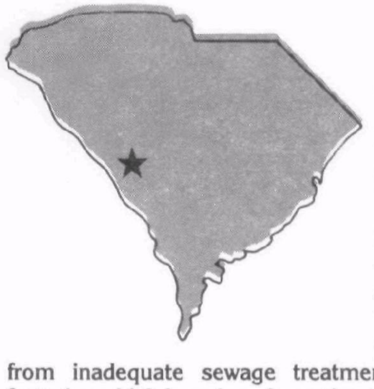
United States
Environmental
Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

January 1985

EPA

Water Quality Progress Report



Horse Creek, South Carolina

Horse Creek is a tributary of the Savannah River on the South Carolina side. By 1970 it had succumbed to point source discharges from inadequate sewage treatment plants and the textile factories which have long been the region's economic mainstay. The stream and its tributaries were murky, discolored, and deadly; sections were devoid of fish and insects. Langley Pond, a manmade impoundment of Horse Creek, was virtually lifeless. Water quality professionals acknowledged Horse Creek as one of the most polluted streams in the southeast.

Today there are no significant point source discharges to Horse Creek. The stream runs clear and has become a community resource instead of a drawback. Although problems that had their start almost a century ago have not been completely eradicated, progress has been dramatic and satisfying.

This report discusses the efforts to rehabilitate a once "dead" stream, the monitoring efforts that defined the extent of the damage and the rehabilitation, and the role of monitoring in Horse Creek's future.

ASSESSING THE PROBLEM

As a major tributary of the Savannah River, Horse Creek was part of a 1970 study by the Environmental Protection Agency (EPA) which documented water quality on the Savannah's middle stretch. At that time, the major discharge sources on Horse Creek and its tributaries were two municipal sewage treatment plants and the mills and plants of two textile companies. Of the combined discharges and their effects on Horse Creek and the Savannah River, the study found that:

- About 55,000 pounds per day of BOD_5 (five-day biochemical oxygen demand) were being discharged into Horse Creek, significantly depleting the creek's oxygen resources. This is roughly the daily equivalent of raw, untreated sewage from a city of 325,000 people.
- Sediments in the creek contained 990 milligrams per kilogram (mg/kg) of chromium, a metal that is toxic to fish and other aquatic organisms and at the time was a component of textile dyes.
- Fecal coliform densities in Horse Creek and its tributaries ranged from 500,000 to over 16 million colonies per 100 milliliters (ml).
- The creek was biologically "dead," with no living macroinvertebrate organisms for at least 1.6 miles upstream from its confluence with the Savannah River.

Following this study, EPA recommended that:

- The textile operations eliminate all chromium discharges to the creek.
- South Carolina, in cooperation with EPA, establish discharge limits for Horse Creek industrial and municipal waste sources.
- A feasibility study be conducted for a waste collection system and centralized waste treatment facility for the entire Horse Creek basin.

A 1972-73 Governor's Study conducted by the State of South Carolina corroborated these findings and reached similar conclusions.

INSTITUTING CONTROLS

In 1973 the Aiken County Board of Commissioners contracted with an engineering firm to study alternatives for wastewater treatment within the basin and to determine the most effective treatment for combined industrial and municipal use. The firm recommended a regional treatment facility with a 20 million-gallons-per-day (mgd) capacity, expandable to 40 mgd, and an extended aeration activated sludge process which their studies had shown was most effective in treating textile wastes. Construction of the new facility began in 1977 under the jurisdiction of the newly established Aiken County Public Service Authority, and was completed late in 1979. This plant now serves the basin's municipalities and industries, discharging treated effluent directly to the Savannah River.

MONITORING FOR RESULTS

In 1979, the South Carolina Department of Health and Environmental Control (SC-DHEC) expanded its trend monitoring program for Horse Creek in order to thoroughly document physical, chemical, and bacteriological water quality conditions before, during and after start-up of the new wastewater treatment plant. Secondary stations, sampling monthly from May through October, were upgraded to primary stations, sampling monthly all year around. Heavy metals sampling was continued on a quarterly basis, and sediments were sampled once a year. All monitoring data was entered into STORET, EPA's computerized data base system for the storage and retrieval of water quality data.

WATER QUALITY IMPROVEMENTS

The Horse Creek wastewater treatment plant virtually eliminated discharges to Horse Creek. As expected, following its start-up in 1979, water quality in the creek showed dramatic improvement as documented by 1982 monitoring data compared to the 1970 EPA findings.

Oxygen. In July 1970, dissolved oxygen (DO) levels in Horse Creek measured less than 2.0 mg/l; Langley Pond contained *no* measurable amounts of DO. (South Carolina water quality standards require an average of 5.0 mg/l of DO to maintain a healthy aquatic habitat.) The 1982 data show oxygen concentrations from 6.7 mg/l to 8.2 mg/l at the sampling stations on Horse Creek. By September 1982, the BOD_5 concentration in the creek had dropped to less than 2.0 mg/l from nearly 30 mg/l in 1970.

pH. Horse Creek is classified for fish and wildlife propagation; South Carolina water quality standards require streams with this classification to maintain a pH between 6.0 and 8.5. In 1970 pH values ranged from 9.3 to 11.6 due to alkaline discharges from the textile processing plants. Following construction of the Horse Creek facility, the stream pH levels dropped to a range of 6.0 to 7.8, the normal range for a healthy stream system.

Chromium. Four of the textile plants contributed most of the chromium discharged into the creek; one plant, which used large amounts of chromium in its dyeing processes, discharged 865 pounds per day. During the 1970 EPA study the chromium concentration in the water at one sampling station was 440 $\mu g/l$ and in the sediment, 990 mg/kg. In 1976 EPA recommended a stream criterion of 100 $\mu g/l$ to protect freshwater aquatic life. By 1982 chromium concentrations in the creek were below detection limits (<50 $\mu g/l$).

Bacteria. During the 1970 study, the two sewage treatment plants were contributing fecal coliform densities to Horse Creek and its tributaries ranging from 500,000 to over 16 million colonies per 100 ml. *Salmonella* bacteria, a genera that is pathogenic to both humans and animals, were isolated in the poorly treated domestic waste of the old plants and in the creek. In 1982, following the removal of these discharges from the creek to the new regional facility, fecal coliform densities in the creek dropped to 200 to 400 colonies per 100 ml, well within the state's limit of 1,000/100 ml. No *Salmonella* were found.

BIOLOGICAL MONITORING PROGRAM

The 1970 EPA study found Horse Creek biologically dead and it remained so until after the regional facility eliminated point source discharges. In 1979 South Carolina added biological monitoring to its stepped-up monitoring program in order to track the anticipated recovery of aquatic life when water quality improvements due to the new treatment plant were realized. Monitoring was done at the existing stations and at a new station on Langley Pond.

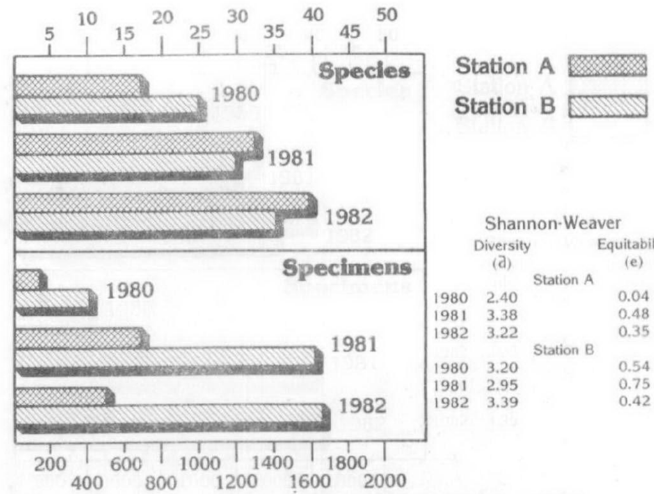
Once each summer macroinvertebrates were collected from Hester-Dendy multiplate samplers after a four-week exposure period. Periphyton was collected with periphytometers after a two-week exposure period. Phytoplankton was collected from the Langley Pond station once during the spring and fall and twice during the summer of each year, and fish were collected from Langley Pond for metals and organic chemical analyses in 1981 and 1982.

Dissolved oxygen, temperature, pH and conductivity measurements were taken each time biological samples were collected and when sampling devices were deployed.

THE RECOVERY OF THE AQUATIC COMMUNITY

In June 1979, no macroinvertebrates were collected from the Hester-Dendy multiplates. But in 1980, following the start-up of the treatment plant, macroinvertebrate communities firmly established themselves. Residual effects of the prolonged discharge of industrial and domestic wastes were still apparent, however. At Station A, the insect order *Diptera,* or true flies, were the only macroinvertebrates represented. Of these, 92 percent were chironomids (midges), a group considered very tolerant of poor water quality and generally the first macroinvertebrate community to colonize a recovering stream. Farther downstream, at Station B, 46 percent of the community were chironomids, but four additional orders of insects and a fairly high number of mayflies and caddisflies were found. These orders are generally intolerant of poor water quality. In 1981, mayflies and caddisflies were represented at Station A as well as Station B. In 1982 the rate of increase slowed as the community showed signs of stabilizing. Figure 1 shows total macroinvertebrate specimens and species for these two sampling stations collected in 1979 through 1982.

Shannon-Weaver diversity indices ($\bar{d}$) and equitability values, also shown in Figure 1, provide generalized indications of the health of biological communities. The $\bar{d}$ is a measure of both the diversity of species and the distribution of individuals among the species; a range of 3 to 4 generally reflects waters unaffected by oxygen-demanding waste. Although the creek has a $\bar{d}$ range of 3 to 4 the measure may not adequately reflect water quality, since it is toxic substances (e.g., chromium) that have been the culprit more than oxygen demanding waste.



Shannon-Weaver

	Diversity ($\bar{d}$)	Equitability (e)
Station A		
1980	2.40	0.04
1981	3.38	0.48
1982	3.22	0.35
Station B		
1980	3.20	0.54
1981	2.95	0.75
1982	3.39	0.42

Figure 1 Macroinvertebrate Population 1980 - 1982

Equitability is that portion of $\bar{d}$ that involves the "evenness" of distribution, and tends to be the more sensitive measure. Equitability values of less than 0.5 (on a scale from 0.0 to 1.0) indicate that specimens are not as evenly distributed among the species as they might be, though a more equitable distribution may occur as the system continues to recover.

Fish. With greatly improved DO concentrations and the virtual elimination of discharges, there was good recruitment of fish into Langley Pond from its nonpolluted tributaries, canals, ditches, and perhaps backwater areas of the pond.

Fish tissue analysis for metals and organics was done first in March 1981, and has been done annually since then. At first, only nongame fish such as chubs and golden shiners could be found for tissue analyses. By September 1981, more important game species such as bluegills, crappie and largemouth bass were being collected, as well as a greater variety of nongame species. Number of specimens also increased.

Since sampling began, no fish have been found with contaminant levels in tissue exceeding the Food and Drug Administration's (FDA) recommended safe tolerance limits. Although high levels of polychlorinated biphenyls (PCBs) and metals (chromium, copper, manganese, lead and zinc) were detected in the sediments in August 1979 and June 1981, accumulation has not reached problem levels in fish, perhaps because the fish are relative newcomers. Continued testing will help determine the longer term effects, if any, on the fish population.

This fish tissue monitoring data will also be incorporated into a statewide data base for future use in setting more inclusive limits for safe and acceptable levels of metals and organics in fish tissue.

The sediment in Langley Pond is still a concern because it contains significant levels of chromium as well as other metals. South Carolina is currently conducting a study to determine the extent of contamination of Langley Pond sediments and will use the data gathered to determine the sediments' potential impact on the water chemistry and biological communities in the pond.

Material for this report was furnished by William Cosgrove, Environmental Services Division, U.S. EPA Region IV, and Russ Sherer and Harry Gaymon, Division of Water Quality Assessment and Enforcement, SC-DHEC.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E.F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460, (202)382-7056.

United States
Environmental
Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

June 1985

EPA Water Quality Progress Report

Lower Fox River, Wisconsin

The 40 mile stretch of the Lower Fox River from Lake Winnebago to Green Bay has one of the heaviest concentrations of point source dischargers for its length in the country. Six municipal wastewater treatment facilities and 15 pulp and paper mills are located along this reach. Since the 1800s, the combination of nearby sources of pulpwood and available hydropower has attracted a number of paper mills. Their development has taken a heavy toll on the river, in terms of degrading water quality, which has gone largely unchecked until recently. Municipal loadings have also been significant, accounting for about 12 percent of the total loadings. In 1973 the average daily five-day biochemical oxygen demand (BOD_5) loadings from industrial and municipal point sources exceeded 218,000 pounds per day, the equivalent of untreated waste from a population of 1.3 million.

Today the Lower Fox River is able to support game fish, and the sludge beds and mats of paper wastes that were common sights have disappeared. Controls implemented by the paper mills and the publicly owned treatment works (POTW) have been responsible for the clean-up, and the river is close to meeting the Wisconsin standard of 5 mg/l DO for recreation and aquatic life protection.

AMBIENT MONITORING

In conjunction with the U.S. Environmental Protection Agency's (EPA) timetable for municipal and industrial compliance with the Clean Water Act, a computer model of the Lower Fox was developed for Wisconsin DNR in 1969 to predict the impact of future best practicable treatment (BPT) and secondary treatment on the water quality of the river. However, little water quality data existed to verify the model. In 1972, an automatic monitoring system was put into operation which consists of five monitoring stations located at hydroelectric plants and paper mills. Still in operation, the stations monitor DO, temperature, pH, and conductivity, transmitting hourly readings to a computer. Besides providing DO profiles of the river, the data is used to detect spills and nonpoint source runoff events.

MONITORING PARAMETERS FOR MODEL INPUTS

Intensive water quality surveys were also instituted by WDNR in 1972 and one or more conducted virtually every year through 1980. These synoptic surveys measured water quality in as many places on the river over as short a period as possible to form an overall picture of the river at a specific time. Field measurements including DO, temperature, pH, conductivity, secchi depth, and light extinction were taken at about one-mile intervals. Laboratory samples were taken at five to ten locations, and analyzed for BOD (five-day and long-term), nitrogen series, phosphorus, solids series, and chlorophyll *a*.

Model input also included all effluent flows and quantities of various pollutants for the day of each survey and the previous five days, and atmospheric conditions, river flow, and other variables. Sediment composition data was collected at several stations and extrapolated to sediment oxygen demand levels. Phytoplankton was collected to determine growth and respiration characteristics of various algae groups.

After each survey was completed, a complete DO profile of the river was drawn. These profiles were compared with the model output and used to calibrate the model to various specific conditions; that is, to determine the coefficients that enable the model to duplicate actual conditions when it is given appropriate input data.

WASTELOAD ALLOCATIONS

Based on the river's assimilative capacity to maintain a DO of 5 mg/l, modeling output indicated that this minimum standard would not always be met under technology-based effluent limits. Therefore, very early in the 1970s WDNR had labeled the Lower Fox River a water quality-limited segment; that is, requiring more stringent controls to meet the Wisconsin standard and other Clean Water Act requirements (e.g., as specified under Sections 208, 303, and 305).

Wasteload allocations (WLAs) were therefore needed for all municipal and industrial dischargers. Following the governor's designation of the area under Section 208 of the Clean Water Act as one having substantial water quality problems, the Fox Valley Water Quality Planning Agency (FVWQPA) was formed in 1976. WDNR asked the FVWQPA to assume responsibility for developing WLAs, with guidance from a task force of EPA, WDNR, municipal, and industrial officials. The dischargers also agreed to the use of the model for developing wasteload allocations.

To generate wasteload allocations, QUAL III, a mathematical computer model, was developed based on variables that had been determined critical to DO levels in the Fox River. QUAL III is a site-specific refinement of the generally available QUAL II model. Parameters include river flow and temperature, headwater biochemical oxygen demand, nutrient concentrations, algae concentrations, sunlight intensity, chlorophyll *a*, and the BOD loading from each discharger. The QUAL III model is unique in incorporating so many parameters, and is thus capable of finely tuning the wasteload allocations for maximum protection of the river without undue restrictions on dischargers. Since dischargers in close proximity to one another affected the river collectively as if they were one large discharger, causing a downstream DO sag, the dischargers were grouped into clusters. There are three clusters on the Lower Fox, each by coincidence made up of five pulp and paper industrial dischargers and two municipal sewage dischargers.

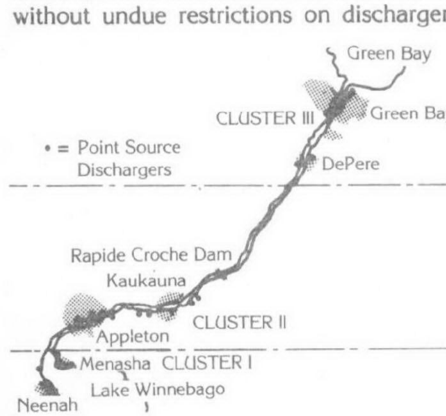


Figure 1. Point Source Dischargers Grouped Into Clusters

QUAL III was not applied to Cluster III dischargers located just below Green Bay, because the model does not incorporate all variables governing the dynamic river-bay estuarial system on that portion of the river. The wasteload allocations for this group of dischargers are currently under development and are expected to be implemented in 1986.

DETERMINING BASELINE LOADS

To allocate BOD_5 discharge wasteloads, it was necessary to calculate baseline loads for each discharger. These baseline loads established each discharger's equitable portion of the cluster's total maximum daily load (TMDL), a figure which is based on the river's assimilative capacity. Baseline loads for the pulp and paper mills were calculated based on each mill's highest production for seven consecutive days in 1973. The loads were expressed in pounds of BOD_5 per day. For POTWs, daily maximum BOD_5 loads were calculated based on 1976 and 1977 flow rates and on the assumption that monthly average BOD_5 for industries is comparable to monthly average loadings for municipalities with secondary treatment. Approximate flow rates were selected in order to calculate BOD_5 concentrations in parts per million (ppm).

Table 1 shows Cluster I's baseline BOD_5 loadings in pounds per day and the dischargers' loads as a percentage of the cluster total. To develop a wasteload allocation that would be equitable to existing dischargers and still allow for residential, commercial, and industrial growth for 20 years in the Fox Valley, a reserve capacity was established for municipal POTWs. No reserve capacity was allocated to the pulp and paper mills.

Table 1 Cluster I Baseline Loads (Including Reserve Capacity)

Name	BOD_5 (lbs/day)	% of Cluster Total
George Whiting Paper Co	365	1.4
Neenah-Menasha POTW	6,336	23.8
Kimberly-Clark-Joint	2,328	8.8
Bergstrom Paper Co	8,788	33.0
Kimberly-Clark Lakeview	4,097	15.4
Wisconsin Tissue	3,198	12.0
Fourth Plant POTW	1,485	5.6
TOTAL	26,597	100.0%

With dischargers grouped into clusters and each cluster baseline load determined, reductions of each cluster's baseline load were made and analyzed using the QUAL III model until a minimum DO standard of 5 mg/l was maintained at all times and all places along the river. It was determined that reductions were not necessary throughout the year but only during times when a combination of factors, notably summer low flows and high river temperatures, reduced the river's assimilative capacity below baseline levels.

Wasteload allocation matrices were developed for each cluster, specifying allowable pounds of BOD_5 per day given varying flow rates and temperatures and representing the assimilative capacity of the river to maintain the minimum DO standard of 5 mg/l. These data were further broken down into four summer and early fall periods to further reflect the fluctuating assimilative capacity of the river throughout the low flow season.

WATER QUALITY IMPROVEMENT

By 1981, daily average BOD_5 loadings had dropped to less than 40,000 pounds per day total from more than 218,000 pounds per day total in 1973. The average DO saturation level near Green Bay rose from an average of 77 percent in 1976 before BPT controls, to 90 percent in 1977 where it has remained. (DO saturation levels are temperature dependent; that is, a 100 percent saturation level in the summer represents a DO level somewhere around 7 mg/l, while a 100 percent saturation level in the winter represents a DO level of about 10-11 mg/l.) In 1973, DO concentrations at Rapide Croche, historically the critical sag point in the river, never reached 5 mg/l from mid-July to late October. In 1983, the DO concentrations at this same point never dipped below 5 mg/l. Improvements in DO levels were attributed mainly to the BPT controls implemented by the paper mills.

Nutrient levels also improved, attributable mainly to the secondary treatment installed by the POTWs. Monitoring data from one station showed that average soluble phosphorus levels decreased 50 percent over the period 1977 through early 1983, from 0.05 mg/l to 0.025 mg/l; total phosphorous levels decreased 41 percent, from 0.22 mg/l to 0.13 mg/l; and organic nitrogen decreased 16 percent, from 1.55 mg/l to 1.3 mg/l.

BIOMONITORING

In 1975, the Institute of Paper Chemistry conducted a biological survey to compare benthic invertebrate communities upstream and downstream of major discharges. The study was repeated in 1979 to assess changes as a result of installed controls. During each study, two sampling stations were located above point source discharges and nine stations were located below major discharges. An artificial substrate sampler was used to collect benthic invertebrates at each station after a six-week colonization period. There were three colonization periods from May through September during each sampling year.

During the 1975 survey, samples from most stations downstream of the discharges were dominated by aquatic worms (*Naididae*), which are indicative of areas of degraded water quality with low DO and high deposition of organic material. The highest worm densities occurred at stations where there were dense bacterial slime growths, suggesting that the worms used bacteria as a food source. During this same period, the more sensitive caddisfly was virtually absent from the middle and lower stretches of the river, although caddisfly communities were found at upstream stations. Caddisflies are associated with enriched but not degraded water where there are no extended periods of low DO and where deposition of organic materials is low.

During the 1979 post-secondary survey, caddisflies populated all sections of the river and worms were virtually absent. Slime growths were also nonexistent.

ASSESSING PROGRESS

In July 1983, the Toxic Substances Task Force on the Lower Fox River System, made up of EPA, WDNR, and other representatives, issued a report which identifies problems still to be addressed. Among their findings:

- The clean-up of conventional pollutants has enabled the river to support gamefish, thus presenting a possible human health risk if toxic substances in the water and sediment bioaccumulate in the fish.
- More than 100 chemicals have been identified in the Lower Fox River system, including PCBs, chlorophenols, and ammonia.
- Thirty-seven toxic pollutants have been identified in the discharges from pulp and paper mills and POTWs on the Lower Fox.

The Lower Fox continues to be monitored by EPA, WDNR, and various other groups, with emphasis on sediment and fish tissue monitoring and analysis. Although toxic pollutants have been found in the water and sediments, not enough is known yet about their activity and fate to determine what, if any, course to pursue in dealing with them. If present controls effectively limit the discharge of toxic pollutants, and contaminated sediments are eventually covered by clean sediments, the threat of their resuspension and bioaccumulation in fish tissue can be minimized.

Material for this report was furnished by Jerome McKersie, Bureau of Water Resources Management, WDNR; Tim Doelger, Lake Michigan District HQ, WDNR; and Michael MacMullen, U.S. EPA Region V. Biological survey data was taken from "Water Quality Improvements in the Lower Fox River, Wisconsin, 1970-1980: An Historical Perspective," by Bruce Markert, published in the Proceedings of the 1981 Environmental Conference *(Atlanta: Trade Association of the Pulp and Paper Industry).*

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E.F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460, (202) 382-7056.

United States
Environmental
Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

August 1985

EPA

Water Quality Progress Report

Flint River, Michigan

The Flint River basin drains approximately 1350 square miles and includes significant agricultural as well as urban areas. It is a major tributary of the Saginaw River, which empties into Lake Huron's Saginaw Bay. As part of the Great Lakes watershed, it is of national and international concern as well as local significance. The entire Flint River system was designated for agricultural and industrial water supply, navigation, partial body contact recreation, warmwater fish, and public water supply in the late 1960s; yet stretches of the river have been consistently unable to support these uses until recently. This report documents monitoring surveys conducted to identify water quality problems and to demonstrate the effectiveness of point source controls. These monitoring surveys have also identified the continuing need for nonpoint source abatement programs as well.

The river flows through the City of Flint before joining the Shiawassee River about 50 miles downstream. The Flint metropolitan area, which is the third largest in Michigan, is the major source of domestic and industrial wastewater inputs to the river. While a number of industrial dischargers have come and gone over the years, the City of Flint publicly owned treatment works (POTW) has been a constant source of nutrient loadings. The City of Flushing POTW and Genesee County's Ragnone POTW (7 and 19 miles downstream of the Flint POTW outfall, respectively) have also contributed to pollutant loadings in the downstream reaches of the river. Storm sewer discharges, combined sewer overflows, county drains, and urban runoff add nonpoint source pollutant loadings.

WATER QUALITY MONITORING

Biological and chemical monitoring surveys have been conducted approximately every five years since 1969 by the Michigan Department of Natural Resources (MDNR). The results have been used to refine discharge permit limits and to identify needed improvements in point source controls.

Fifteen to 18 stations were sampled during these intensive surveys covering the 50-mile reach of the Flint River from about nine miles above the City of Flint to approximately 40 miles downstream, just above the confluence of the Flint River with the Shiawassee River. The stations were consistent for all surveys and were sampled during August of each survey year. Sampling techniques for chemical parameters were standard and consistent for all surveys, though laboratory methods improved with each survey. Qualitative biomonitoring has been used to determine impacts on the Flint River biological communities.

In 1969, degraded conditions were evident from the City of Flint downstream, and the Flint POTW was found to be the major contributor to a significant nutrient enrichment problem in the river. As shown in Figure 1, MDNR survey results indicated that the instream five-day biochemical oxygen demand (BOD_5) concentration nearly doubled from 3.5 mg/l above the POTW to 6.7 mg/l below the POTW outfall, ammonia-nitrogen increased eight times from 0.15 mg/l above to 1.4 mg/l below, and total phosphorus was four times greater below the outfall at 2.1 mg/l than above at 0.49 mg/l. For 10 miles downstream of the city, diurnal dissolved oxygen (DO) fluctuations were extreme, often violating Michigan's 4.0 mg/l daily minimum standard. Macroinvertebrate community structure indicated degraded stream quality.

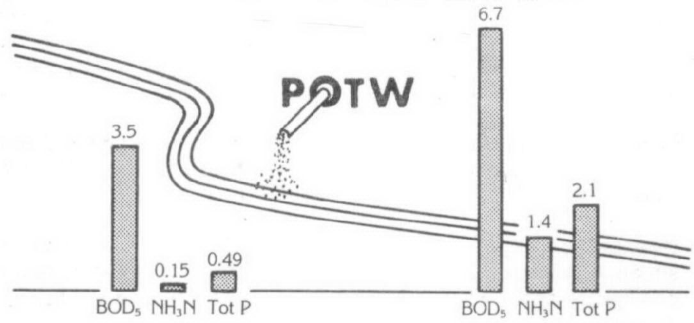


Figure 1. Water Quality Upstream and Downstream of the Flint POTW, 1969 (mg/l)

As a result, significant improvements were made to the Flint POTW over the next five years, with funding from U.S. Environmental Protection Agency (EPA) construction grants, as well as State and local sources. Nonetheless, the 1974 survey showed continued degradation downstream of the Flint POTW, as shown in Table 1. Phosphorus control measures had significantly decreased the Flint facility's average effluent concentration of total and soluble phosphorus by the 1974 survey, as shown in Table 2, but loadings of BOD_5 and suspended solids had increased. This was primarily the result of population growth and the many industrial sources that were now directing their wastes to the treatment facility rather than to the stream. A similar change in effluent loadings had occurred downstream at the Ragnone POTW, where total phosphorus levels had dropped from 10.0 mg/l during the 1969 survey to 7.0 mg/l in 1974; and at the Flushing POTW, where total phosphorus had dropped dramatically from 13 mg/l to 1.1 mg/l over the same period. At Ragnone, BOD_5 and suspended solids, however, increased significantly despite newly constructed secondary treatment facilities.

Table 1. In-stream Survey Results 5 Miles Downstream from Flint POTW 1969-1983; August Survey Data (mg/l)

	1969	1974	1978	1983
DO	5.8	5.9	6.7	7.5
BOD_5	6.7	13.0	13.0	3.6
SS	27.0	38.0	33.7	N/A
Tot-P	2.1	1.8	0.46	0.25
Sol-P	1.5	1.2	0.22	0.16
NH_3-N	1.4	1.8	2.8	0.29

Sources: 1969-78 data from MDNR. 1983 data courtesy of the City of Flint.

In 1978, monitoring data showed that BOD_5 remained a problem at all three POTWs, and suspended solids concentrations were still very high in the Flint and Ragnone POTWs' effluents. Greater operating efficiency at Flint and Ragnone was offset by higher average annual flows at both plants. Total and soluble phosphorus levels continued to improve at all three plants, however.

Table 2. Effluent Survey Results at Flint P^TW; August Survey Data (mg/l)

	Flint POTW Effluent			
	1969	1974	1978	1983
DO	4.6	4.7	5.4	7.7
BOD_5	8.1	17.0	23.7	*
SS	10.5	30.5	48.8	N/A
Tot-P	12.0	7.2	5.9	0.9
Sol-P	11.5	4.7	4.5	0.7
NH_3-N	14.9	6.8	11.6	0.2

*$CBOD_5$ was measured but is not directly comparable to BOD_5.

Sources: 1969-1978 data from MDNR. 1983 data courtesy of the City of Flint.

BIOLOGICAL SURVEYS

Biological surveys over this same period reflected the findings for the chemical parameters. In 1969, rooted aquatic plants and attached filamentous algae essentially blanketed the stream bed, adversely affecting habitat and DO levels for more than 30 stream miles downstream of Flint. Macroinvertebrates that thrive in organically enriched waters were abundant. Bottom-dwelling aquatic organisms, sensitive to pollution, were very low in number over this reach and never approached the species diversity found upstream of the city, where considerable numbers of "clean water" organisms were found.

Fish tissues, analyzed in 1973, indicated levels below the Food and Drug Administration's limits for polychlorinated biphenyls (PCBs), dieldrin, DDD, DDT, and heavy metals.

Biomonitoring in 1974 indicated continued severe impacts on stream organisms. Downstream from the Flint POTW almost to the confluence of the Flint River with the Shiawassee, heavy nuisance growths of aquatic plants persisted, and sewage odors and sludge beds in shallow and backwater areas were still a problem. Macroinvertebrate species diversity and numbers remained depressed, with "clean water" organisms such as mayflies and caddisflies almost completely absent from the entire study reach. The fish community was dominated by carp and minnows — pollution-tolerant species — with only small numbers of panfish.

In 1978, aquatic plant growth was still at near maximum production throughout the study reach, contributing to excessive diurnal variations in pH and dissolved oxygen.

WATER QUALITY PROGRESS

By 1983, however, marked improvements in all the conventional water quality parameters from the Flint POTW downstream were evident. Advanced treatment capability was increased at the Flint POTW that increased the discharge from 20 million gallons per day (mgd) to 50 mgd resulting from expanded collection systems, population growth, and industrial expansion. As shown in Table 1, BOD_5 had decreased over 70 percent in-stream from 1978 to 1983. Phosphorus levels and ammonia-nitrogen levels had decreased significantly in the effluent as well, with corresponding decreases in in-stream levels. Figure 2 shows in-stream phosphorus levels above and below the City of Flint from 1973 through 1983.

Biological surveys verified that aquatic plant growths were decreasing, especially within the river reach three miles downstream of the Flint POTW. Dense plant growth was found only where channel depths were less than one foot. Overall plant growth observed between 1980 and 1983 appeared to be less extensive than in past surveys; this was attributed to reduced point source discharges of nutrients.

Benefits from the improved water quality have been realized in increased recreational use of the river and an improved fish habitat. The MDNR Fisheries Division began planting coho and chinook salmon in the Flint metropolitan area in 1979, and sport fishing has produced satisfactory returns. Walleye have moved into the river from upstream impoundments as well as from Saginaw Bay in Lake Huron, and established themselves in portions of the Flint

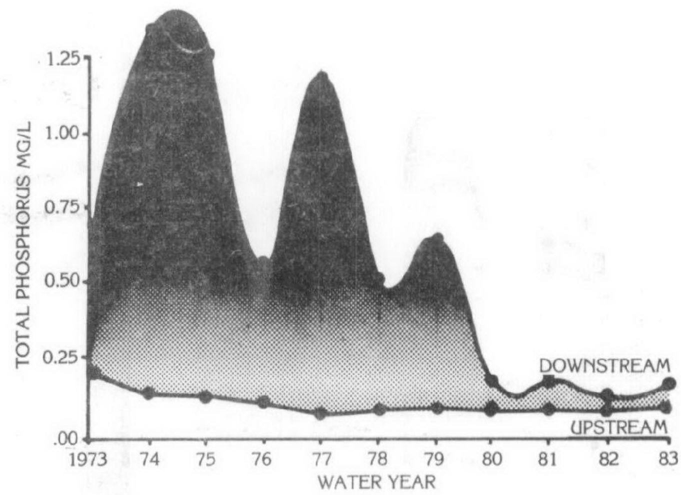


Figure 2. Mean In-stream Phosphorus Levels Above and Below the City of Flint

River. According to U.S. Fish and Wildlife Service survey data from 1980-81, white suckers, yellow perch, northern pike and crappie are also present in considerable numbers during higher flow periods. MDNR plans to conduct an intensive survey of the river's fish population within the next two years to determine production levels.

REMAINING PROBLEMS IDENTIFIED

Although the Flint River has improved markedly since the 1960s, monitoring has shown that urban and agricultural runoff are persistent problems within the Flint metropolitan area and in the river's upstream reaches, respectively. A statewide strategy for the abatement of rural nonpoint source pollution is in the planning stages, based on a 1984 memorandum of understanding signed by representatives of several federal and Michigan agencies. In addition, Michigan strategies for dealing with urban and transportation-related nonpoint sources will be developed.

Monitoring data has also shown chlorine and ammonia toxicity problems, particularly downstream of the Ragnone POTW. Seasonal disinfection and, potentially, dechlorination coupled with improved treatment efficiency at this facility should alleviate toxicity concerns and improve DO levels downstream as well.

Ambient water quality monitoring data collected since the early 1970s at stations above and below the City of Flint has been entered into EPA's STORET system, a national computerized data base for the storage and retrieval of water quality data. MDNR is currently using this data to do a comprehensive long-term trend analysis of conventional pollutants in the Flint River. Though no organic pollutant problems are evident at this time. MDNR plans to focus future monitoring and analysis efforts on organic pollutants such as dioxins.

Future monitoring plans for the Flint River also include its participation in an annual surveillance program for the entire Saginaw basin that has been proposed by the International Joint Commission, an advisory body formed under the Boundary Waters Treaty of 1909 to protect U.S. and Canadian boundary waters. The program recommends both chemical and biological monitoring.

Material for this report was furnished by Mary Ellen Fallon, Water Quality Surveillance Section, MDNR, and Michael MacMullen, U.S. EPA Region V.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460, (202) 382-7056.

United States
Environmental
Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

January 1986

EPA

Water Quality Progress Report

Housatonic River, Connecticut

The Housatonic River drains approximately 2000 square miles in western Connecticut, southwestern Massachusetts, and eastern New York State. As an important regional resource, the river has long supplied hydroelectric power from a series of dams and provided extensive recreational opportunities along its length. Principal recreational opportunities occur in a series of impoundments—Lake Lillinonah, Lake Zoar, and Lake Housatonic—on the lower Housatonic River in Connecticut. Although designated as Class B water bodies (fishable/swimmable), historically these impoundments have suffered from severe eutrophication. Recreation activities have often been impossible during the summer when scum or dense mats of blue-green algae covered the water.

Today, water quality in the three Housatonic Lakes is significantly improved as a result of Connecticut's basin-wide strategy to reduce nutrient loading to the river. Controls implemented at industries and publicly owned treatment works (POTWs) in Connecticut and Massachusetts have reduced phosphorus discharges, resulting in a corresponding decrease in nuisance algal growth.

ASSESSING THE PROBLEM

Starting with the U.S. Environmental Protection Agency's (EPA) National Eutrophication Survey in 1972, a series of studies documented the highly eutrophic condition of the Housatonic Lakes and also identified phosphorus as the growth-limiting nutrient for algae.

To better understand the transport and fate of pollutants in the Housatonic, the Connecticut Agricultural Experiment Station developed a hydraulic model (RVRFLO) and calibrated it for that portion of the river that included Lake Lillinonah. The phosphorus budget developed by the model showed that point sources were an important source of loading in the watershed and that Lake Lillinonah was the major source of phosphorus to the downstream impoundments. Based on the model results, the State conducted a study to assess the effects of phosphorus removal at one of the major point sources (the Danbury POTW) which is described below; in addition, a decision was made to focus on reducing phosphorus loads to the most upstream lake.

The RVRFLO model also supplied important information concerning the relationship between river flow and hydraulic residence time in the impoundments. During the spring high-flow period when nonpoint source input of phosphorus is relatively high, water moves through the impoundments in less than a week. During the July and August low-flow period, when point source phosphorus loads dominate, water takes 3 to 12 weeks to move through the impoundments. Since algal blooms had been observed to occur when the incubation period in quiescent water exceeded several weeks, it was particularly important to control point source input during the summer recreation period, when conditions were most likely to produce algal blooms.

INTERSTATE TRANSPORT OF POLLUTANTS

Previous water quality monitoring studies as well as the phosphorus budget indicated that a significant proportion of nutrients was transported into Lake Lillinonah from outside the State. To deal more effectively with this and other interstate pollution problems, EPA's Region I office formed the Working Group on the Interstate Transport of Pollutants. Quarterly meetings of the Working Group and the involvement of officials from Connecticut, Massachusetts, and New York (as well as representatives from business and municipalities) are resulting in a successful cooperative effort to control point source discharges.

INSTITUTING CONTROLS

In its Housatonic Basin Plan, the Connecticut DEP recommended a strategy of phosphorus controls for all significant point sources. Table 1 lists the important point source dischargers (of phosphorus) that affect the Housatonic Lakes, along with the approximate effluent loads before and after controls. In each case, the NPDES permits were modified to require phosphorus removal; for the Pittsfield plant, the revised permit required Connecticut to monitor water quality in the Housatonic River and Lakes for four years following the beginning of controls.

TABLE 1. Phosphorus Dischargers in the Lake Lillinonah Basin Before and After the Implementation of Controls (lb/day)

Source	Year controls were instituted	Discharge before controls (total P)	Discharge after controls (total P)
Danbury POTW	1977*	250	50
New Milford POTW	1982	12	1
Bethel POTW	1982	15	2
Kimberly-Clark, Inc.	1980	10	1.5
Nestle's, Inc.	1983	30	5
Pittsfield POTW (MA)	1982*	283	95
TOTAL		600	155

*The Danbury plant did not control for phosphorus in 1978, and Pittsfield did not control in 1983 or 1984.

Although nonpoint sources are less significant than point sources as a cause of nuisance algal blooms in the river system, they do represent an important source of nutrients. As a result, Connecticut has identified the Housatonic basin as a priority area for implementation of agricultural best management practices.

WATER QUALITY MONITORING: 1976-1977

To assess the water quality effects of point source phosphorus controls, Connecticut DEP, in cooperation with FMC Corporation, conducted several intensive monitoring studies. The first study was conducted during the summers of 1976 and 1977—before and during the first year of seasonal phosphorus removal at the Danbury POTW. Samples were collected biweekly from April through October for both years at five monitoring stations below the Danbury plant, four monitoring stations on the Housatonic River, and four monitoring stations on Lake Lillinonah. The samples were analyzed for approximately 20 water quality parameters, including critical eutrophication measures such as phosphorus and nitrogen species, transparency, chlorophyll *a*, and phytoplankton composition.

Results from the 1976-77 Danbury study were not conclusive due to operational problems at the Danbury treatment facility and incomplete flushing of the impoundment; however, definite improvements in water quality were observed. This was true particularly in the comparison of August and September data for the two years. During this period in 1977, the lake was undergoing its second flushing since the initiation of phosphorus treatment, and cumulative system downtime improved from 33 to 16 percent. August and September were also the months when algal concentrations had reached peak levels in previous years. Analysis of the limnological data for these August and September months showed the following results:

- Mean chlorophyll *a* concentration was reduced from 35.2 μg/L in 1976 to 25.4 μg/L in 1977
- Mean soluble reactive phosphorus concentrations were reduced from 27.9 μg/L in 1976 to 18.6 μg/L in 1977
- Mean secchi disc transparency increased from 1.2 meters in 1976 to 2.6 meters in 1977.

WATER QUALITY MONITORING: 1981-82

A second intensive monitoring survey was undertaken as a cooperative effort between the EPA's Region I Office and the States of Connecticut and Massachusetts. This study, designed as a two-phase program, examined both the transport and the effects of phosphorus that was discharged (in the summer) from the Pittsfield, Massachusetts, POTW. This plant is located approximately 40 miles north of the State line and 100 miles north of Lake Lillinonah.

In 1981, the Pittsfield plant did not remove phosphorus, and in 1982 the plant removed phosphorus during the summer recreation season. The intensive survey measured flow rate and concentrations of total and dissolved phosphorus twice a month during the summer at four monitoring stations along the Housatonic River (from Pittsfield to the headwaters of Lake Lillinonah) and at three stations on Lake Lillinonah. The Lake stations were sampled for phosphorus, transparency, and chlorophyll *a*. Data from the two years were then compared to evaluate the effects of this change in treatment.

The 1981 survey revealed that a significant fraction of the Pittsfield phosphorus was transported by the river to Lake Lillinonah. In addition, sediment samples in the riverbed above the impoundments contained relatively little phosphorus, indicating that nutrients attenuated by the river during low flows were transported to the lakes during high flow periods.

During the second year (1982), attempts to measure water quality improvements attributable to controls at the Pittsfield treatment plant were complicated by several factors. These included heavy rains and a 100-year flood event in June (which dramatically increased nonpoint loading over that of 1981); a two-week suspension of phosphorus removal at the Danbury plant due to hydraulic problems caused by the flood; and the initiation of phosphorus removal at the New Milford and Bethel POTWs. In spite of these conditions, it was possible to attribute changes in phosphorus levels in the river, above the three Connecticut POTWs and major nonpoint sources, directly to the reduction in loading at Pittsfield. Removal of approximately 190 lb/day at Pittsfield resulted in a reduction of 80 to 100 lb/day at the State line, and a reduction of 50 to 70 lb/day at the headwaters of Lake Lillinonah.

Water quality at three fixed stations in Lake Lillinonah was monitored in 1976, 1981, 1982, and 1984. These data suggest trends as well as the effects of point source phosphorus controls. Summary statistics for three parameters during July and August are presented in Table 2. In the Table, the effects of phosphorus controls initiated at the Danbury plant in 1977 are evident when 1976 data are compared to 1981 or 1982 data. Further improvements, as a result of phosphorus controls at Pittsfield in 1982, are suggested by comparing 1981 data with 1982 data. In 1984, Pittsfield again did not remove phosphorus, and the data indicate a decline in water quality.

TABLE 2. Lake Lillinonah Survey Results: Mean Values for July and August

	1976	1981	1982	1984*
Total P (mg/L)	0.104	0.063	0.050	0.078
Secchi depth (m)	1.39	1.59	1.83	1.42
Chlor. *a* (μg/L)	91.416	16.207	21.167	13.93

*Data are from August only.

BIOMONITORING STUDIES

In 1975, phytoplankton studies conducted by the EPA found the dominant organisms to be the nitrogen-fixing blue-green algae *Anabaena sp.* and *Aphanizomenon sp.* Both species are capable of utilizing atmospheric nitrogen, and are typically found as mats or scum floating on the surface. Additional biosurveys for plankton were carried out as part of both the Danbury and Pittsfield phosphorus removal studies. In the 1976-77 Danbury study, the U.S. Geological Survey monitored for algal growth potential (AGP) during the study period. Stations below the Danbury plant showed a significant reduction in AGP. AGP data collected at a station downstream from the Danbury plant showed 121 mg/L (dry weight of algae) in 1976 compared with an average of 57 mg/L in 1977.

A qualitative study of species composition during the Pittsfield survey in 1982 indicated a shift in species composition. What had been dominated by *Anabaena/Aphanizomenon*, with *Spirogyra* and *Hydrodictyon* as minor dominates, appears to have shifted into a community co-dominated by *Anacystis cyanae* and *Lyngbya birgei*. While all are considered to cause nuisance conditions, the former species are more often found in highly eutrophied water bodies, and, unlike the latter species, form surface mats and scums.

FUTURE MONITORING

Results of the 1981/1982 monitoring study were inconclusive concerning the trophic response of Lake Lillinonah. This was largely the result of variability in river flow and in nonpoint source loadings due to flooding, and changes in point source loadings in addition to the change at Pittsfield. To resolve this question, Pittsfield's revised NPDES permit requires the Connecticut DEP to monitor water quality in the Housatonic River, including Lake Lillinonah, during the summers of 1985 through 1988. Again, the objective will be to compare conditions without phosphorus removal (1981 and 1984) to conditions with phosphorus removal (1982 and 1985-1988). During these future surveys, Connecticut will also monitor river flow records, precipitation records, and the operational records and effluent monitoring data for other phosphorus-regulated dischargers. The intention is to account for all the major factors that influence trophic conditions in Lake Lillinonah.

Efforts to assess water quality in this basin will continue, and additional controls developed as needed.

Material for this report was furnished by Charles Fredette, Principal Sanitary Engineer for the Connecticut Department of Environmental Protection, and Eric Hall, U.S. EPA Region I.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460 (202) 382-7056.

United States
Environmental
Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

March 1986

EPA

Water Quality Progress Report

Upper Potomac Estuary Washington, DC Virginia, and Maryland

The Potomac River estuary forms the border between the States of Virginia and Maryland, with the tidal freshwater portion of the estuary flowing for nearly 35 miles (south from the Chain Bridge) through the Washington, DC, metropolitan area. The Potomac serves as both an aesthetic and recreational resource to a large number of Washington, DC, area residents—over 3 million people. Sport fishing, boating, and to a limited extent, swimming are all available. In 1981 approximately 25 marinas operated on the 40-mile stretch of the Potomac between the District of Columbia and Maryland Point.

During much of the past century, the Potomac estuary has been plagued by problems of high coliform counts, low dissolved oxygen, and nuisance algal growth. The primary source of these problems was urban development: increased loading of organics, nutrients, and sediment from wastewater treatment and stormwater runoff. Unlike other major estuaries along the Atlantic coast, there are very few direct industrial discharges in the Potomac basin.

Early concern by Federal and State officials led to the first Potomac Enforcement Conference in 1957. A second conference, held in 1969, resulted in a formal agreement to control organic and nutrient discharges from publicly owned treatment works (POTWs). Since then, over 1 billion dollars has been invested, and water quality in the tidewater Potomac has improved significantly. During this period, Federal, State, and local agencies supported various water quality monitoring efforts along the river. The result has been both the confirmation of water quality improvements, and an increased appreciation for the complexities of estuarine dynamics. This report documents the role of monitoring in the ongoing Potomac river cleanup.

IMPLEMENTING CONTROLS

U.S. Public Health Service officials, writing on conditions in the Potomac estuary in the late 1950's, described the river as "malodorous . . . with gas bubbles from sewage sludge over wide expanses of the river . . . and coliform content estimated as equivalent to dilution of 1 part raw sewage to as little as 10 parts clean water." Samples collected near the District showed dissolved oxygen (DO) levels with values of 0.1 to 0.6 mg/L and, during the low-flow summer months, massive algal blooms and fish kills were commonplace. In 1970, the District of Columbia, Virginia, and Maryland signed a Memorandum of Understanding that committed each government to sharp reductions in biological oxygen demand (BOD) and nutrient loadings. These limits were incorporated into the first NPDES permits (issued in 1974), and, with the exception of nitrogen removal (dropped from most permits pending further study of the effects of phosphorus removal), the treatment levels called for in 1970 are still in effect.

By 1981, construction of nearly all advanced treatment units had been completed, and 10 smaller treatment plants in Virginia were deactivated, with their combined flows (about 18 mgd) redistributed to other upgraded facilities. The primary pollutant reduction (in terms of mass loading) was achieved by the Blue Plains wastewater treatment plant in Washington, DC. This facility is the largest single point-source discharge to the river, accounting for up to 80 percent of all municipal point-source flow. Blue Plains has an annual average capacity of 309 mgd (with peak flows of 650 mgd) and stringent discharge limits for BOD_5 (5.0 mg/L), total suspended solids (7 mg/L), and phosphorus (0.22 mg/L). Table 1 shows the reduction in total pollutant loading as a result of improved treatment measures undertaken by the nine POTWs that discharge to the upper Potomac estuary.

TABLE 1. Total Wastewater Flow and Loadings to the Tidewater Potomac

Year	Average flow (mgd)	BOD_5 (lb/day)	Total phosphorus lb/day)	Total nitrogen (lb/day)	Suspended solids (lb/day)
1970	325	136,000	23,500	57,700	140,000
1977	361	76,500	7,800	60,400	80,000
1981	437	36,800	4,100	55,000	NA
1983	455	18,700	2,200	59,700	17,600
1984	463	16,818	841	57,213	13,133

Source: Metropolitan Washington Council of Governments

WATER QUALITY MONITORING

Along the Potomac, there is a long history of water quality monitoring that includes efforts by the EPA, the U.S. Geological Survey (USGS), and various State and local agencies. For a long time, however, monitoring systems were not coordinated and, as a result, reported data were often not comparable. In 1977 the USGS began a 5-year monitoring study of water quality in the tidal Potomac. Then, in 1982, with support from State and local agencies in Maryland, Virginia, and the District of Columbia, the Metropolitan Washington Council of Governments (MWCOG) organized the Coordinated Potomac Regional Monitoring Program. Under this program, water quality samples are routinely collected at 15 stations in the free-flowing portion of the river and at 41 stations in the tidewater. Stations are located at or near former EPA and USGS sampling locations to maintain a comparable data base; and all stations are sampled on the same day and at the same low slack tide. Major nutrients (nitrogen and phosphorus series), chlorophyll a, suspended solids, and BOD parameters are consistently measured by all participating agencies, with split-sample analyses used to ensure consistency among laboratories.

As originally designed, the Coordinated Monitoring Program was to consist of regular monthly sampling. However, beginning in August 1983, in response to reports of heavy algae concentrations in portions of the river, sampling frequency was increased from monthly to weekly and the number of stations reduced in order to concentrate efforts in the area of heaviest algal growth. These monitoring efforts during the algal blooms of 1983 and 1984 were invaluable in helping to understand processes at work in the river.

Table 2 presents data on instream water quality during the period before and after treatment plant improvements. These data were gathered at Wilson Bridge (mile 12 below Chain Bridge), site of the traditional DO sag below the Blue Plains facility. The effects of algal blooms, which occurred during 1983 and 1984 are not reflected in this table since these blooms occurred downstream below mile 20.

TABLE 2. Average Summer Concentrations, Mile 12 (Wilson Bridge)

Year	Daytime dissolved oxygen (mg/L)	Chloro. a* (µg/L)	Total phosphorus (mg/L)	Dissolved inorganic nitrogen (mg/L)
1970	4.2	75	0.62	1.75
1981	7.2	50	0.15	2.25
1984	7.5	13	0.10	1.35

Source: MWCOG

*Chlorophyll *a* concentrations, more than other parameters, may be influenced by flow rate.

MODELING WATER QUALITY

By 1980, the control program had significantly improved water quality in the Potomac even though some major investments were still needed to meet the original effluent and water quality goals. Local officials, as well as State and Federal agencies, questioned whether completion of the original program was necessary, and there were suggestions that less costly nonpoint-source controls might be traded off against municipal treatment efforts. To address these concerns, the EPA and MWCOG developed the Potomac Eutrophication Model (PEM) to estimate the effect of point- and nonpoint-source inputs on algal growth and dissolved oxygen. In December 1982, the model was formally approved for planning purposes and it has now become one of the primary tools used to guide nutrient control decisions in the Potomac.

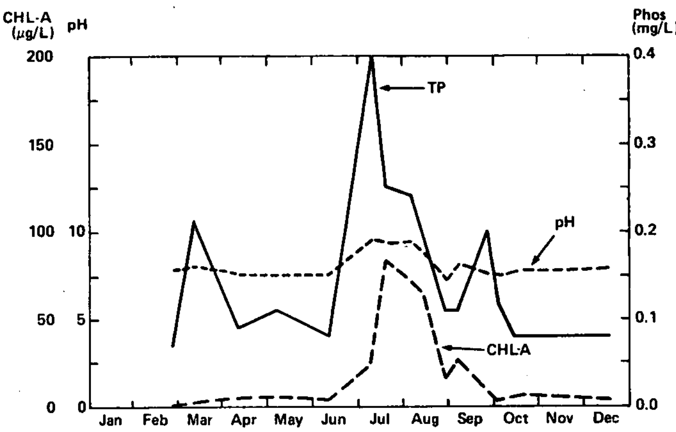
The development of the PEM was enhanced by the relatively long and complete record of monitoring data. The model was calibrated over a 4-year period in the late 1960's and verified for a 3-year period in the late 1970's. The PEM was then applied to evaluate the effectiveness of both planned effluent limitations and other control alternatives. Important conclusions of this modeling effort were that (1) the instream goal of 25 µg/L chlorophyll *a* could not be consistently achieved in the estuary, even with full implementation of the control program, and (2) point-source phosphorus removal would be effective only in the upper 30-35 miles of the estuary, with sediment phosphorus release more important below this point. This was useful information in the effort to reexamine the control program, however, its application was thrown into question with the appearance in 1983 of a major, unexpected algal bloom on the Potomac River.

ANALYZING THE ALGAE BLOOM

With the exception of 1977, no significant algae blooms had occurred in the Potomac since 1971, and a primary nuisance species, the blue-green algae *Microcystis aeruginosa*, had seemingly disappeared. Then, in the summer and fall of 1983, a major outbreak of *M. aeruginosa* took place in a 20-mile stretch of the Potomac estuary. This bloom was similar to those that occurred during the late 1960's, with chlorophyll *a* concentrations as high as 250 µg/L to 300 µg/L. However, in 1983, phosphorus and BOD loads from municipal plant sources were at their lowest point ever. *M. aeruginosa* blooms also occurred during the summers of 1984 and 1985, although these were nowhere near as widespread or persistent as the 1983 bloom. The question was, what went wrong?

The EPA, with support from the States, convened an "Expert Panel" to investigate the cause of the bloom. Using hydrological and nutrient data from the Regional Monitoring Program, the panel first tried to "predict" the 1983 bloom using the PEM. While the model did capture the early phase of the bloom (up to 100 µg/L chlor. *a*), it was unable to reproduce the highest observed concentrations. The model also underpredicted the observed total phosphorus concentration by a factor of 2 to 5. The task of the Expert Panel was to uncover the source of this nutrient.

Monitoring data as well as model calculations suggested that the source was not the result of a nonpoint slug or a treatment plant failure, but rather a sustained event originating in the sediment. Numerous hypotheses were advanced; however, the one that seemed to best explain the observed data relied on a new theory of "pH-mediated" sediment release. The Expert Panel hypothesized that algal uptake of carbon dioxide raised the pH to a point that caused phosphorus to be desorbed from the sediments and enter the water column as an additional supply for algal growth. During the months when chlorophyll concentrations were greatest, sampling in the bloom area recorded large increases in pH (to nearly 10) and total phosphorus concentrations between 0.3 and 0.4 mg/L. Figure 1 shows a plot of chlorophyll *a*, pH, and total phosphorus levels recorded at the center of the bloom area in 1984. As a result of the Expert Panel's analysis, the PEM was modified to include pH-alkalinity chemistry, and the possibility of controlling future blooms by enhancing alkalinity in the water is now under study.



Source: MWCOG

Figure 1. Chlorophyll *a*, Total P, and pH Recorded at Smith Point, 1984

BIOLOGICAL MONITORING

Along with the algae bloom, 1983 may be remembered as the year in which submerged aquatic vegetation (SAV) returned to the Potomac after an absence of several decades. This reappearance is viewed positively since many of these plants are only found in clean water environments. SAVs also play an important role in providing food, cover, and a natural habitat for a variety of aquatic life. Additional surveys, conducted by the USGS in 1984, indicated that SAVs increased in abundance and distribution over levels recorded in 1983; in many cases, three to six different species were present in close proximity. However, Hydrilla *verticellata* has also been noted, and the rapid, dense growth of this plant can disrupt navigation and recreation.

During the summer of 1984, the District of Columbia's Environmental Control Division sponsored a fish survey along the tidewater Potomac. It focused on determining characteristic species, diversity, abundance, and species' habitats at various locations. Since there are no previous surveys with which to compare the results, the 1984 sample is of limited value for assessing trends. Nevertheless, the diversity (36 species) and abundance of fish indicate water quality that is adequate to support a healthy fishery. Future surveys should provide an excellent way to track water quality trends. In the meantime, at least one indicator of renewed fisheries potential in the Potomac is the return of professional fishing guides; at the last count, six were available in the DC Metropolitan area.

Material for this report was furnished by Stuart Freudberg, Metropolitan Washington Council of Governments; Paul Eastman, Director of the Interstate Commission on the Potomac River Basin; Jim Collier, DC Department of Environmental Services; and Charles App, U.S. EPA Region III.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460 (202) 382-7056.

United States Environmental Protection Agency
Monitoring and Data Support Division Office of Water Washington, DC 20460
July 1986

EPA

Water Quality Progress Report

Upper Trinity River, Texas

The upper Trinity River basin drains approximately 8,000 square miles in the area around Dallas and Fort Worth, Texas. Before the early 1900's, when the first water supply reservoirs were constructed, the river ran through the prairie and was dry for most of the year—resembling a true river only after a major rainfall. Today, in nearly all respects the Trinity is an "urban" river. Flow in the river is dependent on the discharge of wastewater effluent, on stormwater runoff from extensive impervious surfaces (overall, about one third of the basin is urban land), and on releases from manmade reservoirs in the upper watershed.

Because of its limited assimilative capacity, the Trinity has long been subject to severe water quality problems. The State Health Department, writing in 1925, described the Dallas-Fort Worth section of the river as having an "inky surface putrescent with oxidizing processes to which the shadows of over-arching trees add Stygian blackness and the suggestion of some mythological river of death." By the early 1970's, primary and some secondary sewage treatment systems had been installed; but the river was subject to numerous small point sources, and many publicly owned treatment works (POTWs) suffered operational problems due to the phenomenal growth that was occurring in the Dallas-Fort Worth region.

Today, many of the smaller treatment plants have been phased out and replaced by a network of larger "joint system" plants with enhanced secondary treatment. As a result, water quality in the river has improved significantly, and there is now a growing interest in utilizing the flood plain along the Trinity. The river flows through the heart of the Dallas-Fort Worth metropolitan area, and both cities as well as other local governments have recently proposed recreational and open space plans to make extensive use of the Trinity River corridor.

Along with the improved treatment, federal, State, and local agencies have cooperated in the development of an innovative monitoring program that uses continuous automated monitors to record water quality values along the river. This monitoring system has both confirmed the positive effects of investments in improved treatment systems and provided a powerful diagnostic tool for investigating remaining water quality problems in the region.

IMPLEMENTING CONTROLS

In the 1960's, local governments around Dallas and Fort Worth began a coordinated process to plan for the future wastewater treatment needs of the region. Working through the North Central Texas Council of Governments (NCTCOG), a designated regional water quality planning agency, the Upper Trinity River Basin Comprehensive Sewerage Plan (UTRBCSP) was developed; this regional plan was one of the first in the nation and it was the first to be approved by the U.S. Environmental Protection Agency (EPA) in 1971.

The Treatment Works Improvement Program that emerged from the plan detailed a system of regional wastewater treatment plants that would eliminate many of the smaller single-community plants. The premise was that larger "joint system" plants, operated by highly trained personnel, would produce a better quality effluent at fewer locations. Additionally, smaller cities could realize economies of scale by eliminating daily operation and maintenance costs in favor of an annual rate for sewage treatment at a regional plant. The original plan delineated plant locations, regional system operators, a plan for financing, and managerial responsibilities.

Between 1970 and 1985, 21 POTWs and 13 private treatment plants were phased out, and the joint systems' share of the total flow increased from 79 to 95 percent. During the same period, the total permitted flow increased from 283 to 485 million gallons per day. As a result of the consolidation and treatment system improvements, oxygen-demanding wastes have been reduced dramatically. For the seven joint-system plants that discharge directly to the river or its tributaries, annual flow-weighted loadings of biochemical oxygen demand (BOD) decreased from 44 mg/L in 1977 to 14 mg/L in 1985. The POTWs, as a group, continue to produce an average effluent that is cleaner than the federal standards for secondary treatment (30 mg/L BOD), and many are now achieving an average that is below the Texas secondary standard of 20 mg/L.

In 1985, the Texas Water Commission completed wasteload allocations affecting two important segments in the upper Trinity River basin. As a result, most of the major POTWs will implement additional treatment to meet more stringent effluent limitations. In particular, seasonal limits on ammonia-nitrogen are required for major dischargers—with lower limits during the summer months when oxygen-demanding compounds have the greatest impact.

WATER QUALITY MONITORING

Monitoring activity in the Trinity River has increased significantly through the installation of a Continuous Automated Monitoring System (CAMS) that was designed as part of the areawide planning studies conducted by NCTCOG in 1974 under Section 208 of the Clean Water Act. The system was installed with the cooperation of the U.S. Geological Survey (USGS) through an interagency agreement with NCTCOG. Following installation, the cities of Dallas and Fort Worth, two regional water authorities, the State, and the USGS assumed funding for the operation and maintenance of the monitors through a cooperative agreement. With the assistance of committees representing all parties, NCTCOG performs the analysis of CAMS data and publishes semiannual reports.

As of April 1986, five CAM stations have been installed in the river basin. Each measures stream flow, dissolved oxygen, temperature, pH, and specific conductance. The monitors operate continuously day and night, with values recorded on digital tapes every hour. The data are retrieved and incorporated into a computerized data base which is used to compute trends.

Sites for the automated monitors, shown in Figure 1, were carefully chosen based on hydrology, relationship to USGS flow gauges, and the location of major dischargers. CAM 1 is located on the West Fork Trinity River and is upstream of all municipal sewage treatment plants, but downstream of the Fort Worth urbanized area. The segment receives runoff from urban and rural portions of the watershed and a few industrial dischargers, but none contribute significant oxygen-demanding pollutants that would affect the monitor. This site was chosen to characterize river flow and water quality before it is impacted by a major POTW. The remaining CAM stations are spaced downriver between and below the major POTWs. CAM 5 is located at the downstream point of the Dallas-Fort Worth designated planning area, and is almost 100 river miles below the CAM 1 station. During the summer of 1986, three more monitors will be added to the CAMS network, two on the East Fork Trinity River and one downstream of CAM 5. While treatment facilities on the East Fork have recently been upgraded, they are now experiencing some of the highest growth rates in the Dallas area—so these monitors are expected to be valuable additions.

Source: NCTCOG

Figure 1. Upper Trinity River Basin Showing CAM Sites and Major Dischargers

WATER QUALITY PROGRESS

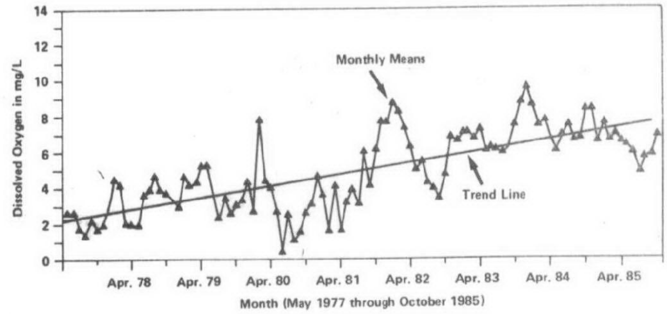
Historically, dissolved oxygen (DO) levels have played a major role in water quality management on the effluent-dominated upper Trinity River. Effluent limitations for the joint system plants discharging to the Trinity River have been established for BOD as well as suspended solids based on water quality modeling of anticipated DO response in the river. For this reason, much of the CAM work to date has focused on dissolved oxygen.

During the eight-year period of record (1977-1985), the five CAM stations have generated approximately 245,900 valid hourly readings of dissolved oxygen. For most years, there are between 6,000 and 8,700 valid readings per CAM station. This compares with a record, prior to the establishment of CAMS, of only a few hundred annual readings at a given location, with most grab sampling conducted during normal business hours.

Funding under Section 205(j) of the Clean Water Act has enabled NCTCOG to analyze this extensive data base. Basic statistics and frequency distributions of DO concentrations have been calculated for each CAM station. Trend regressions have also been calculated for each station (except CAM 3 which has been in continuous operation only since February 1984). The results indicate a general upward trend for the downriver CAM sites that are impacted by major wastewater discharges, while the trend line for CAM 1 remained statistically constant. Figure 2 is a graph of the mean monthly DO values at CAM 2, along with the calculated trend regression over the eight-year period.

All three CAMS (2,4, and 5) show improvements from low annual averages of 2 to 3 mg/L DO during 1977-78 up to average concentrations in the 5 to 6 mg/L range for the 1984-85 period. Equally improved during the same period at the three monitors has been the percent oxygen saturation and the level of mean conductance values.

As indicated in the graph of CAM 2 data, dissolved oxygen values can fluctuate widely. This variability depends on several conditions including water temperature, river flow, BOD, and ammonia levels in effluent discharges. Future work with the CAM data will be directed at analyzing for the effects of temperature and other natural seasonal factors (including flow) in an effort to better represent the trends in dissolved oxygen.



Source: NCTCOG

Figure 2. Mean Monthly Values and Trend Regression for Dissolved Oxygen at CAM 2, 1977 Through 1985

ANALYZING NONPOINT SOURCES AND FISH KILLS

Past analyses have focused on the relationship between ambient DO levels in the river and wastewater effluent quality—usually at periods of critical low flow. Increasingly, however, CAMS data are being used to examine water quality during peak flow events associated with rainfall. Many of the low dissolved oxygen events measured by CAMS during recent years have been associated not only with the low flow summer conditions, but also with periods during and immediately following heavy rainfall.

Fish kills in May 1984 and July 1985 followed peak flow events, and in both cases, dissolved oxygen concentrations at CAM 5 indicated substantial oxygen depletion at that time. The specific cause of dissolved oxygen depressions during high flow events is not yet known, since the effect could result from a variety of sources. In addition to loading from urban and rural runoff, bypasses from overloaded wastewater treatment plants can occur, and sewage lines can be damaged during heavy storms. Resuspension of bottom sediments has also been suggested as an important cause of the dissolved oxygen sags during high flows.

During the spring and summer of 1986, EPA, the Texas Water Commission, and an associated multi-agency committee are monitoring instream impacts during significant rainfall events. During these studies, the CAMS data have supplied crucial information needed for tracking the short-term effects of storms on flow and dissolved oxygen levels. The EPA Region VI office will sample for heavy metals, pesticides, and other toxicants as well as conduct toxicity tests (using biomonitoring techniques) of grab samples taken during storm events. Additional studies will be directed at obtaining more quantitative information on the relative impacts of point and nonpoint source loadings.

Material for this report was furnished by Samuel Brush, NCTCOG; Richard McVay, Texas Water Commission; and Cathy Gilmore, U.S. EPA Region VI.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460 (202) 382-7056.

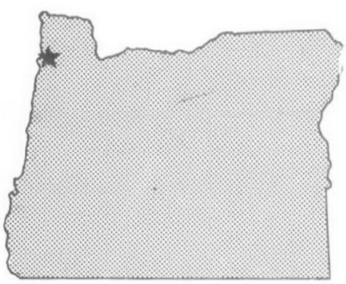
United States Environmental Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

August 1986

EPA

Water Quality Progress Report



Tillamook Bay, Oregon

The Tillamook Bay drainage basin in northwestern Oregon includes five major river systems and Tillamook Bay. The bay, which covers nearly 11,000 acres, is the most productive oyster and clam growing water in Oregon, producing 80 percent of the oysters commercially harvested in the State and generating between 2 and 3 million dollars per year in revenue. However, much of the lowland areas adjacent to the bay and rivers are used intensively for dairy operations, with nearly 20,000 dairy cattle on 118 farms lining the lower portion of the watershed. The presence of concentrated livestock wastes along with the region's wet weather (about 100 inches of rainfall per year) have created severe runoff problems and contaminated conditions in Tillamook Bay.

Over the last ten years, following moderate to large storms, the bay has been closed to commercial shellfishing due to high concentrations of fecal coliform bacteria. Affected along with the commercial oyster industry has been recreational clam digging, fishing, boating and other activities on the river and tributaries that attract nearly a million tourists and sportsmen to the area each year.

In 1981, Tillamook Basin was selected as one of 21 project areas to be funded under the Rural Clean Water Program (RCWP) which is sponsored jointly by the U.S. Environmental Protection Agency and the U.S. Department of Agriculture. This program is designed to encourage the implementation of best management practices (BMPs) to control nonpoint source pollution, and to evaluate the effectiveness of individual BMPs. Although implementation of BMPs is not yet complete, the Tillamook Bay project has been able to show significant water quality improvements in both the rivers and the bay. In 1985 bay closures were invoked less frequently, employment in Tillamook's oyster industry was the highest since 1952.

ASSESSING THE PROBLEM

The fecal coliform (FC) standard for commercial shellfishing waters is a log-mean of 14 cells per 100-mL sample. In late 1977, the U.S. Food and Drug Administration surveyed shellfishing areas in Tillamook Bay and found FC concentrations far in excess of the standard; the agency strongly recommended closure of the bay for oyster harvesting until appropriate controls could be developed. In response, the Oregon Department of Environmental Quality (DEQ) initiated the Tillamook Bay Bacteria Study to comprehensively assess the sources, extent, and dynamics of fecal contamination in the watershed. There were three major aspects to the study.

Water Quality Monitoring. During 1979 through 1981, DEQ conducted an intensive weather-related survey to determine fecal coliform densities and to identify the major sources of fecal contamination in the basin. The survey included 79 river and stream stations selected on the basis of adjacent land use, 14 bay sampling stations selected for proximity to shellfish growing areas, and the 5 small sewage treatment plants that discharge either to the bay or into the lower reaches of one of the major rivers. Because nonpoint source loading is closely related to precipitation and soil conditions, water quality data were collected during four different weather periods: (1) heavy rain on saturated ground, (2) rain after a period of dry weather, (3) summer low-flow during dry weather, and (4) first "freshet" storm at summer's end with sampling beginning prior to soil saturation.

Data were analyzed by comparing the concentration at each station for each weather event against the fecal coliform standard. By examining monitoring results in light of upstream and surrounding land uses, DEQ established that the primary sources of contamination were surface water runoff from dairy operations, inadequate onsite septic systems, and malfunctioning sewage treatment plants. Of the three, agricultural operations were found to be the single largest source.

Analysis of Dispersion and Residence Time. The fecal coliform standard for rivers and tributaries that flow into the Tillamook Bay (waters that are designated for recreational use) is over 10 times higher than is allowed for shellfishing. For this reason an important study was conducted to determine the dispersal and purging of the bacteria contained in rivers that entered the bay near shellfishing beds. Data from dye studies indicated that following moderate rainfall, the bay purges itself in 2 to 3 days; following periods of heavy rains, especially during the winter, purging takes 3 to 7 days. These relatively short residence times make water quality in the bay responsive to changes in FC inputs.

Development of Harvesting Criteria. Using the results of monitoring and dispersion studies, DEQ and the State Health Department developed a set of five criteria, specific to the Tillamook watershed, any one of which can be used to close shellfish beds for 5 to 10 days. The criteria, implemented in 1982, are based on rainfall and river flow conditions or on known sewage bypasses. In 1987, these closure criteria will be re-evaluated based on continuing FC monitoring results and trends.

INSTITUTING CONTROLS

To attack the problem of animal waste management, the Tillamook Soil and Water Conservation District (SWCD), with funding under Section 208 of the Clean Water Act, developed an extensive nonpoint source pollution abatement plan in 1981. Although the plan specified that waste management practices should be individualized for each farm, the overall strategy relied on two basic principles: (1) prevent rainwater and clean surface water from coming into contact with manure and (2) when this is not possible, prevent contaminated surface water from reaching the streams or the bay.

One hundred nine dairy farms, covering 9800 acres, were designated as "critical" dairies, and these farms were eligible, under the RCWP project, to receive up to 75 percent of the cost of implementing approved BMPs up to $50,000. To achieve the goal of a 70-percent reduction in fecal coliform loading, all critical dairies must undertake BMPs. As of July 1986, contracts to implement BMPs had been signed by 103 of the 109 dairies, and the Tillamook SWCD, which is administering the RCWP project, has received over $4 million in cost-share funds. Farmers in the project area have committed more than $2 million of their own money. The most common BMPs were the installation of underground storage tanks for manure, the addition of gutters to barns to control runoff, and the construction of fences to keep cattle out of streams.

The two nonagricultural sources of coliform bacteria were also addressed in the SWCD plan. A study of the five sewage treatment plants located in the drainage basin found that while treatment levels were adequate when the plants operated properly, malfunctions did occur. DEQ worked with the staff of each plant to improve monitoring as well as operations and maintenance procedures to ensure that malfunctions occurred less frequently; in addition, each plant agreed to install alarms to alert operators in case of equipment failure. The second nonagricultural source of pollution was failing onsite septic systems, and many of these have been eliminated by extending a municipal sewer line.

WATER QUALITY MONITORING

The bay and tributaries in Tillamook basin were sampled for many years prior to the initiation of the RCWP project in 1981. As part of the RCWP, this sampling was continued at 14 bay sites and 12 river stations. Bay sites were sampled quarterly for salinity, temperature, and fecal coliform; tributary sites were sampled monthly for pH, temperature, stream flow, and fecal coliform. All data are entered into EPA's STORET system.

Starting in January 1985, DEQ and the SWCD began a coordinated 2-year monitoring effort using monies available under Section 205(j). This survey has been designed to both assess the effectiveness of site-specific BMPs and to evaluate progress toward reducing fecal coliform concentrations in the bay and tributaries. The first part will be accomplished by focusing on smaller tributary sites where the effectiveness of individual BMPs can be evaluated by monitoring comparable sites above and below dairies. The second objective will be accomplished by monitoring all bay and river stations during weather conditions as close as possible to those monitored in the 1979 to 1981 DEQ study. The resulting data will aid in evaluating progress, as well as provide an overall assessment of the effectiveness of BMPs.

WATER QUALITY IMPROVEMENT

Tillamook Bay. Coliform concentrations in Tillamook Bay are the result of complex interactions involving upstream manure inputs, prior precipitation, stream flow, estuary tide stage, and bottom-stirring action by winds. As a result, a large amount of monitoring data and some relatively sophisticated analytical techniques were needed to isolate water quality trends in the bay. An additional complication was introduced since post-BMP monitoring focused more on runoff events (when coliform concentrations would be expected to be higher) than did pre-project monitoring. However, with assistance from the National Water Quality Evaluation Project (NWQEP), Oregon has been able to document unequivocal success in improving the impaired water resource.

Table 1 shows the percentage reduction in FC concentration at the eight bay sampling sites that are located within oyster and clam beds. (Six other bay sites are within channels formed by the tributaries draining into the bay, and as such represent incomplete mixing zones with expected higher coliform levels.) The percentage reductions are based on a linear regression model that uses salinity measurements to account for meteorologic differences in pre- and post-treatment sampling.

DEQ estimates that mid-1983 was the point at which over half of the total BMPs were installed or under construction; thus, as remaining BMPs are completed and the number of observations is increased, FC reductions will be quantified with greater certainty.

Rivers. Five major rivers empty into Tillamook Bay and each of these has numerous tributaries often with only a few dairies located in their drainages. Tributary water quality data are being analyzed, focusing on both "before and after" changes in mean FC concentrations and "above and below" trends in several small tributaries where only one or two dairies have implemented BMPs. Definitive results on these studies await monitoring data from the intensive survey to be conducted during 1985-86.

TABLE 1. Fecal Coliform Reductions in Tillamook Bay (pretreatment: 1/1975 - 6/1983; post-treatment: 7/1983 - 7/1985)

Bay sampling site	Percent reduction FC concentration
1	56%*
6	41%
7	56%*
8	59%*
10	16%
11	43%*
13	60%*
14	64%*
Mean FC reduction =	49.4%

Source: NWQEP 1985 Annual Report
*Statistically significant at 95% confidence level.

Table 2 shows reductions in FC concentration at sampling sites along the five rivers. Using January 1982 as the dividing date between pre- and post-treatment, four of the five river sites show statistically significant reductions. Again, as more data become available, the evaluation can be improved, since interim data (data collected during the time when BMPs were being installed) can be deleted from the pre- and post-data sets to obtain a clear picture of results.

TABLE 2. Fecal Coliform Reductions in Tillamook Rivers (pretreatment: 1/1975 - 12/1981; post-treatment: 1/1982 - 6/1985)

River (Site)	Log mean FC concentration		Percent reduction
	Pre	Post	
Kilchis (K4)	87	61	30%
Miami (MM4)	276	60.7	78%*
Trask (TR8)	168	63.4	62%*
Tillamook (T4a)	387	162	58%*
Wilson (W13)	147	68.6	53%*

Source: NWQEP 1985 Annual Report
*Statistically significant at 95% confidence level.

FUTURE PROJECTS

Results of the intensive survey now underway in the Tillamook basin will be used to develop a bay water quality model. The model will more accurately describe the water quality effects following specific precipitation events, and it will be used to refine and supplement the bay closure criteria that are now used to determine when shellfishing is hazardous.

Material for this report was furnished by John Jackson, Water Quality Division, Oregon DEQ; The National Water Quality Evaluation Project, North Carolina State University; and Elbert Moore, U.S. EPA Region X.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460 (202) 382-7056.

United States Environmental Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

October 1986

EPA

Water Quality Progress Report

Passaic River, New Jersey

The freshwater portion of the Passaic River is 70 miles long and drains approximately 800 square miles in northeastern New Jersey. In the upper two thirds of the basin, the river is a slow moving stream that flows through residential and rural land. Municipal treatment plants are a major source of organic pollution, and high nutrient loading in this subbasin. The lower third of the river drains the densely populated and older urban area of Paterson, New Jersey. Along this section, there are approximately 35 industrial point sources and eight major publicly owned treatment works (POTWs). The Passaic River also serves as a source of potable water for many of the urban and suburban communities in northeastern New Jersey, and, as such, water quality in the river is a major public health concern.

By the 1960's, because of rapid population growth and industrial development in the basin, water quality in the Passaic River had become severely degraded. Large diversions for water supply and industrial use reduced the capacity of the river to assimilate wastewater, and violations of dissolved oxygen and ammonia standards were common during the summer months. Domestic sewage was identified as the primary source of oxygen demanding waste, and, consequently, efforts to improve water quality and meet the dissolved oxygen (DO) standard focused on upgrading treatment levels at POTWs.

While several sections of the Passaic River still exceed the standards for dissolved oxygen and ammonia toxicity during the summer months, monitoring efforts have demonstrated significant improvements in the river's water quality. Improvements have been documented both by routine monitoring over the last ten years and by intensive surveys completed before and after upgrading a POTW from secondary to advanced wastewater treatment (AWT). This report documents continuing efforts by the State of New Jersey to restore water quality and to refine management options in the Passaic River basin.

PREVIOUS MONITORING STUDIES

In 1973, a report prepared by the U.S. Geological Survey (USGS) examined water quality and streamflow in the Passaic River Basin above Little Falls, New Jersey. This portion of the watershed includes about 80 percent of the total basin, and its streams are designated primarily for water supply. A statistical analysis of water quality data in STORET (EPA's water quality file) showed that water quality in the basin had deteriorated steadily from 1945 to 1970. An upward trend in the concentrations of dissolved solids, hardness, chloride, and sulfate was evident during this period as was a gradual decline in DO.

In 1976 and again in 1979, the New Jersey Department of Environmental Protection (NJDEP) carried out comprehensive water quality management studies in the Passaic River basin with funding under Sections 303(e) and 208 of the Clean Water Act. To investigate the water quality impacts of projected pollutant loadings, NJDEP utilized a steady-state model to simulate levels of DO, carbonaceous BOD (CBOD), and nitrogenous BOD (NBOD) in the Passaic basin. This model was based on the original U.S. Environmental Protection Agency (EPA) SNSIM model, which uses an expanded form of the Streeter-Phelps equation. Based on the projections of this modified model, the State established water quality-based effluent limits for most dischargers and AWT requirements for nearly all POTWs.

However, the SNSIM model used for the 208 and 303(e) studies was inadequate in several respects. Because field data were not available, the model did not adequately represent photosynthesis, sediment oxygen demand (SOD), and nitrification processes. Also, nonpoint source loadings were not addressed, and some important hydraulic characteristics were not modeled. It was felt that to better evaluate management options and to justify the stringent AWT requirements, the State should collect new field data and employ a more complex water quality model.

1983-84 PASSAIC RIVER STUDY

To support the application of a more comprehensive water quality model, NJDEP conducted three intensive surveys (August 1983, October 1983, and September 1984) of the entire Passaic River watershed. These surveys, carried out during low-flow conditions, each lasted two or three days, and provided a comprehensive "snapshot" of water quality in the river. Altogether, 44 sampling stations were located to account for prominent hydrologic features as well as point and nonpoint discharges. Every station was sampled once on each day of the survey period, and at each station, three samples were collected across the width of the river and then combined to provide a single composite for the station.

The 1983-84 Passaic River Study, partially funded under Section 205(j) of the Clean Water Act, yielded data that have been used for three major tasks. First, EPA's QUAL II model was calibrated and verified using the survey results (i.e., model parameters were adjusted to fit site-specific conditions). Second, NJDEP predicted the present and future water quality response under various wasteloads and water diversions. The model was used to simulate hydraulics and water quality for conventional pollutants, including DO, CBOD, nitrogen species, dissolved phosphate, dissolved solids, and chlorophyll *a*. This information was used to establish effluent limitations, including seasonal limits, for individual dischargers. Finally, water quality improvement due to previous point source controls was evaluated.

MODELING RESULTS

Once it was calibrated and verified using the 1983-84 monitoring data, QUAL II was used to gain a better understanding of the physical and chemical processes at work in the river. For example, this model enabled NJDEP to analyze the DO deficit (the difference between measured and potential DO concentrations) along the length of the river. The model calculated the relative contribution of the three principal oxygen-demanding components (DO sinks) CBOD, NBOD, and SOD, as well as the effect of the individual oxygen producing components, reaeration and net photosynthesis. The results for the deficit sink components are shown in Figure 1.

Figure 1 shows that the range of values and the importance of individual deficit components vary greatly over the length of the river. The two DO source components, reaeration and photosynthesis (not shown in the figure) act to reduce the DO deficit, and these also vary along the length of the river. Reaeration dominates in the

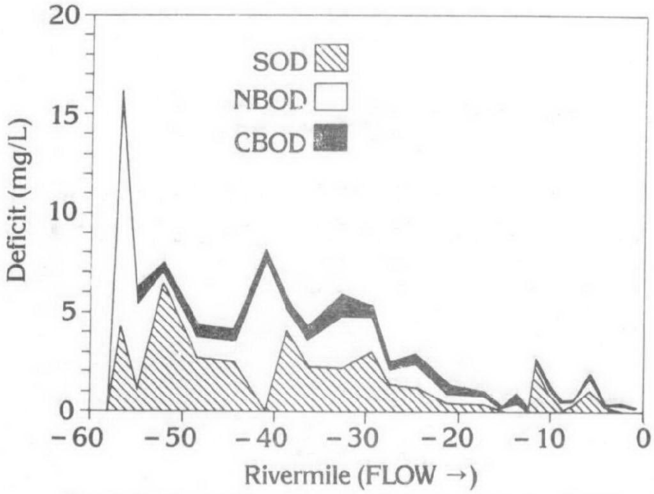


Figure 1. Components of the dissolved oxygen deficit.

upstream areas where its magnitude counterbalances high SOD. Downstream, in backwater areas, algal photosynthesis provides the greater portion of available DO.

There are several important ramifications of the deficit component analysis. First, because the major determinants of DO in the upstream reaches are sediment deposits and reaeration, this area of the Passaic River is likely to show only marginal improvement as a result of reduced pollutant loading from upgrading POTWs beyond AWT. In addition, the segments just downstream of two waterfalls (mile 12 and 5) show a high SOD. Although these zones are characterized by high reaeration and a sharp DO peak (or valley on the deficit curve), this DO is quickly consumed. Thus, the significant reaeration occurring at the waterfalls affects only a small portion of the river.

WATER QUALITY PROJECTIONS

Currently there are 12 POTWs, with a combined design flow of approximately 50 million gallons per day (mgd) in the mainstem or near to the mainstem Passaic River. While several POTWs have been renovated to provide advanced treatment, the majority of plants hold permits for secondary treatment. Because of the high costs involved in upgrading to AWT, an important objective of the Passaic River Study was to determine whether the comprehensive AWT requirement would be effective for restoring water quality in the river. The model was used to examine water quality outcomes (under critical low flow) for three conditions: actual point source discharges, existing permitted discharge levels, and recommended discharge levels assuming AWT at all treatment plants.

Model results indicated that under summer low-flow conditions, existing effluent levels and the current permitted levels have a similar impact—extensive violations of DO and unionized ammonia standards along the river. In several sections, the minimum average DO concentration could drop to zero. Under the advanced treatment alternative, the portion of the river experiencing DO violations would be significantly reduced, and the minimum DO concentration would be upgraded to 2.8 mg/L and 4.2 mg/L in the upper and mid-Passaic River, respectively. In addition, no ammonia violations were predicted under the AWT scenario.

Of particular interest is the fact that some areas which continue to show DO violations under the AWT scenario contain no significant point source discharges. In these segments the DO violations can be attributed to nonpoint sources (e.g., SOD or bank erosion) or natural processes such as low reaeration rates. Consequently, efforts to upgrade treatment levels beyond AWT cannot be justified by the model due to nonpoint source impacts on the river.

WATER QUALITY IMPROVEMENTS

As a result of past and ongoing federal and State efforts to upgrade treatment levels, measureable water quality improvement has been observed in parts of the Passaic River system. A review of historical monitoring data indicates that pollution levels peaked in the 1960's and since then there has been a gradual trend toward improved water quality.

Direct evidence that upgrading treatment levels does improve water quality was obtained during NJDEP's 1983-84 Passaic River Study. Bernards Township sewage treatment plant discharges approximately 1.5 mgd of treated effluent to the Dead River, an important headwater tributary of the Passaic River. This plant was upgraded from secondary to advanced waste treatment in 1984—prior to the last NJDEP survey and after the 1983 surveys. Table 1 shows a comparison of water quality before and after treatment plant improvements were completed. Measurements were taken at a station downstream of the outfall.

TABLE 1. Water Quality Improvement Downstream of Bernards Township Treatment Plant (mg/L).

Survey	DO	BOD_5	NO_3-N	TKN*	TP*
August 1983 (secondary WT)	3.2	10.3	0.75	9.94	2.53
September 1984 (advanced WT)	8.4	1.55	11.0	1.07	2.35

Source: NJDEP
*TKN = Total Kjeldahl nitrogen, TP = Total phosphorus.

Except for nitrate (NO_3) and phosphorus, a dramatic improvement in water quality of the Dead River is evident from the "before and after" study. The concentration of nitrate increased due to nitrification of the plant effluent, and although phosphorus limits for point sources are under consideration by NJDEP, currently there are no phosphorus removal requirements for the Passaic River.

A major component of nonpoint source pollution in the Passaic is benthic deposits. These deposits, which are the result of both natural conditions and previous wastewater discharges, can serve as a dissolved oxygen sink for years before they are fully oxidized or become buried in deep sediments. Nevertheless, the 1983-84 Passaic River Study did show evidence that a decrease in the oxygen demand of benthic deposits had occurred. This reduction was particularly significant at the station downstream of the Whippany River confluence which has historically shown high levels of SOD (a measure of DO consumption by sediments). In 1973, SOD at this station was measured as 10.1 to 12.8 g DO/m^2/day; in 1978, SOD was 1.4 to 3.6; and in 1983, the measured SOD ranged from below detection limits to 5.6 (both in situ and laboratory measures were employed). This improvement may be attributed, at least in part, to upgrading treatment at several POTWs (located upstream) and the removal of a large industrial discharge.

FUTURE STUDIES

The 1983-84 Passaic study was the first step in an ongoing project to assess water quality in the river. Future monitoring studies will include sampling for toxic constituents and biomonitoring for sediment and water column toxicity in the river. In addition, NJDEP hopes to conduct additional studies of SOD rates in the river since this parameter appears to be a dominant DO sink during low flow periods.

Material for this report was furnished by Dr. Shing-Fu Hsueh, Bureau of Water Quality Standards and Analysis, NJDEP; and Rosella O'Connor, U.S. EPA Region II.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460 (202) 382-7056.

United States Environmental Protection Agency
Monitoring and Data Support Division
Office of Water
Washington, DC 20460
February 1987

Water Quality Progress Report

Koshkonong Creek, Wisconsin

Over the past 5 years, the Wisconsin Department of Natural Resources (WDNR) has conducted more than 50 monitoring surveys to document water quality impacts resulting from the construction of new or upgraded wastewater treatment plants. The primary objective of these surveys is to ensure that water quality standards are being met; a secondary objective is to evaluate mathematical models that may have been used to assign effluent limits. Most of the surveys to date have been carried out on small streams where advanced wastewater treatment (AWT) was required.

WDNR has developed a streamlined procedure in which effluent and instream water samples are collected during a 1- or 2-day period of low stream flow both before and after the startup of a new or upgraded treatment plant. Biomonitoring is included in the procedure through the use of a macroinvertebrate screening survey. This survey is usually carried out during the spring and fall prior to, and 1 or 2 years after the improved treatment processes have been in use.

This report documents one such monitoring study, conducted on Koshkonong Creek in southern Wisconsin. This creek is one of many small streams that has been subject to gross organic pollution due to inadequate wastewater treatment. Construction of the new Sun Prairie publicly owned treatment works (POTW), an AWT facility with ammonia removal and tertiary sand filters, has brought about greatly reduced pollutant loadings and a corresponding improvement in ambient water quality.

THE STUDY AREA

Koshkonong Creek is a channelized stream draining 138 square miles near Madison, Wisconsin. The creek originates in the town of Sun Prairie (population approximately 14,000) and flows 42 miles through agricultural areas to join the Rock River. The creek is effluent dominated with most of the flow originating as the discharges from Sun Prairie's POTW and cooling water from two industrial facilities.

While much of Koshkonong Creek has been dredged and straightened to facilitate agricultural drainage, the stream has a very low gradient and many channelized portions are clogged by vegetation. Consequently, flow in the creek is sluggish, and most of the creek bottom is covered by a foot or more of silt. Figure 1 shows the configuration of the creek along with the locations of water monitoring stations used in the

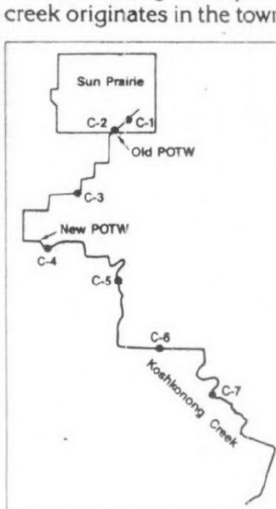


Figure 1. Koshkonong Creek showing the location of

Largely as a result of these physical constraints (channelization and low flow), the creek's current designated use, from the headwaters to station C-5, is "marginal surface water." As such, the stream is considered suitable for only very tolerant aquatic insects and forage fish. Below station C-5, the creek is designated for warm water sport fishing, full aquatic life, and surface water recreation such as canoeing.

PREVIOUS MONITORING STUDIES

Water quality monitoring conducted on Koshkonong Creek during the 1970's showed severe organic pollution below the original Sun Prairie POTW. This treatment facility was hydraulically overloaded and discharged high levels of biochemical oxygen demand (BOD) and nutrients into the creek. Because of the low natural stream flow, dilution of the wastewater was insignificant, and the concentrated organic wastes stimulated nuisance growths of filamentous bacteria extending nearly 4 miles below the plant. Samples of the macroinvertebrate population (bottom-dwelling aquatic and other organisms) also indicated very poor water quality below the former treatment plant.

Base flow samples collected in 1977 at station C-2 showed that the creek was often devoid of oxygen in the summer, with BOD reaching levels of 15 to 60 mg/L. While ammonia levels were normal in the short stretch of stream above station C-2, below that point, levels were quite high with an average concentration of 7 mg/L and a maximum of 14.5 mg/L ammonia. The 1977 survey also showed extremely high average values for conductivity, chloride, fecal coliforms, and total phosphorus.

"BEFORE AND AFTER" SURVEYS: CHEMICAL STUDIES

Water samples were collected in 1981 (before AWT operation) and in 1982 (after AWT operation) at one upstream station (C-1), the original POTW outfall (C-2), and 3 downstream stations (C-3, C-4, and C-5). Samples were analyzed at the Wisconsin State Laboratory of Hygiene.

Pre-operational Survey. Consistent with previous monitoring results, the 1981 pre-operational survey indicated significant water quality degradation. Assimilation of the high strength organic wastes lowered the upstream dissolved oxygen (DO) level of 8.5 mg/L to 2.5 and 3.4 mg/L at downstream sampling stations C-3 and C-4, respectively. At station C-5, approximately 6 miles below the former discharge point, the stream showed a partial recovery with a maximum DO concentration (noon reading) of 6.7 mg/L.

However, a significant daily fluctuation in DO levels was observed, particularly at station C-5. Here, an early morning concentration of only 0.9 mg/L was apparently caused by respiration of abundant aquatic plants at this location. At station C-3, the daily DO swing was less significant, probably because filamentous bacteria covered all available substrates. At C-4, the substrate was covered with a combination of filamentous bacteria and algae, and the DO fluctuation was of intermediate magnitude.

High fecal coliform and ammonia concentrations during the pre-operational survey also reflected polluted conditions below the former POTW. Upstream (station C-1) concentrations were 700 organisms/100 mL fecal coliforms and 0.06 mg/L ammonia. At C-3, fecal coliform and ammonia concentrations were 50,000 organisms/100 mL and 17 mg/L, respectively. At station C-5, which marks the starting point of the full fish and aquatic life classification zone, ceeded 1 6 mg/L to ensure a healthy environment for fish and aquatic life

Post-operational Survey. The new Sun Prairie POTW, with a capacity of 3 1 million gallons per day, was built to accommodate both municipal waste and substantial seasonal pollutant loading from a local cannery The facility began operating in December 1981, and the post-operational chemical survey was performed in July 1982 Effluent monitoring data showed that BOD and suspended solids concentrations had been reduced by 45 percent and 92 percent, respectively Total Kjeldahl nitrogen (TKN, a measure of organic nitrogen plus ammonia nitrogen) dropped from 23 mg/L to 1 1 mg/L

Water quality in Koshkonong Creek below the new wastewater treatment plant reflected the improved effluent concentrations. As shown in Table 1, BOD, TKN, and ammonia concentrations were low, and nitrate- plus nitrite-nitrogen ($NO_2 + NO_3{-}N$) concentrations were high. Decreased levels of TKN and ammonia and increased $NO_2 + NO_3{-}N$ concentrations show effective assimilation of nitrogenous wastes in the treatment plant

TABLE 1. Water Quality Improvement Downstream of Sun Prairie POTW (mg/L)

Station No.	Year	BOD	TKN	Ammonia nitrogen	NO_2 + NO_3–N
C-4	1981	8.0	12 0	9 5	0.15
	1982	3.3	0 8	0 06	6.7
C-5	1981	6.8	12 0	10 0	0 06
	1982	2 4	1 0	0 08	6 1

The increase in DO concentration, as well as the relative magnitude of the diurnal oxygen shift, is shown in Figure 2 The persistence of low nighttime DO levels is caused primarily by aquatic plant respiration although residual sludge deposits in the sediments also may contribute significantly to the total oxygen demand.

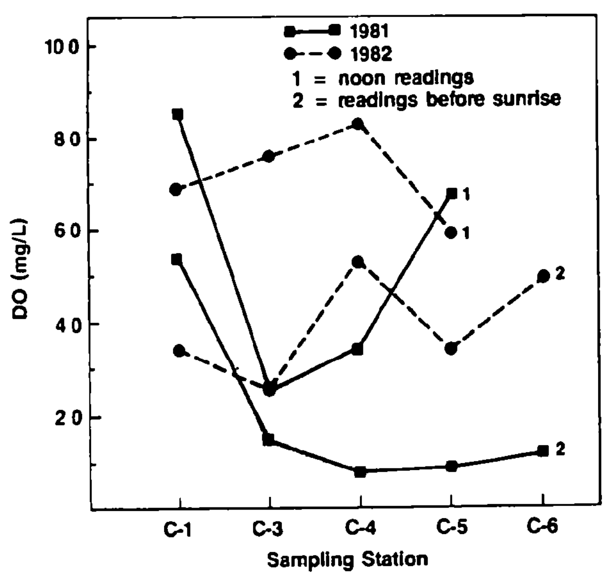


Figure 2. 1981 and 1982 diel dissolved oxygen measurements.

"BEFORE AND AFTER" SURVEYS: BIOMONITORING STUDIES

To further assess water quality improvements following startup of the Sun Prairie POTW, WDNR staff conducted biomonitoring surveys during the spring and fall of 1980 and 1983 Macroinvertebrates were collected (at the same sampling stations used during the chemical surveys) using a D-frame net and kick sampling to collect these bottom-dwelling organisms Samples were preserved in 95 percent ethyl alcohol in preparation for laboratory sorting and identification

Macroinvertebrate samples were used to determine the Hilsenhoff Biotic Index at each station. Developed by W L Hilsenhoff at the University of Wisconsin-Madison, this method uses the first 100 arthropods (insects, amphipods, and isopods) in a sample to evaluate the water quality of a stream The index values, which are based on the varying tolerances of different species to organic pollution, range from 0 to 5, with lower values reflecting better water quality A value of 0 is assigned to species found in pristine streams of high water quality, while a value of 5 indicates species tolerant of severe organic pollution The biotic index is an average tolerance value for the entire sample

Upstream of the POTW (station C-1), biotic index values of 2 88 to 3 74 indicated fair (1983) to poor (1980) water quality Such an unbalanced macroinvertebrate community reflects the intermittent and marginal characteristics of the Koshkonong Creek headwaters.

At station C-3, 1980 surveys resulted in biotic index values ranging from 4 63 to 5 0 These values indicated very poor water quality and severe organic pollution In all cases, the benthic macroinvertebrate communities were limited to two to four very pollution-tolerant species In one sample, only eight specimens could be found. Macroinvertebrate samples collected during the post-operational surveys showed a slight increase in pollution-intolerant species and greater species diversity Figure 3 shows the average biotic index values for the 1980 and 1983 surveys at each stream station The limited recovery of the macroinvertebrate community may be due in part to the continuing effect of abundant filamentous algae and macrophytes that consume available oxygen

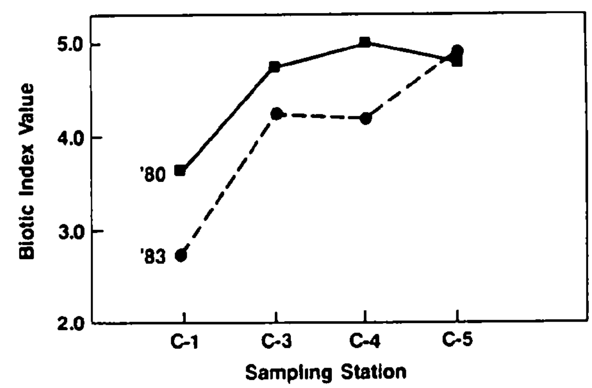


Figure 3. 1980 and 1983 average biotic index values.

The most obvious water quality improvement following completion of the new wastewater treatment plant was the elimination of filamentous bacteria in the stream Effective treatment at the new facility eliminated the nutrient rich conditions required for this growth, and as a result, algae and other periphyton typical of similar streams in the basin have returned to Koshkonong Creek

FUTURE IMPROVEMENTS

Koshkonong Creek is an example of a small stream that has been saved from gross organic pollution by the construction of a new POTW. While the physical characteristics of the stream may limit its biological quality, establishment of more diverse aquatic communities in the upper 8 miles of the creek is expected to occur over several years as sludge deposits are gradually reduced As this progress continues, WDNR will periodically review the stream's use classification for possible upgrading Additional improvements in the lower portions of the creek, which are classified for full fish and aquatic life uses, are expected as the quality of the upstream water is improved

Material for this report was furnished by Jerry McKersie, Chief, Evaluation and Special Projects, WDNR, Water Resources Management, Dave Marshall, WDNR Water Resources Management, Southern District, and Noel Kohl, U S EPA Region V

This report is produced by EPA to document progress achieved in improving water quality Contributions of information for similar reports are invited Please contact E F Drabkowski, EPA, MDSD, WH 553, 401 M Street S W, Washington, D C 20460 (202) 382 7056

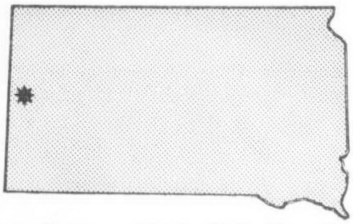
United States
Environmental
Protection Agency

Office of Water Regulations and Standards
Monitoring and Data Support Division
Washington, DC 20460

June 1987

EPA

Water Quality Progress Report



Whitewood Creek, South Dakota

Whitewood Creek flows for 32 miles through the Black Hills of South Dakota to its confluence with the Belle Fourche River. For over 100 years, the stream was polluted by mine tailings and mill wastes from a number of gold mining and milling operations and raw sewage from the towns of Lead and Deadwood. Although most mining companies had ceased operations in the area by 1920, the largest of them, Homestake Mining Company, continues to operate. Wastewater from the mine (containing, at various times, high levels of mercury, arsenic, cyanide, and other metals as well as suspended solids) effectively killed all life in the river and turned the Creek bleak grey in color. As far as 20 miles downstream from Whitewood Creek, the Belle Fourche River was devoid of aquatic life, and pollutants from these discharges were detected through nearly 200 river miles to the Missouri River. In 1972, Whitewood Creek was listed by South Dakota as "the most polluted stream in the State."

During the past ten years, South Dakota's Department of Water and Natural Resources (DWNR) and Department of Game, Fish and Parks (DGFP), as well as the Lead-Deadwood Sanitary District, the Homestake Mining Company (HMC), and the U.S. Environmental Protection Agency (EPA), have worked together to resurrect Whitewood Creek. Significant activities have included creekbed restoration, upgraded municipal wastewater treatment, the construction of a tailings pond and an innovative waste treatment process for cyanide and other heavy metals from the mine, and the use of toxicity testing by EPA and the State to diagnose remaining water quality problems in the river.

While the creek still shows some effects of past discharges, it has improved enough so that trout and other pollutant-sensitive species are now present throughout the stream. As a result of this progress, DWNR has considered nominating Whitewood Creek for inclusion in the State's system of Scenic and Recreational Streams.

GOLD MINING ON WHITEWOOD CREEK

Gold was discovered in the Black Hills in 1874 during an expedition led by Lt. Colonel George A. Custer. The first mine and mill were constructed in 1876, and HMC was incorporated in late 1877. Although mining and milling technology have changed over the last 100 years, the basic approach for obtaining gold has remained the same: underground rock containing the gold ore is pulverized to a fine sand and treated with chemicals to dissolve, then precipitate the metal. Early methods used mercury compounds to separate gold from the ore, but in 1970 HMC switched to a complete cyanidization process. Wastewater from the mine consists of both a tailings slurry (crushed rock that remains after the gold has been removed) containing the residual cyanide and other heavy metals and mine water from drilling, cooling, and other processes.

IMPLEMENTING CONTROLS

Following the passage of the Clean Water Act amendments in 1972, DWNR classified Whitewood Creek as a "cold water fishery" (suitable for reproduction and propagation of coldwater fish). In 1981, a comprehensive bioassessment conducted by HMC was used to reclassify the creek as a "cold water marginal fishery." This classification requires water quality that is suitable for stocked coldwater fish during portions of the year, but due to critical natural conditions (e.g., low flow, siltation, or warm temperatures) is not expected to support a permanent coldwater fish population.

HMC was issued an NPDES permit that required the company to drastically reduce its discharge of suspended solids, cyanide, and metal compounds in order to support the coldwater fishery standard. To reduce the discharge of suspended solids, HMC constructed a large tailings pond upstream of the mine using a dam 280 feet high and 1220 feet wide. The pond, which allows sediments to settle out prior to passage through a waste treatment plant, was completed in 1977 and won a national award from the Council on Environmental Quality and the Environmental Industry Council.

To investigate methods for treating its wastewater, HMC constructed experimental pilot plants as well as facilities to conduct bioassays on effluents from the different processes. However, many of the first attempts to chemically remove the cyanide failed. Homestake's engineers found that the metal complex cyanides used in the milling process (e.g., iron cyanide and copper cyanide) could not be removed using conventional cyanide treatment processes.

As a result of these initial difficulties, by 1980 Homestake was out of compliance with its permit and still without an effective treatment process. At this point a three-party consent decree signed by South Dakota, EPA, and HMC permitted the company to extend the deadline for NPDES compliance, but required the payment of $390,000 to begin the rehabilitation of Whitewood Creek. While the consent decree did not contain specific effluent limits for cyanide or other metals, all parties did agree on a common goal: that water quality should support the designated beneficial use of the waterbody.

Working under the consent decree, HMC began testing new treatment approaches, and in 1982 the company obtained encouraging results with a simple and cost-effective biological treatment process. Subsequent testing (using chemical analysis and onsite bioassays) proved the effectiveness of the process, and in August 1984 a full-scale treatment plant went on-line. The process, which has been patented by Homestake, uses a mutant strain of bacteria that has been acclimated to the high levels of cyanide found in the mine's effluent. (This bacterium, which has been designated *Pseudomonas mudlock*, is named after Homestake's chief environmental engineer and chief chemist, T. I. Mudder and J. C. Whitlock, respectively.) Water from the tailings pond is mixed with mine water and pumped to the treatment plant where the bacteria break down complex cyanides into comparatively harmless sulfates, carbonates, and nitrates. To handle the system's design capacity of nearly 5.5 million gallons of wastewater per day, the bacteria are attached to 48 rotating biological contactors (RBCs), each of which contains approximately 100,000 square feet of surface area. In addition to the RBC process, the plant also includes a sand filtration system (for the removal of remaining suspended solids).

WATER QUALITY IMPROVEMENTS

Data provided by DWNR's fixed station monitoring and by HMC's own instream monitoring network showed dramatic water quality improvements following the implementation of controls.

Suspended Solids. During the two years prior to completion of the tailings pond, total suspended solids in Whitewood Creek just below the mine's outfall averaged approximately 62,000 mg/L. During 1978 and 1979, after the pond was in use, monitoring at the same station showed suspended solids levels of approximately 120 mg/L. These concentrations were reduced even further during the 1980s by using sand filtration; in 1985, the average instream concentration at this station was 9 mg/L.

Cyanide. Instream cyanide levels (measured as total cyanide) fell sharply in 1984 and 1985 following the start-up of HMC's RBC treatment system. Table 1 shows the annual average cyanide levels measured at two sites downstream of the outfall. During the same period, background cyanide concentrations (measured at stations upstream) remained nearly constant at 0.01 mg/L.

TABLE 1. Annual Average Cyanide Concentrations Below the Homestake Outfall (mg/L)

Station	1981	1982	1983	1984	1985	1986
CS28GR[a]	—	—	2.02	1.33	0.18	0.35
WQM85[b]	0.87	0.25	0.20	0.13	0.06	0.08

[a] Monthly samples taken by HMC just below the outfall.
[b] Quarterly samples taken by DWNR 4 miles below the outfall.

Copper. Copper as well as other heavy metals were present in the HMC wastewater, and these also have been reduced through the biological treatment process. The bacteria absorb significant quantities of the metals during their lifetime, after which the organic residue is recycled to the tailings pond. Table 2 summarizes annual average copper concentrations upstream and at two stations below the mine discharge. At present, South Dakota has not developed a water quality standard for copper; however, it should be noted that the waters in this region are extremely hard (Whitewood Creek ranges from 500 to 800 mg/L hardness) so the relative biological availability of total copper is low.

TABLE 2. Annual Average Copper Concentrations Above and Below the Homestake Outfall (μg/L)

Station	1981	1982	1983	1984	1985	1986
WQM86[a]	2.4	4.0	<10	7.5	6.0	<13
SC35BS[b]	—	300	227	86.9	21.0	28.5
WQM85[c]	414	120	94	55.	33.	38.

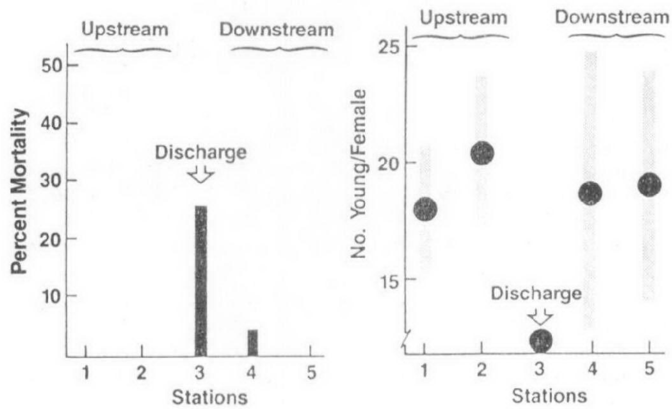
[a] Background concentrations measured upstream of HMC outfall; quarterly samples by DWNR.
[b] Sampling station located 1 mile below HMC outfall; monthly samples by Homestake Mining Co.
[c] Sampling station located 4 miles below HMC outfall; quarterly samples by DWNR.

BIOMONITORING

Under a cooperative arrangement, South Dakota DWNR and EPA Region VIII have conducted surveys of ambient water toxicity in the area surrounding Homestake's discharge. Using an easily cultured macroinvertebrate *(Ceriodaphnia sp.)*, tests were run in July 1983, and again in November 1984, several months after the new treatment plant had come on-line.

In 1983, two series of tests were conducted. Initial screening tests used undiluted water taken from six sites—three upstream and three downstream of the mine discharge. The results of these tests were unequivocal: organisms placed in the upstream water were unaffected, while all downstream samples resulted in 100 percent mortality. Dilution tests were then carried out using samples from the three downstream sites. These tests resulted in the following estimated toxicities expressed as a 48-hour LC_{50} (the concentration of sample that is lethal to 50 percent of the test organisms over 48 hours): at the point of discharge, the LC_{50} was less than 10 percent (i.e., organisms could not survive in a mixture containing 10 percent streamwater and 90 percent upstream dilution water); downstream from the discharge, just after mixing, the LC_{50} was 25 percent; and 100 yards further downstream the LC_{50} was 65 percent.

During post-treatment bioassays (November 1984), more sophisticated studies were undertaken to test chronic and reproductive effects below the outfall. Figure 1 illustrates the dramatic recovery below HMC's outfall. While in 1983, *Ceriodaphnia* could not survive in samples taken downstream of the outfall, by 1984, over 70 percent of the organisms survived in pure mine effluent—station 3—although they could not reproduce. At stations 4 and 5, just downstream from the discharge, they lived and reproduced as well as organisms tested in water from upstream, stations 1 and 2.



Source: U.S. EPA Region VIII

Figure 1. Cumulative mortality (left) and reproductive capabilities (right) of *Ceriodaphnia* at stations upstream and downstream of the Homestake discharge (station 3), November 1984.

Additional evidence of water quality progress has been provided by the return of trout to Whitewood Creek below the Homestake mine. Although fish were present in waters upstream of the discharge prior to waste treatment, they would not pass below the outfall. Within a month after the full treatment process was underway however, biologists documented the presence of wild brook trout below the outfall. By early spring of 1985, when DGFP added Whitewood Creek to its regular stocking program, the numbers of brook and brown trout were increasing steadily.

FUTURE STUDIES

Future monitoring studies in Whitewood Creek will be concerned with elucidating the relative toxicities and degradation rates for the different components of total cyanide. While it appears that free cyanide is the most toxic component, this is also the one that *Pseudomonas mudlock* prefers. However, other components (e.g., iron cyanide) contained in the Homestake effluent may be broken down instream to release weak-acid dissociable cyanide, which is also toxic. For this reason, Homestake's revised NPDES limits (to be determined in November 1987) may be expressed in terms of both total and weak-acid dissociable cyanide. These limits will be based, in part, on extensive chronic toxicity tests conducted onsite by Homestake's biologists using fish and invertebrates found in the Whitewood Creek Basin.

Material for this report was furnished by Joe Bower, South Dakota DWNR, Office of Water Quality; Fred Fox, Environmental Director, and Ronald Waterland, Environmental Technician, Homestake Mining Company; and Del Nimmo, U.S. EPA Region VIII.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, D.C. 20460 (202) 382-7056.

United States
Environmental
Protection Agency

Assessment and Watershed Protection Division
Office of Water
Washington, DC 20460

April 1991

EPA

Water Quality Progress Report

Duwamish River, Washington

The Duwamish River is vital to Washington's commerce as a primary navigational route, a major contributor to the State's salmon and steelhead trout industry, and a potentially attractive recreational resource. It is influenced by tidal action over its lower 10 miles and is the principal source of fresh water to Elliott Bay, near Seattle. The lower 6 miles of the once meandering river is now a straightened navigational channel (the Duwamish Waterway) that flows through a heavily industrialized area of Seattle where airplane factories, shipyards, metal scrap yards, oil tank farms, and port facilities are located (Figure 1).

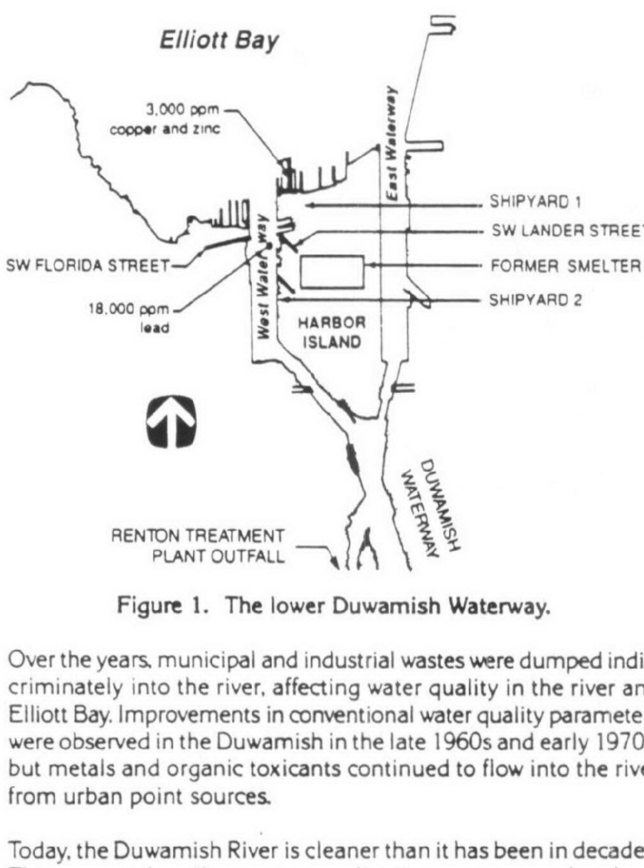


Figure 1. The lower Duwamish Waterway.

Over the years, municipal and industrial wastes were dumped indiscriminately into the river, affecting water quality in the river and Elliott Bay. Improvements in conventional water quality parameters were observed in the Duwamish in the late 1960s and early 1970s, but metals and organic toxicants continued to flow into the river from urban point sources.

Today, the Duwamish River is cleaner than it has been in decades. This report describes water quality improvements that have resulted from use of an innovative approach to identify toxic chemical contamination from urban nonpoint sources in the lower Duwamish watershed.

ASSESSING THE PROBLEM

When trace metal concentrations in the waterway were first measured in 1971, researchers found lead concentrations that were some of the highest recorded in western Washington waters. High concentrations of other metals were also identified, and there was concern that these metals put migratory fish, birds, mammals, and other estuarine organisms at risk. Researchers first assumed that the metals present in the water were contributed primarily by the Renton Treatment Plant (RTP) effluents and by untreated sewage mixed with stormwater runoff discharged by combined sewer overflows. However, in 1979 it was demonstrated that RTP effluent was not a major source of metals present in the river. Other known point sources of metals were industrial wastewater discharges permitted under the National Pollutant Discharge Elimination System (NPDES) program administered by the Washington Department of Ecology (Ecology). However, these permitted discharges were limited to stormwater runoff and noncontact cooling water. Known metal loadings from these point sources could not account for the high metal concentrations observed in the river.

Thus, it appeared that nonpoint sources continued to degrade the river's water quality. Because of the river's commercial and aesthetic value, EPA and Ecology designated the Duwamish a high-priority area for study and action. A Clean Water Act Section 208 grant was awarded to the Municipality of Metropolitan Seattle (Metro) in 1979 to inventory pollutants entering the river and to develop an abatement program.

WATER QUALITY AND SEDIMENT MONITORING STUDIES

In the early 1980s, water quality studies conducted during low flow months (July-September) revealed that copper concentrations exceeded the EPA acute freshwater criterion (18 μg/L) and lead concentrations exceeded the EPA chronic freshwater criterion (3.2 μg/L). The highest concentrations of metals (e.g., lead, copper, arsenic, zinc, mercury, and cadmium) and other contaminants were found unevenly distributed in the sediments of the Duwamish Waterway, which suggested that contaminants from localized sources were contributing to the formation of "hot spots." Sediments near a storm drain outfall in the West Waterway (Figure 1) were found to contain 18,000 ppm lead. Lead concentrations decreased away from the storm drain outfall. At another site off Harbor Island, copper and zinc concentrations were as high as 3,000 ppm in marine sediments (Figure 1).

Metro continued investigating industrial discharges along the waterway to identify chemical use and disposal at facilities that might contribute contaminants to stormwater runoff. EPA and Ecology assisted Metro with regulatory actions [e.g., revised permit requirements, best management practices (BMPs), fines] at facilities with pollution problems.

METRO'S STORM DRAIN ANALYSIS

In 1984, Metro received a Clean Water Act Section 205(j) grant, which was used to conduct an innovative sediment sampling program in storm drain systems. Storm drain sediment sampling is easier and more efficient than direct monitoring of stormwater discharges, for these reasons. First, sediments in storm drains represent an accumulation of contaminants over time, whereas a stormwater sample represents contaminant input to a system only at a given point in time. Second, toxicants are easier to detect in storm drain sediments than in stormwater samples. Third, sediment sampling efforts do not need to be coordinated with rainfall events.

Metro collected sediment samples from the low energy sections (i.e., manholes) of 12 municipal storm drain systems that discharged to the Duwamish Waterway. These samples were analyzed for metals, organic compounds, and conventional contaminants.

Sediments within four drainage systems contained substantially higher concentrations of contaminants than those found in street dust in the area. Additional sediment samples were collected and pollutants were tracked up through the drain systems until, by process of elimination, the sources were identified.

At a storm drain on Southwest Lander Street, a major source of lead to the river was discovered (Figure 1). Storm drain sediment samples containing 350,000 ppm lead, or 35 percent lead, were found in a storm drain adjacent to a former smelter that had recovered lead from used batteries. Metro, Ecology, EPA, and the City of Seattle removed over 20 cubic yards of contaminated sediments from the line and sent them to a recycler.

In a storm drain on Southwest Florida Street, which empties into the West Waterway, high concentrations of creosote, pentachlorophenol, copper, and arsenic were traced to a wood-treatment facility (Figure 1). The company later pleaded guilty to charges of illegal dumping. High concentrations of PCBs in the same storm drain system were traced to a scrap yard that recycled old PCB-containing electrical transformers. Contaminated storm drain sediments were removed and shipped to a hazardous waste disposal facility.

SUCCESS OF THE STORM DRAIN MONITORING APPROACH

Cleanups of sediments in storm drain systems and reductions in contaminant inputs from industrial facilities eliminated major sources of contamination to the Duwamish Waterway. Researchers found lower contaminant concentrations in subsequent storm drain sediment sampling efforts. In 1989, sediments in the Southwest Lander Street line contained 10,000-50,000 ppm lead, which is substantially lower than the 350,000 ppm lead found in 1984 (cleanup at the former lead smelter is still in progress).

One can assume that the removal of contaminated sediments from a storm drain system would reduce contaminant input from the system to the Duwamish Waterway and Elliott Bay. However, it is difficult to monitor nonpoint sources of pollutants and thus evaluate the effectiveness of pollution abatement programs.

To evaluate the success of this cleanup program, net loadings of metals (lead, copper, and zinc) from the Duwamish Waterway to Elliott Bay were quantified using data collected by NOAA from 1980-1986. Dissolved metal concentrations, salinity, and flow were measured in the water column near the mouth of West Waterway, where the majority of the river flow is discharged, and throughout Elliott Bay. NOAA calculated net loadings of trace metals using a water transport model. Researchers knew that the net loading of metals to the bay included metals discharged directly from industrial sources and from the RTP outfall, plus metals naturally present in the Duwamish River. Therefore, to determine net loadings of metals from industrial sources to the river (Figure 2), NOAA subtracted known metal loadings from the RTP and natural metal loadings in the river from the calculated total loadings.

NOAA found that metal concentrations measured in the water column at the mouth of the West Waterway were far less than those found in early 1970 studies. Dissolved lead concentrations at the mouth of the West Waterway were 0.047 μg/L in 1985 and 0.041 μg/L in 1986, which is dramatically less than lead concentrations of 5.4 μg/L found in 1971. Lead reductions may be attributable to several factors. Between 1981 and 1985, the lead smelter ceased operations and initial remedial actions were completed at the site. The decreased dissolved lead concentrations in the waterway following these actions, and the calculated net loadings of lead from industrial sources suggest that these initial control measures were effective in reducing dissolved lead discharges from industrial sources.

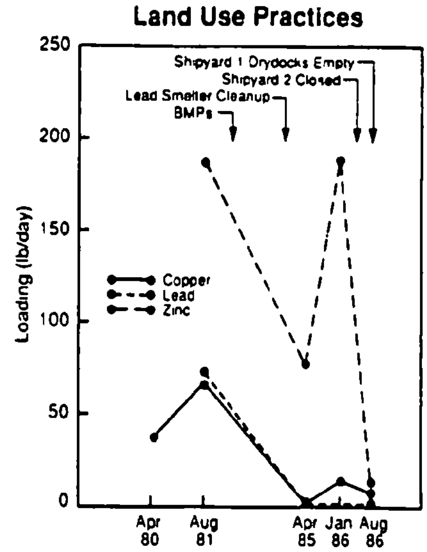


Figure 2. Industrial metal loadings from the Duwamish River to Elliott Bay (NOAA).

Data on copper suggest that voluntary BMPs undertaken by two shipyards prior to January 1986 were not totally effective in reducing net loadings of dissolved copper to Elliott Bay. Between January and August 1986, one shipyard closed for economic reasons. Activities at a second shipyard were reduced substantially, and mandatory BMPs were instituted.

In contrast to changes in lead and copper loadings, little change in the net loadings of dissolved zinc from industrial sources was observed between the August 1981 and January 1986 samples. These data suggest that voluntary and mandatory BMPs at the shipyards were ineffective in reducing net loadings of dissolved zinc. However, activities at the shipyards were decreasing between January 1986 and August 1986, and loadings of dissolved zinc from industrial sources to Elliott Bay were reduced by 92 percent from 194 lb/day to 15 lb/day. Alternatively, investigative work conducted by Ecology, which resulted in the implementation of BMPs at other contaminant sources (e.g., salvage yards), may have resulted in reduced loadings of zinc to the waterway.

FUTURE ACTIVITIES

Local agencies are continuing to explore options to further reduce contaminant inputs to the Duwamish River. Although water quality has improved in the river, bottom sediments in the river and bay have been contaminated with toxic substances for many years. Agencies are currently identifying potential remedial alternatives (e.g., dredging, detoxification, in-place capping) for the contaminated sediments. In the near future, the Washington Urban Storm Water Management Program will be implemented to reduce contaminant inputs. One of its key provisions will be to issue NPDES permits to cities for urban stormwater discharges.

Materials for this report were furnished by Tom Hubbard, Municipality of Metropolitan Seattle (Metro), Tony Paulson, NOAA Pacific Marine Environmental Laboratory; John Armstrong, EPA Region X Office of Puget Sound, and Lee Dorigan and Dan Cargill, Washington Department of Ecology.

This report is produced by EPA to document progress achieved in improving water quality. Contributions of information for similar reports are invited. Please contact EPA, AWPD, Monitoring Branch, WH 553, 401 M Street S.W., Washington, DC 20460 (202) 382 7056

EPA | United States Environmental Protection Agency | Monitoring and Data Support Division Office of Water Washington, DC 20460 | April 1986

Water Quality Program Highlights

New York State's Wasteload Allocation Procedure

Section 303(d) of the Clean Water Act requires States to identify as water quality limited: "those waters . . . for which effluent limitations . . . are not stringent enough to implement any water quality standard applicable to such waters." For each water so identified, States are required to establish "the total maximum daily load for those pollutants that the Administrator identifies under section 304(a)(2) as suitable for such calculation." Using the total maximum daily load (TMDL), States assign individual wasteload allocations (WLA) for point sources along water quality limited segments.

NEW YORK'S WATER QUALITY PERMIT PROGRAM

The New York State Department of Environmental Conservation (NYSDEC) Division of Water administers approximately 3,300 NPDES permits for surface water dischargers. Of these, approximately 1,600 are classified as "significant" dischargers; this group includes all publicly owned treatment works (POTWs), industrial plants, and any other discharge that contains toxic pollutants. All significant permits are processed by permit writers and water quality analysts at the State offices in Albany. The remaining 1,700 permits are predominantly concerned with conventional pollutant limits, and these are processed and issued directly by one of the nine Regional Offices around the State.

The central feature of New York's water quality-based permit program is the list of Ambient Water Quality Standards and Guidance Values, which serves as a basic resource in the State's regulatory and permit-writing activities. The list contains quantitative water quality criteria (based on either aquatic life or human health protection) for approximately 210 toxic and nonconventional pollutants. At the present time, criteria values for about half of these substances have been codified as regulatory standards. The remaining criteria termed "water quality guidance values," are used pending completion of the administrative and review process specified for standards development; once this process is complete, all guidance values will be adopted as water quality standards. As new substances of concern undergo sufficient review, additional guidance values are developed.

In addition to the list of ambient standards and guidance values, the State has also developed "threshold criteria" for screening effluent concentrations of toxic and nonconventional pollutants. Existing threshold criteria for toxics are 1.0 lb/day for total (or total recoverable) metals, total cyanide, total phenols, volatiles, and acid and base/neutral compounds; and 0.001 mg/L for pesticides. Threshold criteria for nonconventional pollutants cover cyanide amenable to chlorination, sulfide, total residual chlorine, fluorides, and other "Substances of Concern."

Where existing or expected discharge levels exceed the threshold criteria, then a BAT/BPJ determination must be made and a technology-based limit established for that pollutant. (This limit may be superseded if the pollutant is found to be water quality limiting.)

Where a threshold pollutant is present in an effluent, but does not exceed the criterion (i.e., does not warrant additional technological controls), then an "action level," along with specific monitoring requirements, is included in the permit. The action level is not a discharge limitation, but rather a numerical reporting level developed using a specified methodology to obtain a multiple of the reported concentration. If the action level is exceeded, the permittee is required to undertake a more intensive monitoring effort; where action levels are consistently exceeded, the permit may be reopened to specify either an effluent limitation or a revised action level.

Thus, for any effluent that contains toxic or nonconventional pollutants, a permit is developed using action levels, technology-based limits, or water quality-based limits.

WASTELOAD ALLOCATION PROCEDURES IN NEW YORK

Oxygen-Demanding Substances. For oxygen-demanding substances, TMDLs/WLAs are calculated using mathematical water quality (dissolved oxygen) models. These models apply to specific waterbody segments, and whenever possible, they are calibrated and verified using site-specific survey data. Where appropriate, dissolved oxygen models consider the following factors: reaeration; photosynthesis; aquatic plant respiration; biological oxygen demand; carbonaceous/nitrogenous oxygen demand; sediment oxygen demand; and advection and diffusion.

For oxygen-demanding substances, the TMDL is essentially equivalent to the waste assimilative capacity of the water during a critical period. Assimilative capacity analyses are conducted using the minimum average 7-day flow with a recurrence interval of 10 years (7Q10 low flow). Unless temperature records at the design flow are available, models assume a critical temperature of 25 °C for non-trout waters and 24 °C for trout waters. Complete mixing is assumed for discharges to riverine systems.

Where the waste assimilative capacity is exceeded, and minimum technology-based treatment has been implemented for all dischargers, then the segment is classified as water quality limited. Wasteload allocations are assigned using the following principles:

- Reductions are required of the discharger(s) that most directly and significantly affect the dissolved oxygen violation.
- For multiple discharges, allocations are proportioned according to the relative contribution to the oxygen deficit at the point of violation. Consideration is given to costs and the degree of treatment required by each discharger.
- New discharges that cause a segment to become water quality limited are required to bear the full burden of maintaining water quality standards (provided other dischargers meet minimum technology-based treatment levels.)
- Water quality-based allocations are generally written as seasonal limits for the period June 1 through October 31, unless conditions indicate that a different time period would be appropriate.
- Effluent limits may be expressed as 7-day average and/or 30-day average for conventional pollutants depending on the sensitivity of the waste assimilative capacity analysis.

Toxic Substances. For toxics and nonconventional pollutants, the maximum allowable load for each water pollutant is determined for an entire river basin. The State has 17 river basins, and an average basin might contain 10 pollutants that are water quality limiting (some basins may have 20, others only 2 or 3). TMDLs/WLAs are developed by assuming that all toxic substances behave conservatively (i e , that there are no losses due to degradation, settling, adsorption, or volatilization)

To provide some balance to the assumption of no instream losses, nonpoint source contributions and background levels in the water are assumed to be zero, unless river basin or stream-specific data are available In most cases, downstream concentrations are calculated using a standard mass balance equation, sometimes referred to as the point-of-discharge-dilution model In a few cases where site-specific data are available, nonconservative modeling techniques may be used.

Figure 1 illustrates New York's TMDL/WLA process for substances other than oxygen-demanding wastes The procedure begins with the State's technology determination or action levels, which are specified as loading rates in lb/day Minimum technology-based treatment must be specified (BAT, secondary treatment, BPJ) If threshold values are not exceeded, toxics are still included in permits as action levels Where threshold values are exceeded and the substance appears on the State's list of standards and guidance values, then the analyst goes on to determine whether the substance is water quality limiting For substances that are not listed, minimum technology-based limits are assigned, and the State may require effluent toxicity testing

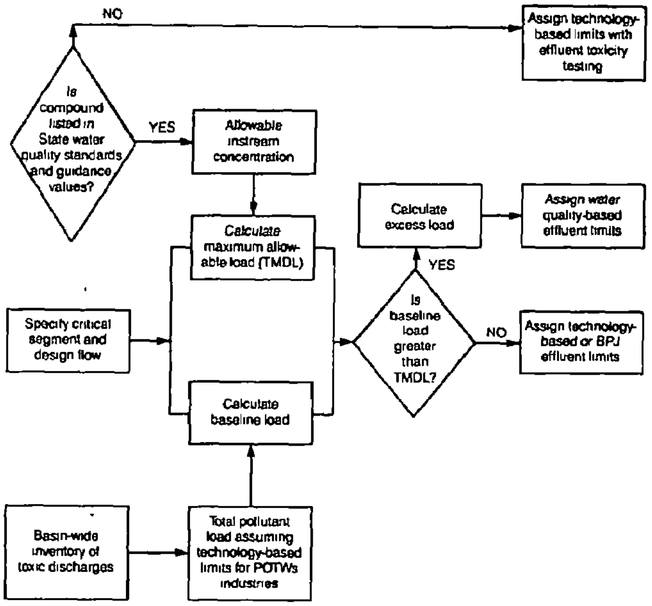


Figure 1. TMDL/WLA process for toxics in New York State.

To support its basin-wide toxics allocations, NYSDEC has developed an inventory of the toxics discharged in each of the State's 17 drainage basins Sources of information for the inventory include current and proposed permits, pretreatment analyses, discharge monitoring reports, compliance sampling, and industrial chemical surveys The computerized inventory lists each discharger with its associated parameters and effluent concentrations Then, when a new discharge permit or a permit modification is received, water quality staff can quickly assess the changes in total loading for a given pollutant

Each toxic pollutant is regulated according to its concentration in a "critical segment" The critical segment is defined as that portion of the basin where water quality classification or standards are most stringent Allowable pollutant load in this segment is calculated using the 7Q10 flow for standards that protect for aquatic life, and the 30Q10 flow for standards that protect for human health Where standards exist for both human health and aquatic life, the more stringent is applied

Using the appropriate water quality standard (or guidance value) and streamflow in the critical segment, the analyst calculates the maximum allowable load (for each pollutant) for that segment. Then a "baseline load" is calculated for each substance The baseline load calculated for the critical segment reflects expected loading following the adoption of technology-based treatment by all industries and municipalities Where technology-based limits are not specified for a particular substance, the "action-level" concentration is used to calculate baseline load

Comparing the baseline load with the maximum allowable load results in a determination of whether the basin or stream segment is water quality limited or effluent limited for each pollutant Where the waterbody is effluent limited, discharge limits are developed using technology-based requirements For each substance for which the basin is water quality limited, wasteload allocations are established as follows·

- At the critical water quality limiting segment, the baseline load is compared to the maximum allowable load The amount by which the baseline load exceeds the allowable load is the "excess load"
- The excess load is allocated among dischargers in the ratio of a discharger's baseline load to the total baseline load
- Individual effluent limits are set as the difference between the discharger's baseline load and their proportion of the excess load
- The water quality-based effluent limit for a specific substance is expressed as a maximum daily value when the criterion is based on 7Q10 flow The water quality-based effluent limit for a specific substance is expressed as a 30-day average value when the criterion is based on 30Q10 flow
- For certain waterbodies, naturally occurring or man-made conditions may preclude the technical development and defensibility of a water quality-based effluent limit for a specific toxic substance In these situations, technology-based limits and effluent toxicity testing are considered as a permit requirement in lieu of a water quality-based limit
- Where a standard or criterion value does not exist for a substance, technology-based limits along with effluent toxicity testing are again considered

PROGRAM PROGRESS

During the fiscal year October 1984 through September 1985, New York State reviewed about 1,000 discharge permits Of these, NYSDEC's Central Office in Albany reviewed 270 significant permits to check permit limits against TMDL criteria The remaining permits concerned conventional limits and were reviewed by the State's Regional Offices In FY 86, the State expects to calculate or check approximately 2,500 wasteload allocations for both toxic and nontoxic pollutants This number is based on an average of 250 permits per year that contain water quality limited parameters multiplied by an average of 10 water quality parameters for each permit.

Material for this report was furnished by Albert W Bromberg, Chief, Water Quality Evaluation Section, NYSDEC and Robert Vaughn, U S EPA, Region II Technical and Operational Guidance Series (TOGS) memorandums issued by NYSDEC, 50 Wolf Road, Albany, NY 12233 contain the standards and guidance values as well as specific guidance concerning procedures discussed in this report.

This report is produced by EPA to highlight monitoring and wasteload allocation activities Contributions of information for similar reports are invited Please contact E F Drabkowski, EPA, MDSD, WH-553, 401 M Street S W, Washington, D C 20460 (202) 382-7056

EPA

United States
Environmental
Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

July 1986

Water Quality Program Highlights

The Delaware River Cooperative Monitoring Program

The Delaware River forms the boundary between Pennsylvania, New York, and New Jersey, and water quality management in the area is the shared responsibility of a dozen or more State, local, and federal environmental and public health agencies. In addition to the States, the Delaware River Basin Commission (DRBC), a federal-interstate agency, has jurisdiction throughout the river basin, and the National Park Service (NPS) operates within the boundaries of two scenic river areas.

Location of Study Area

In 1984, the DRBC and the NPS initiated a cooperative water monitoring program focusing on the upper and middle sections of the Delaware River. These two sections include the Upper Delaware Scenic and Recreational River (UDSRR) and the Delaware Water Gap National Recreation Area (DWGNRA), both of which are part of the National Wild and Scenic Rivers system. Together these two reaches, administered by the NPS, span nearly 120 river miles in the three States and provide fishing, boating, and swimming recreation for over 300,000 visitors annually.

Prior to initiation of the monitoring program, water quality in both the Delaware and in most tributaries was thought to be good due to the rural nature of the area. However, this assumption was based on scattered, infrequent monitoring or on occasional special-purpose water quality studies. The three States maintained only four routine (fixed) monitoring stations along the upper and middle Delaware River, and only 6 out of 75 tributaries were monitored. Because of this, it was determined that a coordinated monitoring program was necessary to provide a consistent flow of water quality data.

DEVELOPING THE MONITORING PROGRAM

To make the best use of existing resources and skills, a water quality "screening" approach was developed with monitoring responsibilities shared between the DRBC and the NPS. The program uses a limited number of parameters, but relies on frequent sampling at numerous locations, and follow-up surveys (where necessary) to provide the greatest amount of useful information at the lowest cost.

The cooperative monitoring program was designed to expand monitoring activities in three ways:

- Sampling was to be extensive (rather than intensive), covering, to the extent possible, numerous Delaware River locations and all significant tributaries during the 3-month recreational season.
- Sampling was to be frequent (biweekly for many locations) because water quality can vary rapidly over time.
- Data turnaround was to be rapid so the program could respond quickly to potential public health problems.

MONITORING PARAMETERS

The parameters selected for screening water quality were fecal coliforms and fecal streptococci, water temperature, dissolved oxygen, pH, conductivity, and species diversity (macroinvertebrates). Rainfall information is readily available from other agencies and was not collected by the program itself. Stream flow measurements are being phased in over time.

These eight parameters yield additional data when they are used together. The ratio of the two fecal bacterial parameters serves as an indicator of possible human sewage contamination. Water temperature and dissolved oxygen data are used to calculate the percent dissolved oxygen saturation. Saturation information, in conjunction with pH data, is used to assess aquatic plant activity. Finally, information obtained from macroinvertebrate analyses is converted to one or more biological indices that serve as a surrogate for measuring the presence of toxics.

Biological monitoring focuses on benthic macroinvertebrates. All river samples and several tributary samples are analyzed taxonomically; a computer program is then used to calculate the Species Diversity Index value and the equitability number for each sample. For other tributaries, the Sequential Comparison Index, a technique that is relatively simple, fast, and usable by nonbiologists, is applied.

LOCATION AND FREQUENCY OF SAMPLING

In 1984, the cooperative monitoring effort was implemented on a trial basis in the DWGNRA. This approach proved to be highly successful, and in 1985, a decision was made to expand the program into the UDSRR. During May through September 1985, a total of 88 locations were sampled (24 river stations, 64 tributaries). In almost all cases, tributary sampling stations were located near confluences with the Delaware River.

With the exception of three designated swimming areas, which were sampled weekly, nearly all stations were sampled every other week. During the 1985 sampling season, 550 station-visits were carried out by DRBC and NPS personnel. In addition, seven follow-up surveys were performed in response to data findings. Follow-up surveys, which generally involve more intensive sampling in a limited area, have been used to locate specific sources of agricultural and urban runoff and natural causes of water quality problems as well as point source problems.

USE OF PARAMETERS TO SCREEN WATER QUALITY

The primary purpose of the screening program is to determine the need for water quality management actions. These actions can be short-term (e.g., closing a bathing beach or initiating an intensive survey) or long-term (e.g., establishing pollution control priorities).

Although questions have been raised about their public health implications, fecal coliform (FC) and fecal streptococcus (FS) remain excellent indicators for screening pollution in a watershed. For example, completely undeveloped watersheds show bacteria levels that are very low. In other watersheds with varying levels of development, streams have correspondingly higher bacteria levels and FC/FS ratios. In this way mean fecal coliform and FC/FS values tend to "fingerprint" the level of development in a watershed. By sampling frequently for these parameters, it is possible to compare similar watersheds to screen for potential water quality problems. By contrast, monthly, quarterly, or even intensive surveys rarely "catch" the almost random nature of bacterial fluctuations or the "fingerprints" of typical watersheds.

Frequent data collection under varying dry and wet conditions also serves to pinpoint problems. For example, two impaired tributaries in the study area are Brodhead and Cherry Creeks Brodhead Creek receives discharges from two overloaded sewage treatment plants, a combined storm and sanitary sewer system, and several industries Its watershed also contains large second home and resort developments Data from Brodhead Creek show that bacterial levels and FC/FS ratios increase dramatically following rainfall, indicating that these pollutants may originate from nonpoint sources and/or bypasses of untreated sewage. Conversely, Cherry Creek's bacterial levels and FC/FS ratios increase during low flows, indicating a chronic problem caused by raw sewage discharges (there is one municipality located in this watershed).

Based on DRBC-NPS fecal bacterial data, wastewater treatment improvement projects have been accelerated in both the Cherry and Brodhead Creek watersheds. The DRBC-NPS cooperative monitoring program continues to alert State and local jurisdictions when problems arise, particularly problems resulting from point source discharges that may require intensive analyses including effluent sampling and toxicity testing The New York State Department of Environmental Conservation, for example, is planning a survey of Callicoon Creek in 1986 as a result of screening data that showed higher-than-expected levels of bacteria.

Dissolved oxygen measurements are most valuable when used in conjunction with water temperature to calculate percent saturation, which is generally a measure of aquatic plant activity (photosynthesis) This is verified by corollary increases in pH values. During 1985, drought management activities led to drastic reductions in reservoir releases and resulting flows downstream. Monitoring data demonstrated that a major impact of the altered reservoir operations was increased aquatic plant activity and violations of the pH standard (above pH 9) during daylight hours In response to these observations, measurements were conducted at night to determine if increased plant respiration during the night was causing violations of dissolved oxygen standards. The data showed large drops in dissolved oxygen levels, but standards were not violated.

Conductivity is another parameter that appears to "fingerprint" the amount of development in a watershed Generally, conductivity values increase with the degree of human activity in a watershed Monitoring in one DWGNRA stream, White Brook (a mostly undeveloped watershed), showed consistently high conductivity compared to streams with similar levels of development and physical characteristics It was speculated that a landfill might have been located in the watershed during clearing operations for a recreation area in the early 1970's A follow-up investigation was completed that determined that the cause of the high conductivity was natural—a small limestone formation traversed the basin in the headwaters Still, the ability to identify potential water quality problems and to determine their origins is evident.

DETERMINATION OF MONITORING PRIORITIES

An important initial objective of the cooperative monitoring program was to collect baseline water quality for as many tributaries and river locations as possible. To accomplish this, many stations were sampled five or more times during the 1984 and 1985 sampling seasons—a level that could not be sustained over the long run given available resources To define a more efficient monitoring strategy for 1986, the DRBC developed a method for determining reach-by-reach priorities.

The method selected divides the 120-mile study area into 10 segments, varying from 8 to 20 miles in length The 10 segments were determined by evaluating hydrology, land use, extent of urbanization, known or suspected problems, and access points along the river. Then, the segments were ranked in order of priority using the rating system shown in Figure 1

Based on the distribution of the scores, segments scoring greater than 4 are considered highest priority. Three segments qualified as high priority segments and, along with significant tributaries, will be the

A WATER QUALITY IMPACTS	
• Potential for problems	(1 point)
• Problems known	(2 points)
• Possible problem warrants investigation	(3 points)
B DEGREE OF URBANIZATION	
• No significant urbanization	(no points)
• Small town type of urbanization	(1 point)
• Significant urbanization	(2 points)
C PUBLIC BATHING OR WATER RECREATION AREA	
• Yes	(1 point)
D AVERAGE NUMBER OF TRIBUTARIES PER MILE	(fraction)

Figure 1. Criteria for rating monitoring priorities on designated segments of the Delaware River.

subject of intensive surveys, and macroinvertebrate studies will be conducted in two locations in each segment Four segments scored between 2 and 4 and are considered second priority; these will be sampled biweekly to monthly, with one location subject to biomonitoring. Low-priority segments (with scores below 2) are to be sampled only once, with other monitoring to be conducted as time and resources permit.

PROGRAM ADMINISTRATION

While the cooperative monitoring program is administered without the use of formal interagency agreements, the DRBC and NPS staff work together closely and solicit assistance from other governmental agencies as necessary. Although most of the sampling and analysis is carried out by the two principal agencies, State and county officials are involved in program planning, along with representatives from EPA Regional Offices and the U S Geological Survey

When monitoring results indicate an immediate problem, follow-up actions are initiated by State or local agencies. All monitoring data are entered into EPA's water quality data system, STORET At the end of each sampling season, a report of findings and recommendations is prepared and distributed to local government agencies, the public, and the press.

During the 1986 sampling season, monitoring staff will study river foam found at various locations along the Delaware Although possibly natural in origin, foam currently is perceived as a pollution problem in the region Longer-range objectives for the program include establishment of a scenic rivers research center with a water laboratory and the institution of a land-use monitoring system, possibly using high-altitude and remote-sensing data.

Material for this report was furnished by Richard C Albert of the Delaware River Basin Commission, John Karish of the National Park Service, and Charles Sapp, U.S. EPA Region III

This report is produced by EPA to highlight monitoring and wasteload allocation activities Contributions of information for similar reports are invited Please contact E F Drabkowski, EPA, MDSD, WH-553, 401 M Street S W, Washington, DC 20460 (202) 382-7056.

EPA United States Environmental Protection Agency

Monitoring and Data Support Division
Office of Water
Washington, DC 20460

September 1986

Water Quality Program Highlights

Arkansas' Ecoregion Program

Traditionally, State water quality standards have been based upon national criteria developed by the U.S. Environmental Protection Agency (EPA). However, these criteria may be too general for some local conditions, and States are encouraged to develop site-specific criteria and designate more specialized uses where they are appropriate for individual water bodies. Yet the development of numerous site-specific standards can be resource intensive.

To resolve this problem, several States and the EPA are developing an intermediate method that employs a regional framework for water quality management decisions. Instead of developing standards around individualized waterbodies, homogeneous ecological regions or "ecoregions" are identified. These ecoregions integrate characteristics such as climate, land surface form, soils, vegetation, and land use, to form distinct biological and chemical units.

In 1982, the Water Division of Arkansas' Department of Pollution Control and Ecology (DPC&E) began a 5-year project to test the aquatic ecoregions concept as a basis for reevaluating stream classifications. The State is examining the physical, chemical, and biological characteristics of carefully selected streams in each of six ecoregions within Arkansas. As the project nears completion, DPC&E staff are convinced that the concept is sound and that the results will be directly applicable during the 1987 triennial review of State water quality standards. The State has already successfully employed ecoregion data in the development of use attainability analyses.

THE ECOREGION CONCEPT

Ecoregion analyses have been applied for both research and regulatory purposes. For example, an ecoregion approach has been used to identify surface waters that are sensitive to acidic deposition. Other applications include the definition of aquatic uses in biological terms and defining impact thresholds associated with EPA's antidegration policy. In Arkansas, the primary use of this concept has been to reexamine State water quality criteria and standards.

To define realistic standards for a disturbed water body, it is necessary to compare the water quality with a control or reference site where the disturbance is absent. The most commonly used reference sites are upstream and downstream of a stressed water segment. By contrast, the ecoregion approach uses carefully selected "least-disturbed" streams within the same ecological region as water quality reference sites.

To carry out an ecoregion analysis, it is necessary to first designate areas where physiographic and biological characteristics are similar. Then, within these ecologically homogeneous regions (ecoregions), a series of reference streams are selected corresponding to different size drainage basins. Streams of roughly equal size in the same ecoregion would be expected to have similar water quality and ecological indicators and, thus, respond similarly when subjected to comparable effluents or habitat disruptions.

The advantages of a regional framework for stream classification are that it provides an objective ecological basis to define specific subcategories of aquatic uses and it allows such uses to be developed efficiently, without conducting numerous site-specific surveys for similar water bodies. Subcategories allow the expansion of general aquatic life expressions—e.g., "warmwater fishery," or "cold-water fishery"—to reflect diversity in species composition, within a category, from region to region; this allows States to establish realistic biological uses and goals.

DEVELOPING THE ECOREGION PROGRAM

The motivation for undertaking the ecoregion program in Arkansas was the knowledge that many of the State's cleanest streams and lakes did not meet national water quality standards—not because of pollution, but because of naturally occurring physical and chemical conditions. Rather than enforce inappropriate standards, State officials undertook an ambitious program to assess water quality and ecological conditions in representative least-disturbed streams. These least-disturbed streams will be used as "reference streams" to refine use classifications and associated water quality criteria for similar streams and rivers around the State.

A workplan and grant request were submitted to fund the study under provisions of Section 205(j) of the Clean Water Act. Funding was approved by the EPA Regional Office in Dallas, Texas; however, before stream surveys could be initiated, it was necessary to complete four preliminary tasks.

1. *Define Ecoregions.* The approach used for defining regions and, ultimately, the specific sites to be investigated, was based on techniques developed by James Omernik, Robert Hughes, and others at EPA's Environmental Research Laboratory in Corvallis, Oregon. This method incorporates consideration of geographic characteristics including land surface form, soils, potential natural vegetation, and land use. By determining the dominant types of these four characteristics, then mapping their different combinations, 76 relatively homogeneous ecoregions were identified in the coterminous United States. Six of these ecoregions are within the State of Arkansas (Figure 1).

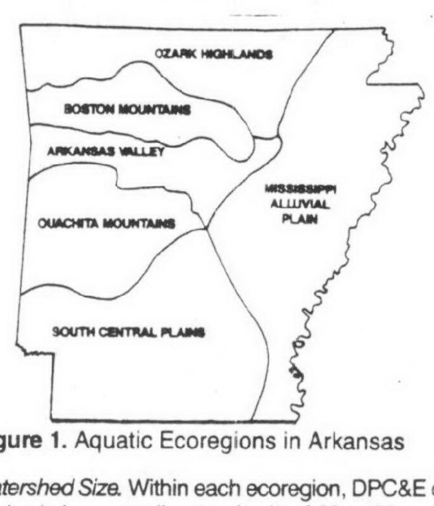


Figure 1. Aquatic Ecoregions in Arkansas

2. *Select Watershed Size.* Within each ecoregion, DPC&E designated three watershed sizes: small watersheds of 20 to 50 square miles; medium watersheds of 100 to 200 square miles; and large watersheds draining 300 to 500 square miles. It was felt that this range would include the beneficial uses for those State streams for which reclassification would be proposed.

3. *Select Survey Periods.* Two sampling periods were selected to capture critical and seasonal dissolved oxygen (DO) levels: late summer

(August or early September) during the high-temperature, low-flow period when DO levels should be minimal, and during spring when DO requirements for fish reproduction are crucial. The exact timing for the spring sampling period was chosen by monitoring stream temperature to determine appropriate fish-spawning conditions.

4. *Select Survey Sites.* Reference streams were selected by reviewing the location of known dischargers and using the field experience of DPC&E staff to eliminate streams with known pollution sources. All potential watersheds were outlined on a map and reviewed for nonpoint source pollution Extensive field evaluations of potential sites were conducted to confirm their suitability and final selection as representative least-disturbed streams

STREAM SURVEY METHODOLOGY

In 1983-84, DPC&E collected water quality and ecological data from least-disturbed streams in small watersheds of all six ecoregions. Medium-size and large watersheds were surveyed during 1984-85 and 1985-86, respectively. Each stream survey followed identical procedures, and the same 1-week work schedule was carried out to assess physical, chemical, and biological parameters. In most cases, two representative streams for each size watershed were sampled in each ecoregion. The following parameters were measured:

• *Dissolved Oxygen.* Dissolved oxygen was measured continuously during the 5-day survey period, with DO probes placed in a pool (at mid-depth) and in a riffle. Both temperature and DO data were recorded, and a computer was used to calculate the percent saturation of DC as well as the daily maximum, minimum, and average DO concentration.

• *Chemical.* Chemical analyses were performed on three grab samples taken at least 1 hour apart within an 8-hour period. Four containers were used to test for parameters as follows:
- Coliform bottle—fecal coliform
- Filtrate vial—ammonia-nitrogen and ortho-phosphate
- Dark bottle—chlorophyll *a*
- Light bottle—turbidity, total suspended solids, total dissolved solids, biochemical oxygen demand (BOD_5 and BOD_{20}), total phosphorus, nitrate+nitrite-nitrogen, chloride, sulfate, total iron, specific conductivity, alkalinity, hardness, and manganese.

• *Physical.* Evaluation of physical parameters was an important part of the survey and included both hydrologic measurements and habitat conditions. Hydrologic parameters assessed for each site included stream flow and stream velocity, stream gradient, and mean width and depth. Habitat measures included an assessment of stream substrate, instream and canopy-cover vegetation, bank stability, and riparian vegetation.

• *Biological.* DPC&E conducted biological studies of both benthic macroinvertebrates and fish populations. Samples were used to taxonomically characterize the aquatic community, identify indicator taxa, and determine relative abundances. For both types of biota, the Shannon-Wiener diversity index and indices of evenness, variety and dominance were calculated to assess overall community health.

SURVEY RESULTS

Results of the small watershed surveys reveal the diversity of water quality conditions among some of the most pristine waters in the State. Daily minimum summertime DO values ranged from less than 3 mg/L in the Mississippi Alluvial Plain, South Central Plains, and Arkansas Valley streams (well below the existing water quality standard of 5 mg/L) to over 6 mg/L in the Boston Mountain and Ouachita Mountain Regions.

However, even in streams where minimum DO values were less than 3 mg/L, significant numbers of fish species were collected (28 to 31 species) and all included black bass (Centrarchidae family), which are particularly sensitive to habitat disruptions. Three of the streams sampled had minimum flow at the time of sampling, yet they supported 28 or more species of fish, including black bass. Table 1 lists the results for selected parameters in the small watershed streams.

TABLE 1. Selected Results of Small Watershed Surveys

Arkansas Ecoregions	Minimum DO during critical period* (mg/L)	Average No. fish species collected	Predominant stream substrate	Overhead canopy (%)
Mississippi Alluvial Plain	2 7	31	mud/silt	>90
South Central Plains	1 0-1 4	30	sand	>90
Arkansas Valley	2 2-3 0	28	bedrock	50
Ouachita Mountains	5 6-6 8	27	gravel	50
Ozark Highlands	4 5-4 7	17	gravel	>75
Boston Mountains	5 8-6 4	24	gravel	50

*Critical period is during the late summer (high temperature, low flow)

In addition to the seasonal grab samples collected from least-disturbed streams, in 1984, DPC&E selected representative sites in each ecoregion to be part of the ambient monitoring network. Monthly samples collected from these sites were analyzed for the full complement of chemical parameters as well as 11 heavy metals. These additional data substantiate the seasonal grab samples.

PROGRAM APPLICATIONS

The Arkansas ecoregion program was designed to provide a sound basis for reclassifying streams where existing criteria and standards are either too stringent or too lenient. Although the project is not yet complete and the triennial review of water quality standards will not take place until 1987, the State has successfully incorporated the ecoregion approach into the preparation of use attainability analyses (UAA). Under the State's UAA procedures, DPC&E staff conduct a brief field survey to evaluate a stream where change of use is proposed. The characteristics of this stream are then compared to the detailed data from the least-disturbed reference stream of similar size in that region.

For example, UAA conducted for Caney Creek, a low-flow stream subject to a single municipal discharge, recommended continuation of the existing designated use (perennial fishery). This was based on the strong similarity between fish samples and the macrobenthic population in both Caney Creek and the least-disturbed reference stream in the Mississippi Alluvial Plain region. However, as a result of the survey, Caney Creek was reclassified from "warmwater fisheries" to the more explicit descriptor, "small watershed, Mississippi Alluvial Plain warmwater fisheries." Along with the modification in use, the DO criterion was also revised from 5 mg/L to 3 mg/L to reflect levels found in similar least-disturbed streams in the region.

To assist the State in its plan to revise water quality standards in 1987, EPA is working with DPC&E to develop a national criteria and standards database and interactive procedure that would allow the State to easily access and update designated uses and criteria for all reaches or portions of reaches in EPA's Reach File.

FUTURE STUDIES

Arkansas has demonstrated the utility of the ecoregion approach for developing and evaluating water quality standards, particularly those concerned with the designation of fisheries and DO criteria. In the future, the State plans to use the same approach in its development of water quality standards for toxic pollutants. For example, background levels of pH and hardness may vary from region to region with correspondingly different effects on metals toxicity.

Material for this report was furnished by John Giese, Arkansas Department of Pollution Control and Ecology; David P Larsen, EPA Environmental Research Laboratory, Corvallis; and Larry Champagne, U S. EPA Region VI.

This report is produced by EPA to highlight monitoring and wasteload allocation activities. Contributions of information for similar reports are invited. Please contact E. F Drabkowski, EPA, MDSD, WH-553, 401 M Street S W, Washington, DC 20460 (202) 382-7056.

EPA
United States Environmental Protection Agency
Monitoring and Data Support Division
Office of Water
Washington, DC 20460
November 1986

Water Quality Program Highlights

EPA's National Dioxin Study

"Dioxin" is the generic term for a group of 75 related compounds known as polychlorinated dibenzo-p-dioxins; however, in common use the name refers to the most toxic and thoroughly studied of these compounds: 2,3,7,8-tetrachlorodibenzo-p-dioxin, or 2,3,7,8-TCDD. This compound, which has caused toxic effects at concentrations lower than any other man-made chemical, is not produced intentionally but rather is a byproduct in the manufacture of several pesticides, chiefly 2,4,5-trichlorophenol (2,4,5-TCP). Environmental contamination can occur: (1) during the production of 2,4,5-TCP, (2) during the production of pesticides derived from 2,4,5-TCP (principally, the herbicides 2,4,5-T and silvex), or (3) where any of these pesticides have been applied. Certain types of combustion sources have also been found to emit dioxins.

While the use of many products that may cause dioxin contamination has been suspended, once the compound is in the environment it is persistent. In addition, dioxin bioaccumulates so that even if present in extremely low concentrations, it can concentrate in organisms to much higher levels, increasing the likelihood of hazard.

During the past three years, the U.S. Environmental Protection Agency (EPA) has conducted a national monitoring program, using new and sensitive analytical techniques, to estimate the extent of 2,3,7,8-TCDD contamination in the environment. This report highlights the scope of the National Dioxin Study and the results for those portions of the study that were carried out by EPA's Office of Water, Monitoring and Data Support Division.

LEVELS OF CONCERN

Criteria or levels of concern regarding dioxin contamination have been established by several Federal agencies for different environmental media. EPA has estimated an increased lifetime risk of one additional cancer per 1 million people from drinking water and eating fish from waters containing dioxin at 1.3×10^{-8} $\mu g/L$ (0.013 parts per quadrillion). For soil, the Centers for Disease Control considers 1 part per billion (ppb) to be a level of concern in residential areas (where there is a potential for ingestion by children). However, this level varies depending on land use. Soil concentrations as low as 6 parts per trillion (ppt) could be of concern in areas where dairy cattle are grazing, while concentrations above 1 ppb could be acceptable in many industrial areas.

THE NATIONAL DIOXIN STRATEGY

In 1983, the EPA issued its National Dioxin Strategy. This strategy was designed to provide a framework for the study of dioxin-related problems, including the nature and extent of dioxin contamination throughout the country and risks to people and the environment. The strategy also addressed the clean-up of contaminated sites and the destruction or disposal of existing dioxin. To implement the information-gathering portion of the strategy, EPA defined seven categories (or tiers) of sites for investigation. The tiers were believed to exhibit a decreasing potential for 2,3,7,8-TCDD contamination.

- *Tier 1* — Facilities where 2,4,5-TCP was produced and associated waste disposal sites.
- *Tier 2* — Facilities and associated waste disposal sites where 2,4,5-TCP was used as a precursor to manufacture other pesticide products.
- *Tier 3* — Sites where 2,4,5-TCP and its derivatives (2,4,5-T, silvex, erbon, ronnel, hexachlorophene, and isobac 20) were formulated, blended and packaged.
- *Tier 4* — Combustion sources.
- *Tier 5* — Sites where suspected contaminated pesticides were commercially applied.
- *Tier 6* — Sites where the manufacture of certain organic chemicals and pesticides could have resulted in the inadvertent formation of 2,3,7,8-TCDD.
- *Tier 7* — Control sites where contamination from 2,3,7,8-TCDD was not suspected.

EPA conducted a complete investigation of all sites in tiers 1 and 2, which was managed by the Office of Solid Waste and Emergency Response. However, because of the large number of sites in tiers 3 through 7, only a representative sample of these was investigated initially. Studies of sites in tiers 3, 5, 6, and 7 were carried out by EPA's Office of Water; tier 4 studies were managed by EPA's Office of Air and Radiation.

THE NATIONAL DIOXIN STUDY

The National Dioxin Study was designed to characterize the extent of 2,3,7,8-TCDD contamination in tiers 3, 5, 6, and 7. To accomplish this, over 4,000 samples, in various media, from 862 sites across the nation were collected and analyzed.

Several approaches were used to identify the potential sampling sites. For tiers 3 and 6, samples were taken at both statistically selected sites (using EPA and industry databases) and at sites of particular interest to States and the EPA Regional Offices. Sites in tier 5 were selected based on pesticide use information provided by EPA's Office of Pesticide Programs, the Regional Offices, and State agencies. In this tier, a statistical sample was not practical, and sites were selected to represent a wide range of conditions and uses. For tier 7, sampling sites for soil, fish, and shellfish were statistically selected from three national environmental monitoring networks; in addition, Regional Offices selected fish sampling stations of particular interest.

Sample analysis in the National Dioxin Study was carried out by both commercial laboratories under EPA contract and EPA research laboratories. Analytical methods used in the commercial labs had a nominal detection limit of 1 ppb for soils, while methods used by the EPA had a detection limit of approximately 1 ppt for all media other than water and approximately 10 parts per quadrillion (ppq) for water. Generally, commercial laboratories analyzed soil samples from tiers 3 and 6; EPA analyzed soil samples from tiers 5 and 7, as well as samples from other media in all tiers.

STUDY RESULTS: TIERS 3, 5, AND 6

Sites in tiers 3, 5, and 6 were suspected of showing 2,3,7,8-TCDD contamination. Sampled media in these tiers included soil, water, stream sediment, and biological tissue. Table 1 summarizes the results for tiers 3, 5, and 6, while the following paragraphs highlight the conclusions for each tier.

Tier 3. This study was designed to evaluate the percentage of all tier 3 facilities expected to have soil contamination above 1 ppb or at any detectable level in other environmental media. To accomplish this, EPA statistically selected 61 facilities that formulated one or more tier 3 compounds between 1976 and 1981. Of these, 41 were actually sampled. (Information request letters revealed that 20 facilities either did not handle tier 3 compounds, or that soil on the site had been ex-

TABLE 1. Results of the National Dioxin Study for Tiers 3, 5, and 6.

	No. of sites	No. of sites sampled	No. of sites contaminated
Tier 3, statistically selected sites	61	41	6[a]
Tier 3, additional sites	23	23	6[a]
Tier 5 sites	26	26	15[b]
Tier 6, statistically selected sites	25	15	2[a]
Tier 6, additional sites	3	3	1[a]

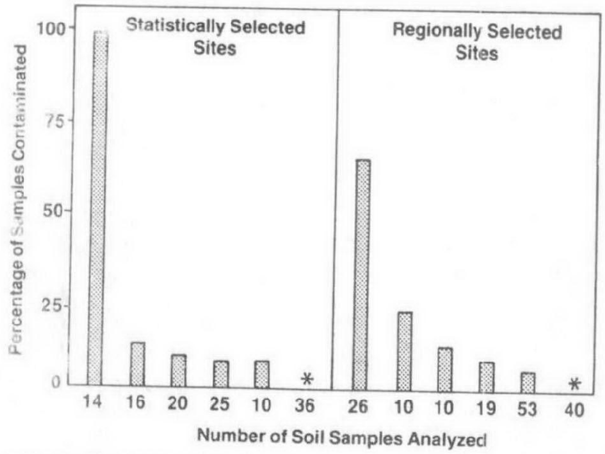
[a]Sites with soil concentrations greater than 1 ppb or detectable levels in other media.

[b]Sites with detectable levels (ppt) in soils, stream sediment, or biological tissue.

tensively disturbed or paved over.) Additionally, 23 sites were identified by EPA Regional Offices based on known activities at a facility or on previous contamination incidents.

Based on the survey results, EPA estimated that of all tier 3 facilities nationwide (approximately 300), about 10 percent would have concentrations of 2,3,7,8-TCDD in soil above 1 ppb or detectable levels (above approximately 10 ppq-1ppt) in other media.

Of the 12 sites where contamination was detected, all were at or near facilities handling the pesticides 2,4,5-TCP, 2,4,5-T, and/or silvex. As shown in Figure 1 (six statistical and six regionally selected sites), only two tier 3-sites were extensively contaminated. As a result of these findings, EPA concluded that the immediate investigation of the remaining tier 3 sites is not warranted, although the Agency will conduct further evaluations of specific large pesticide manufacturers where 2,4,5-TCP, 2,4,5-T, and silvex are formulated.



* Contamination was in media other than soil

FIGURE 1. Percentage of soil samples from tier 3 contaminated sites containing greater than 1 ppb 2,3,7,8-TCDD.

Tier 5. For tier 5, the objective was to determine whether 2,3,7,8-TCDD could be detected at any level in soils, stream sediment, or biological tissues in areas where pesticides suspected of containing dioxin had been used. Twenty-six sites were sampled including forested areas, rice and sugarcane fields, rangeland, and aquatic sites.

At the 15 sites where 2,3,7,8-TCDD was detected, soil and sediment contamination was extensive, with over 40 percent of the samples analyzed at each site containing levels above the ppt detection limit. Two sites had detectable levels in fish, and at one of these, all fish samples were contaminated. While contamination in soil and sediment was widespread, concentrations were generally quite low (less than 5 ppt). Levels detected in fish fillets were between 8 and 23 ppt, and dioxin was not detected in other animal tissue or in vegetation samples.

Of particular interest was the fact that, with the exception of loading areas, 2,3,7,8-TCDD levels were much lower, and in most cases, not detectable in areas where pesticides were uniformly applied by spraying. Due to low levels found at tier 5 sites where 2,4,5-TCP-based spraying occurred, EPA concluded that further national investigation of spray areas is not warranted.

Tier 6. The objective in tier 6, as in tier 3, was to determine the percentage of facilities nationwide expected to have soil contamination above 1 ppb or at detectable levels in other media. EPA identified 67 facilities thought to manufacture one or more of the 60 compounds whose production can create dioxin. Of these, 25 sites were selected for sampling; three additional tier 6 sites were selected by EPA Regional Offices based on known activities or previous contamination incidents.

None of the three sites where 2,3,7,8-TCDD was found were extensively contaminated (detectable levels were limited to one or two samples). As a result, it was concluded that additional investigation of the tier 6 sites was not warranted.

STUDY RESULTS: TIER 7

EPA used tier 7 sites to evaluate background levels of 2,3,7,8-TCDD in soil and fish tissues. Thus, sampling was carried out at sites that had no previously known sources of dioxin contamination. Using established national databases, EPA randomly selected locations for testing rural soils, urban soils, and fish tissue. Also, additional fish sampling sites were selected based on proximity to population centers or recreational fishing activity.

The results, summarized in Table 2, show that 2,3,7,8-TCDD was detected infrequently and at very low levels in soil, while background fish contamination was somewhat higher. Of the fish samples, the highest proportion of contaminated samples was found in Great Lakes sites. This is consistent with previous findings and is a result, to some extent, of the long water retention times (which tend to increase bioaccumulation potential) and the many pollutants entering the lakes.

TABLE 2. Results of Tier 7 Dioxin Study: Background Levels of Contamination

	No. of sites sampled	No. of sites contaminated	Maximum conc. detected (ppt)
Urban soils	221	17	11.2
Rural soils	138	1	0.5
Fish tissue	90	17	19
Fish tissue[a]	305	95	85

[a]Sites were not statistically selected.

The two sites with the highest levels of dioxin contamination were the Androscoggin River in Maine (maximum of 29 ppt) and the Rainy River in Minnesota (maximum of 85 ppt), and in both cases, the rivers were subject to upstream pulp and paper mill discharges. Further investigations at these and similar sites are being conducted by EPA, the States, and the paper industry to determine the sources of 2,3,7,8-TCDD within the mills. As a result of the study, fish consumption advisories were issued by the two States.

MAJOR STUDY ACCOMPLISHMENTS

The National Dioxin Study has produced a major increase in EPA's knowledge of 2,3,7,8-TCDD levels in the environment, and it has also helped to refine the tools needed for futher study. Guidance to ensure uniform sampling procedures for dioxin monitoring and the development of uniform review procedures to assess analytical data are two important accomplishments. In addition, the study has resulted in the development of more reliable and less costly analytical methods to routinely measure dioxin at concentrations that are close to the levels of concern for human health.

Material for this report was furnished by Stephen Kroner of EPA's Monitoring and Data Support Division.

This report is produced by EPA to highlight monitoring and wasteload allocation activities. Contributions of information for similar reports are invited. Please contact E. F. Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W., Washington, DC 20460 (202) 382-7056.

EPA
United States Environmental Protection Agency
Monitoring and Data Support Division
Office of Water
Washington, DC 20460
January 1987

Water Quality Program Highlights

The Massachusetts Fish Toxics Monitoring Program

Toxic water pollutants can affect human health through several pathways including the ingestion of contaminated fish and shellfish In addition, toxicants can have significant adverse impacts on the health of aquatic life Since the late 1970's, the U S Environmental Protection Agency (EPA) has encouraged States to monitor and control the discharge of toxics An important part of such efforts includes the determination of contaminant levels in fish tissue and the risks associated with these levels Of the many known toxicants, numerical criteria for determining fish edibility currently exist for only a handful of substances These numerical criteria are the "action levels" developed by the U S Food and Drug Administration for eight pesticides and for mercury, polychlorinated biphenyls (PCBs), and dioxin

A program currently underway in the Commonwealth of Massachusetts is monitoring toxic substances in fish tissue This report describes the program's implementation and demonstrates how toxic monitoring results were used to assess human health risks associated with the consumption of fish from the Sudbury River

IDENTIFYING THE NEED FOR A FISH TOXICS PROGRAM

The construction of municipal and industrial water pollution control projects has significantly reduced pollutant loadings to Massachusetts rivers and coastal waters The resulting water quality improvements have led to the reestablishment of viable and diverse fish populations in many river systems that previously sustained few, if any, species of fish This enhancement of recreational fishing opportunities coupled with the increased awareness of toxic pollution led to concerns about the health risks associated with consuming freshwater fish from some Massachusetts waters Major sources of toxics in Massachusetts' waters are industrial discharges such as those from electroplating facilities, discharges from municipal wastewater plants that receive significant industrial input, and nonpoint sources including urban runoff and in-place sediments.

In 1984, the Massachusetts Department of Environmental Quality Engineering's Division of Water Pollution Control (MDWPC) and the Division of Fisheries and Wildlife (MDFW) established the Toxic Chemicals in Fish Program To address the problem in a comprehensive way, a Toxics in Fish Committee was formed, with membership consisting of representatives from several State and Federal agencies Early discussions revealed that while existing data on fish contamination in the State were sparse, such information would be useful in the development of surface water quality standards, NPDES permits, and human health risk assessments.

IMPLEMENTING THE PROGRAM

Massachusetts implemented the Toxics in Fish Program to accomplish three major objectives

- Develop a Statewide database of levels of toxic contaminants in freshwater fish
- Identify waters where levels of toxic chemicals in fish may impact human health
- Identify waters where toxic chemicals may impact fish populations and other aquatic life

To date, fish surveys generally have been restricted to waterbodies where discharge information (e g , NPDES permit applications) or previous studies have suggested a potential toxics problem In addition, sampling has been conducted in areas where heavy industrial development or hazardous waste disposal are present Because of limited resources, human health concerns have received highest priority in the surveys carried out thus far, for this reason, fish tissue analysis has been restricted to edible fish fillets

The fish toxics monitoring program is carried out using a three-phased approach for data collection

1 *Screening Survey.* During this initial survey, five to ten fish from at least two species are collected for analysis Target species include at least one bottom feeder (e g , bullhead) and one resident game fish (e g , largemouth bass or pickerel) Left fillets are pooled and analyzed as a composite, right fillets are archived as individual samples

2 *Confirmatory Analysis* If levels found in screening composites are high relative to existing criteria (where they exist) or baseline literature values, the archived fillets are individually analyzed to provide a range of concentrations, and a mean value is calculated

3. *Follow-up Survey* If contaminant concentrations are at levels of concern in individual fillets, additional fish of several different species are collected and individually analyzed

In some cases, MDWPC has begun analyzing both individual fillets and composites in screening surveys This change was necessary because of variability in both the size of fish collected, and in the number of fish per sample Fish are now individually analyzed during screening surveys if (1) only one fish of a desirable species is captured, or (2) if one of five samples is significantly larger than the other four In the second case, the other four are combined for a composite analysis, and, as before, the right fillets are archived for future reference

Uniform protocols, designed to assure accuracy and prevent cross contamination of samples, are followed for fish collection, processing and shipping Fish are taken with electroshocking gear or gill nets Lengths and weights are measured, and fish are visually examined for tumors, lesions, or other indications of disease Scale samples or other hard parts (e g , pectoral spines) are obtained from each sample to determine the approximate age of the fish

Tissue samples are frozen before being transported to the laboratory for analysis Preparation of the samples differs depending on the nature of the suspected toxicant where organics are suspected, samples are wrapped in aluminum foil, for metals, plastic wrap is used Once at the laboratory, samples may be analyzed for specific toxicants (where a particular source is suspected) or for a broad spectrum of heavy metals, pesticides, or organic chemicals Laboratory analytical methods include atomic absorption spectroscopy and gas chromatography/mass spectrometry

ADMINISTERING THE PROGRAM

The fish toxics monitoring program is a cooperative effort that involves several State agencies MDWPC presently employs one full-time aquatic biologist to direct the program (this position is funded under the Clean Water Act's Section 106 Program Grant), and he is assisted with field work and sample preparation by one or more seasonal employees during summer months. In addition, MDFW provides a biologist to assist with sampling and furnishes necessary equipment, such as electroshocking gear and nets Massachusetts' Lawrence Experiment Station analyzes fish and related samples for toxic chemicals and also advises the program committee on analytical methods and data interpretation Finally, the agency's Office of Research and Standards coordinates with State and local public health agencies who communicate health risks to the public when necessary

In 1986, annual operating costs associated with the Toxics in Fish Program included approximately $27,000 for sample collection, preparation, and data management, $15,000 for chemical analyses, and $3,000 for administrative costs, data analysis, and the preparation of health advisories These costs include the salary of one full-time biologist

TOXICS MONITORING TO DATE

MDWPC performed its first fish toxics work in response to public concern about the environmental impact and human health effects of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD or dioxin) The presence of dioxin was suspected in several Massachusetts lakes and ponds that had been treated with the herbicides Silvex, Kuron, or 2,4,5-T (dioxin can occur as a contaminant in these herbicides), and in 1983, MDWPC and MDFW conducted a screening survey of six ponds where these three herbicides had been used

In five of the six ponds surveyed, dioxin levels in both fish tissue and in sediment samples were below the detection limits However, in Lake Winthrop, the composite fish sample measured 71 parts per trillion (ppt) — exceeding the FDA's dioxin advisory for consumption of fish caught in the Great Lakes (50 ppt) As a result, the Massachusetts Department of Public Health issued a health advisory concerning fish caught in Lake Winthrop

Follow-up studies, currently underway in Lake Winthrop, include further analyses of sediment, fish, and aquatic vegetation for the presence of dioxin, the examination of historical records of herbicide applications, and the investigation of other possible sources of the contaminant

In 1984, fish tissue monitoring was carried out as part of a water quality survey designed to support the reissuance of 17 major NPDES permits in Massachusetts' Ten Mile River Basin The basin contains a number of metal plating and finishing plants, and the development of wasteload allocations and permit limits required a thorough evaluation of the water quality impacts from existing toxic discharges Five composite samples of fillets from nine sites were analyzed for ten metals, and results were compared with concentrations reported in the literature as having adverse impacts on fish Chromium, copper, lead, nickel, and zinc were present in fish at concentrations only slightly below those literature values, and of the metals sampled, lead and mercury approached levels that could cause public health impacts Findings from this survey resulted in a fish consumption advisory (because of elevated lead levels in Ten Mile River fish) and the justification for advanced waste treatment and stringent NPDES permit limits for many industrial facilities in the river basin

In 1985, the Toxics in Fish Program was expanded to include ten different fish flesh monitoring surveys Two surveys sampled lakes located near hazardous waste sites The remaining eight surveys addressed riverine waterbodies, and all but one were screening surveys The one exception was the Sudbury River where previous work by MDFW suggested the need for follow-up surveys

A total of 12 surveys were performed during 1986, the majority designed to screen for metals contamination, although some analyses for PCBs and other organics were also done The Toxics in Fish Program was also expanded in several directions A comprehensive microcomputer database was created for all fish toxics data Also, sampling is taking place in clean-water or "least-impacted" waterbodies to begin the creation of a reference database containing background levels for various chemicals This reference database will be enlarged as additional clean water sites are sampled in the future

SUDBURY RIVER CASE STUDY

The Nyanza Chemical Company, a manufacturer of organic dyes, discharged wastes near the headwaters of the Sudbury River between 1917 and 1970 Downstream of the discharge are two large reservoirs, several small impoundments, and an extensive winding wetland, part of which is included in the Great Meadows National Wildlife Refuge Although only the headwater segment of the river is stocked with trout, the entire river, above and below the reservoirs, has long been popular with anglers, many of whom consume their catches of bass, perch, and bullheads Sampling of fish tissue performed in the Sudbury River in 1972 revealed high levels of chromium, mercury, and other toxic substances A second fish survey conducted in 1981 confirmed the high metals concentrations, and in 1983, EPA identified the Nyanza property as a Superfund hazardous waste site

Follow-up sampling was conducted in 1985 to determine whether fish from the Sudbury River contain mercury levels in excess of the FDA's 1 0 part per million (ppm) market standard and to evaluate mercury concentrations in the water column and sediments MDWPC chose six sampling locations that coincided with the stations used in 1981 One station was upstream of the Nyanza site, with five stations spread along the approximately 20 miles below the site Five individual fillets were analyzed at each station, and water and sediment samples were collected from all but the most downstream site

Table 1 presents the results of the 1985 study The highest contaminant levels were found in three resident species often taken by anglers in the two reservoirs Six of the ten fish sampled at stations 2 and 3 had mercury concentrations greater than 1.0 ppm and as high as 3.2 ppm Although the mercury concentrations declined in fish taken further downstream, at four of the six stations at least one fish exceeded the FDA market standard

TABLE 1. Mercury Contamination in the Sudbury River, Upstream (Station 1) and Downstream (Stations 2-6) from the Nyanza Hazardous Waste Site, 1985

	Fish Fillets				
Station No	Range (ppm)	Mean (ppm)	% of Samples > 1 ppm	Water Column	Sediment (ppm)
1	0 12-0 63	0 38	0	ND	0 24
2	0 30-2 2	1 40	60	ND	13
3	0 02-3 2	1 19	60	ND	7 2
4	0 42-1 0	0 67	20	ND	13
5	0 02-1 2	0 53	40	ND	0 022
6	0 19-0 70	0 42	0	—	—

ND — Not detected (detection limit = 0 2 ppm)

All data from the Sudbury River Study were submitted to the Office of Research and Standards, which then coordinated with the State's Department of Public Health and other members of the Toxics in Fish Committee The result was a decision to post an advisory against eating fish along the entire length of the Sudbury River

FUTURE CONSIDERATIONS

Creation of a baseline or reference database along with continued monitoring of fish tissue in the Commonwealth's rivers and lakes are long-term goals of the Toxics in Fish Program Experimentation with alternative preparations, e g , skin off vs skin on, will also be addressed in future years In addition to addressing human health considerations, MDWPC hopes to standardize techniques for assessing the impact of toxic pollutants on aquatic life To do this, methods for processing and analyzing fish may have to be modified to include the analysis of whole fish and/or specific target organs known to bioaccumulate toxicants

Material for this report was furnished by Arthur Johnson, Robert Maietta, and John Jonasch, Massachusetts Division of Water Pollution Control, Technical Services Branch and Michael Bilger, U S EPA Region I, Environmental Services Division

This report is produced by EPA to highlight monitoring and wasteload allocation activities Contributions of information for similar reports are invited Please contact E F Drabkowski, EPA, MDSD, WH-553, 401 M Street, S W, Washington, D C 20460, (202) 382-7056

EPA

United States
Environmental
Protection Agency

Office of Water Regulations and Standards
Monitoring and Data Support Division
Washington, DC 20460

April 1988

Water Quality Program Highlights

Maine's Biologically Based Water Quality Standards

Section 101 of the Clean Water Act states that "it is the objective of the Act to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" Of the three characteristics, biological integrity has been the least considered, however, it may be the most important since organisms not only integrate the full range of environmental influences (chemical, physical, and biological), but complete their life cycles in the water and, as such, are continuous monitors of environmental quality

To take advantage of this fact and to improve its surface water management capabilities, the State of Maine has developed biologically based water quality classifications and water quality criteria In April 1986, after four years of negotiation with industry and environmental groups, the Maine Legislature enacted a revised Water Quality Classification Law. The new law includes language specifically designed to facilitate the use of biological assessments. Thus, each water class contains aquatic life standards that describe the minimum conditions necessary to attain that class. To implement the new classification system, the Maine Department of Environmental Protection (MDEP) is now developing specific biological measures that will be used to support the statutory aquatic life standards in the Water Quality Classification Law

This report summarizes Maine's biologically based water classification system and the associated aquatic life standards for freshwater streams and rivers Also summarized is the State's instream biological monitoring program that will be used to ensure compliance with the new law.

A BIOLOGICALLY BASED CLASSIFICATION SYSTEM

The 1986 law that revised Maine's water classification system was not designed to change existing water quality levels but to improve MDEP's ability to monitor and manage rivers and streams Under a previous law, the same aquatic life standard, "Discharges shall cause no harm to aquatic life," applied to four classes of waterbodies (A, B-1, B-2, and C) However, countless biological studies demonstrated the impossibility of enforcing such a restrictive standard across all classes of effluent-receiving waters Maine waters that were clearly attaining the minimum chemical and physical standards of Class C could not meet the "no harm to aquatic life" criterion due to the displacement of some sensitive indigenous species

The revised classification system recognizes the necessity of having waters of different quality, including pristine recreation-oriented waters and waters of lesser quality for economic and social needs Table 1 describes the aquatic life standards for waters under the new classification system In addition to these standards, the Water Quality Classification Law specifies designated uses, dissolved oxygen levels, and allowable bacteria concentrations for each of the four classes

Class AA, the class with the highest degree of protection, is intended for waters of special value to the State No impoundments or discharges of any kind are permitted, consequently, no change in the biological community is expected and the standard states that aquatic life should be "as naturally occurs" This is interpreted to mean that essentially the same species and numbers of organisms should be found as in similar habitats that are free of human influence

TABLE 1. Aquatic Life Standards for the State of Maine

Water quality class	Biological standards
AA	No direct discharge of pollutants, aquatic life shall be as naturally occurs
A	Natural habitat for aquatic life, aquatic life shall be as naturally occurs
B	Unimpaired habitat for aquatic life, discharges shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community
C	Habitat for aquatic life, discharges may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community

Class A waters would be managed much as Class AA, although hydropower and some highly treated effluents would be permitted (discharged effluent must be equal to or better than existing quality of receiving waters) Because of the expected high level of treatment, the same standard is used that aquatic life shall be as naturally occurs

The third level, Class B, requires that discharges have no adverse impact on aquatic life, but allows for some changes in the residential biological community This standard has two distinct parts The first is that the receiving water be of sufficient quality to support all indigenous species—to be determined through effluent toxicity testing (using *Cenodaphnia* and brook or brown trout) where effluent is appropriately diluted in receiving water This does not mean that a species has to exist in the river or stream—only that water quality cannot be the limiting factor The second part is that changes in the resident community must not be detrimental, under the new law, detrimental change is defined as a significant loss of species or excessive dominance by any species or group as a result of human activity (The previous law stated that the composition of the bottom fauna could not be altered) Class B waters typically receive discharges from municipal wastewater treatment plants. In such cases, increased nutrient and organic loading, in the absence of toxic compounds, has an enriching effect on the biological community, resulting in increased numbers of individuals Generally, however, such effects are not harmful and should be differentiated from detrimental changes.

Class C waters are the lowest level in the Maine system In these waterbodies, discharges may cause some changes to aquatic life, provided that water quality continues to support all indigenous species of **fish** and the biological structure and function of the community is maintained. The first part, which can be determined through effluent toxicity testing (using *Cenodaphnia* as the most sensitive surrogate species for trout), is necessary to meet the requirements of the Clean Water Act Again, it is not necessary that all indigenous fish are actually found; factors other than water quality (e g , competition, predation, lack of habitat) may preclude the presence of some species. The second part of the Class C standard is that community structure and function be maintained Briefly, structure is the number of species and individuals within a community, while function is the means by which they interact to utilize food and other resources. Within Class C waters, significant losses and shifts in species would be allowed Although it is expected that pollutant-sensitive species may disappear, it is essential that there is some replacement by more tolerant species and that these tolerant species fulfill all vital functional roles in the aquatic community

These biological standards allow Maine to assess the success of its overall water quality program in terms of cumulative biological effects and provide the statutory framework to directly protect the actual condition of aquatic life

MACROINVERTEBRATE MONITORING PROGRAM

In order to develop specific numeric and descriptive criteria to support the aquatic life standards in the State's Water Quality Classification Law, the MDEP initiated a statewide biological monitoring program in 1983. Under this program, benthic macroinvertebrates (e.g., aquatic insects, snails, clams, worms, and crayfish) were selected as the primary indicators of biological integrity in streams and rivers. These organisms were chosen because of their

- Limited mobility (compared to fish) which makes them less able to avoid the effects of pollutants
- Longer, more complicated life cycles (compared to algae or bacteria) which allow them to reflect or integrate water quality over time
- Wide range of pollutant tolerances among the various species
- Importance as a food source for freshwater gamefish
- More diverse feeding and energy use strategies than higher level organisms (e g , fish) and thus the ability to provide information about disturbances in nutrient cycling through the ecosystem
- Ease of collection using accepted and well-established sampling and analysis procedures

Sampling locations were chosen with two major considerations (1) to represent the range of water quality conditions in the State (e g , on different size streams, both with and without discharges) and (2) to provide information on the presumed worst-case condition of all river and stream reaches known to be significantly affected by human activity Thus, the benthic macroinvertebrate data will serve the dual purposes of generating qualitative and quantitative biological classification criteria and assigning reach-by-reach biological classifications

To date, MDEP has collected macroinvertebrate samples from 161 sites on 55 rivers Samples were taken above and below all significant discharges in the State, as well as from some pristine areas, and this information is now being subjected to extensive statistical analyses All decisions about specific numeric criteria will be made after the data have been thoroughly analyzed. MDEP, which is responsible for proposing waterbody classifications and assessing compliance (actual assignments are made by the State legislature), expects to complete this process during 1988.

BIOMONITORING PROTOCOL

Measures of biological integrity are fundamentally dependent on the sampling methods used to collect raw data Thus, standard practices must be set for all evaluation procedures including both environmental factors (e.g., season and type of habitat sampled) and methodological factors (e g , sampling device and sieve size used to collect organisms) To ensure consistency, the MDEP has prepared a manual (*Methods for Biological Sampling and Analysis of Maine's Waters*, January, 1987) that establishes specific guidelines and procedures for site selection, sample collection, and sample analysis

For example, biomonitoring efforts are to focus on benthic macroinvertebrate communities of flowing streams and rivers having a hard eroded substrate which is characteristic of the majority of effluent receiving waters in Maine Sampling sites are to be representative of the stream or river reach as a whole and should not be influenced by man-made structures, river bank effects, or slackwater areas Reference (control) and effluent-impacted sites must be matched for similarities in water velocity, substrate composition, canopy cover, water depth, and all other upstream influences except the discharge source to be evaluated.

DEVELOPMENT OF NUMERIC AND DESCRIPTIVE CRITERIA

With its well-defined biological classification system and standardized benthic macroinvertebrate database in place, Maine is now in the process of developing the specific numeric and descriptive criteria necessary to identify the biological classification attained by a given waterbody The criteria are being developed (in cooperation with biologists from industry and environmental interests) by examining the responses of various biological indices and measures across the range of water quality conditions represented in the database Table 2 presents the general types of measures that will be applied to each classification

TABLE 2. Potential Measures for Biological Statutory Criteria

Water quality class	Standard	Type of biological measure
AA & A	As naturally occurs	Comparative measures (e g , percent similarity)
B	No detrimental change	Population and community measures (e g , coefficient of community loss, species population reduction, retention/recruitment)
C	Maintenance of community structure and function	Structure measures (e g , richness, abundance, diversity) Function measures (e g , feeding groups, specialist/generalist ratio)

The measures chosen will be those which demonstrate a consistent correlation to known water quality conditions and which best address the specific statutory language for each classification Measures that are selected will be incorporated into an hierarchical evaluation process that proceeds from the least ambiguous conditions (e g , total absence of aquatic life or 90 percent dominance by one type of organism) to conditions requiring more rigorous biological interpretation Past experience has shown that no single biological measure or index can provide an adequate summary of community status, so MDEP will employ several evaluation measures to confirm each decision

In most cases, the interpretation of biomonitoring results will depend upon an examination of the relative differences between a downstream test community (below a discharger) and a matched reference community (usually upstream) that is not impacted In other cases, a matched reference site may not exist, and the site must be evaluated on the degree to which descriptors of the benthic community are comparable to characteristics of communities from similar natural areas

FUTURE CONSIDERATIONS

The primary goal for MDEP's instream biomonitoring program is to provide feedback concerning the State's efforts in protecting its aquatic life resources The program is not expected to have a significant role in permitting, although effluent toxicity testing has been required in some discharge permits for the last three years Information from the program will be used, however, to assess the degree of protection afforded by effluent limitations. As the freshwater biomonitoring program matures, the State will be devoting increasing attention to the development of a marine biomonitoring program to complement similar biological standards adopted by the State for coastal waters

Material for this report was furnished by Susan Davies and David Courtemanch, Maine Department of Environmental Protection, Bureau of Water Quality Control, and Mike Bilger, U S EPA Region I, Environmental Services Division

This report is produced by EPA to highlight monitoring and wasteload allocation activities Contributions of information for similar reports are invited Please contact E F Drabkowski, EPA, MDSD, WH-553, 401 M Street S W, Washington, DC 20460, (202) 382-7056

EPA

United States
Environmental
Protection Agency

Office of Water Regulations and Standards
Monitoring and Data Support Division
Washington, DC 20460

May 1988

Water Quality Program Highlights

Minnesota's Nonpoint Source Assessment Program

Section 319 of the 1987 amendments to the Clean Water Act authorized a new direction and significant Federal financial assistance for the expansion of State nonpoint source (NPS) control programs. The U.S. Environmental Protection Agency (EPA) is encouraging States to build on existing information to develop NPS programs that include three major elements:

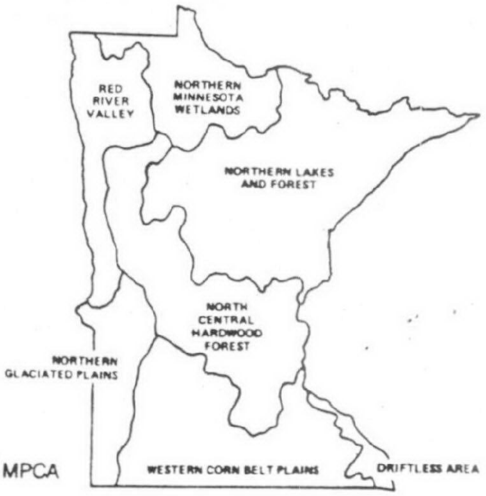
- A comprehensive assessment of State waters impacted by NPS pollutants
- A procedure for targeting high-priority geographic areas
- A State Management Program describing actions that will be taken on a watershed-by-watershed basis.

The Minnesota Pollution Control Agency (MPCA) is developing a procedure to rank the NPS pollution potential of all watersheds in the State. The procedure will include three levels of analysis. Level I, completed in November 1986, assessed the general vulnerability (to nonpoint pollution) of seven ecoregions within the State and identified the major NPS pollutants. Level II, which is now being completed, will assess NPS problems at a smaller scale by identifying the potential for water quality impacts in the State's 5,611 "minor watersheds." Finally, Level III analyses will be conducted as necessary by local units of government to address source-specific nonpoint loading prior to the implementation of controls.

This report highlights the approach and the specific methods to be used by the MPCA in each level of its NPS assessment procedures.

LEVEL I: ECOREGION NONPOINT SOURCE ASSESSMENT

Both the Level I and Level II assessments are based on the concept of aquatic ecoregions as developed by EPA's Environmental Research Laboratory in Corvallis, Oregon. Using this approach, areas with similar land use, soils, topography, and potential natural vegetation are categorized into identifiable geographic areas or ecoregions. Waterbodies within these areas generally exhibit physical, chemical, and biological characteristics that are more similar to each other than to waterbodies in other ecoregions. Thus, streams and lakes within the same ecoregion are likely to react similarly when subjected to NPS pollutant loads. Figure 1 shows the seven aquatic ecoregions identified within Minnesota.



Source: MPCA

FIGURE 1. The seven aquatic ecoregions in Minnesota.

The Level I study was designed to provide information about major problems over broad geographic areas. For example, the Level I analysis suggested that, while lakes in the North Central Hardwood Forest are not currently experiencing widespread problems, many waterbodies in this region are near critical nutrient levels so that minor additional pollutant loading may result in use impairment. This is in contrast to lakes in the Western Cornbelt Plains ecoregion where nutrient levels are uniformly high and pollution related problems common. Information such as this helps the State focus its efforts and programs on protective or restorative activities within a given region.

The MPCA assessed existing and potential NPS pollution for each ecoregion by examining three types of information in each area: land use, topographic features, and water quality. Land use and topographic features were assessed by using Minnesota's Land Management Information Center data base, which was developed from aerial photo interpretations of each 40-acre parcel in the State. Water quality data were taken from EPA's data storage and retrieval system, STORET. The general approach used for the ecoregion analysis is outlined in the following paragraphs.

Land Use Assessment. It was assumed that land uses may be rated according to their "intensity" and that high-intensity uses encourage greater NPS pollution. Urban development, mineral extraction, transportation, rowcrops (corn and soybeans), and small grain cultivation were categorized as intensive land use activities. Pasture and open lands, forested areas, water, and marsh were considered to represent lower intensity land use activities.

Topographical Assessment. MPCA selected four topographical features associated with NPS pollution potential: water orientation, slope, soil texture, and soil hydrologic group. Each 40-acre parcel was defined as water oriented if it either contained or adjoined a waterbody. Because an inverse relationship exists between NPS pollutant delivery and the distance to the nearest watercourse, nonpoint loading is likely to be greater where a large proportion of the 40-acre parcels are water oriented—assuming that each land area generates equal pollutant loads.

The generation of runoff and the transport of NPS pollutants to waterbodies is strongly influenced by the other three topographic features that were evaluated. Steep slopes, which are associated with increased runoff potential, were evaluated for each ecoregion by grouping the average slope for each 40-acre parcel into five slope categories: <1%, 1-2%, 2-3%, 3-6%, and >6%. Soil texture affects runoff because fine-textured soils generally limit infiltration; in addition, once suspended, fine soils are more easily transported, and their larger surface area enhances the adsorption of pollutants. Soil texture was evaluated by grouping 40-acre parcel data into four categories: sand, silt, clay, and water (including peat and mine dumps). Finally, soil hydrologic groups were evaluated as a direct measure of soil permeability. For this evaluation, each 40-acre parcel was grouped into one of five categories according to the rate at which their soils would transmit water: high, moderate, slow, very slow, and no rating.

Water Quality Assessment. MPCA examined monitoring data collected over a 12-year period (1973-1985) from 149 ambient monitoring stations segregated by ecoregion. Other monitoring stations whose drainage area included large areas of more than one ecoregion or did not include at least 4 years of data were excluded.

The results of the initial assessment show both increasing and decreasing water quality trends over the 12-year period. As expected, waterbodies in ecoregions that are more intensively developed tend to have high and increasing concentrations of pollutants such as total suspended solids, nitrite, and nitrate, while the less developed ecoregions are not as affected by these pollutants.

STORET data was used to calculate the mean values (by ecoregion) for 10 water quality parameters (temperature, pH, conductivity, total suspended solids, turbidity, nitrate + nitrite, ammonia, total phosphorus, BOD_5, and fecal coliforms). It was then necessary to determine statistically significant differences among these means. The usual test for comparing means is the t-test, but it was necessary to simultaneously compare means from several ecoregions, so Duncan's multiple range test was used. This procedure identified a set of ecoregions for each water quality parameter where the mean value for that parameter is statistically different. Because Duncan's multiple range test is a parametric measure and water quality data is seldom normally distributed, the MPCA is currently investigating the use of a nonparametric measure of statistical difference.

LEVEL II: MINOR WATERSHED NONPOINT SOURCE ASSESSMENT

The Level II analysis, designed to assess NPS pollution potential for each of the State's 5,611 minor watersheds, is based on statistically significant relationships between water quality parameters and the various ecoregion characteristics. The analysis can be divided into two steps as described below.

Step 1. The ecoregion means, calculated in the Level I water quality assessment, were correlated with detailed land use and topography information to test the relationship between these ecoregion characteristics and water quality. Two types of correlation coefficient were calculated the Pearson product moment correlation (a parametric measure) and Kendall's tau-b (a nonparametric measure). Although the water quality values themselves usually are not normally distributed, the ecoregion means that were analyzed are likely to be normally distributed However, because there are only seven observat ons (ecoregions), a normal distribution of the data may still be questionable For this reason, both Pearson and Kendall's correlations were calculated, and a relationship was considered significant only if it was significant for both measures.

Because land resources data represented the period 1965-70, MPCA examined relationships between ecoregion characteristics and water quality parameters for the same time period This procedure resulted in 34 relationships where either the water quality mean, median, or both were significantly correlated with an ecoregion characteristic. For example, total suspended solids were correlated to stream orientation, and total phosphorus levels were correlated to the percent of land in agriculture

Step 2. Not all of the 34 relationships identified are applicable or appropriate for an NPS assessment of minor watersheds. Some factors used to develop the relationships are not provided at the necessary level of detail (e.g , Department of Agriculture statistical data are recorded by county and minor watersheds are smaller than counties) Other factors are related to water quality parameters that may not pose a serious threat to the aquatic environment at levels typically observed in Minnesota With these limitations in mind, MPCA has made a preliminary selection of nine factors or "predictors" of NPS pollution potential These predictors are· (1) percent of land in cultivation, (2) percent of land that is urbanized, (3) percent of land with forest cover, (4) silt soils, (5) sandy soils, (6) stream orientation, (7) lake orientation, (8) slopes of 3 to 6%, and (9) slopes greater than 6% The objective is to map the pollution potential of each minor watershed based on these nine predictors. The selection of these predictors and the Level II assessment will help MPCA meet requirements under Section 319 of the Clean Water Act Amendments.

TESTING THE LEVEL II PROCEDURE

The Western Corn Belt Plains ecoregion was used to test the MPCA's proposed Level II NPS assessment procedure. First, the nine predictors were rank ordered for each of the 1,238 minor watersheds in this ecoregion Second, the pollution potential score for each minor watershed was calculated by summing the rank scores for each of the nine predictors (individual scores for stream and lake orientation were doubled to reflect the importance of these factors) The watershed with the highest score was considered to have the greatest NPS pollution potential. Finally, the scores were displayed graphically by mapping the percentile scores of each minor watershed.

It should be noted that the map produced by this exercise does not identify waterbodies with NPS pollution, but rather identifies areas where such problems are likely—i.e., where watershed conditions encourage NPS pollution in the absence of proper land use management. The MPCA hopes to use this procedure to identify areas both where further study is required and where protective measures may be needed.

LEVEL III: SITE-SPECIFIC NONPOINT SOURCE ASSESSMENT

Under the Minnesota Clean Water Partnership Act, enacted in May 1987, the MPCA will fund up to 50% of the costs for both diagnostic studies (to assess the need for site-specific NPS controls) and the implementation of such projects. Level III NPS assessments will be undertaken primarily by local authorities (e.g., counties, municipalities, or watershed districts) in conjunction with projects to be funded under this State program. Level III studies will include on-site water quality monitoring and the use of analytical tools such as the Minnesota Feedlot Model and the Agricultural Nonpoint Source Model (AGNPS) developed cooperatively by MPCA and by the U S. Department of Agriculture.

The feedlot model may be used to estimate the mass loading and concentrations of nitrogen, phosphorus, and chemical oxygen demand discharged from a feedlot into receiving waters after a storm These computations can be performed manually on a hand-held calculator. If the calculated discharge exceeds State standards for these pollutants, a numerical rating based on the potential severity of the hazard is assigned to allow comparison and ranking with other feedlots.

AGNPS is a computer simulation model (for use on personal and mainframe computers) developed to analyze the quality of runoff from Minnesota watersheds. The model predicts runoff volume and peak rate; eroded and delivered sediment; and nitrogen, phosphorus, and chemical oxygen demand concentration in runoff for single storm events. AGNPS is formulated on a grid-cell basis, so that the model can provide water quality information for specific locations within each watershed. Most of the information required for model input is available from the Minnesota Land Management Information Center

Within Minnesota, AGNPS has been utilized in the Big Stone Lake restoration project to identify critical areas in two sub-watersheds where upland erosion and runoff resulted in high concentrations of sediment and nutrients at the outlets of these watersheds. Once these critical areas were identified, Soil Conservation Service personnel conducted on-site inspections and recommended best management practices to reduce specific sources of pollution

PROGRAM SUMMARY

Level I of the nonpoint source assessment revealed NPS problems throughout Minnesota As a result, the State developed the Clean Water Partnership program to address this problem Through this program, MPCA will administer both State and Federal nonpoint source control funds, and Levels II and III of the assessment will help direct resources to areas where the most benefit will be obtained

Material for this report was furnished by Gary Fandrei and Gaylen Reetz, Minnesota Pollution Control Agency, Division of Water Quality; Robert Young, U S Department of Agriculture, Agricultural Research Service; and Thomas Davenport, U S EPA, Region 5 For additional information, contact Mr Fandrei (612) 296-7363

This report is produced by EPA to highlight monitoring and wasteload allocation activities. Contributions of information for similar reports are invited Please contact E F Drabkowski, EPA, MDSD, WH-553, 401 M Street S.W, Washington, DC 20460, (202) 382-7056.

EPA United States Environmental Protection Agency | Assessment and Watershed Protection Division, Office of Water, Washington, DC 20460 | May 1990

Water Quality Program Highlights

Ohio EPA's Use of Biological Survey Information

BACKGROUND

The Federal Clean Water Act has been amended numerous times since it was completely rewritten in 1972, but its principal goal remains unchanged to restore and maintain the physical, chemical, and biological integrity of our surface waters To achieve this environmental goal, we – EPA, the States, the regulated community, and the public – need information about the aquatic environment We need information to help us develop meaningful yet workable water quality goals, wisely direct our limited resources to those waters that will benefit most from restoration or control efforts, and ensure that our efforts result in measurable environmental improvements

EPA and State monitoring programs have historically relied on one type of information – measurements of individual pollutants in the water column Only slowly have chemical analyses of the water column been supplemented by other monitoring methods There seems to be a consensus today that to manage our remaining water quality problems cost-effectively, we must employ a variety of methods capable of assessing the impact of chemicals in tissue and sediment as well as in the water column, the condition of the physical habitat as well as water column chemistry, and the response of resident biota as well as laboratory test species

HIGHLIGHTS OF OHIO EPA'S MONITORING PROGRAMS

The Ohio Environmental Protection Agency (Ohio EPA) uses a combination of chemical, toxicological, and ecological approaches to monitor the quality of its rivers and streams This Highlight focuses on Ohio EPA's Biological and Water Quality Survey (BWQS) Program, and briefly discusses Ohio's long-term ambient water quality monitoring network (NAWQMN) Both programs make use of integrated chemical and biological monitoring In the early 1980s, the highest priority in the BWQS was evaluating the need for publicly owned treatment works (POTW) to install advanced treatment, the current priority is to evaluate nonpoint sources and assess toxicity due to point sources The main use of the NAWQMN data is to evaluate the effectiveness of selected pollution control projects

Because the biological component of Ohio EPA's programs is likely to be of greatest interest, this Program Highlight focuses on the potential uses, advantages, and limitations of the biological survey information collected in these two programs

Ohio EPA has found that incorporating biological survey methods into its water quality assessment program produces several benefits compared with relying exclusively on chemical-by-chemical or whole effluent toxicity monitoring First, biological assessments can detect water quality problems that other methods might miss or underestimate The resident biota act as continuous monitors of environmental quality, increasing the likelihood of detecting the effects of episodic events (e g , spills, nonpoint sources) or other highly variable impacts that monthly or even weekly chemical sampling might miss And sampling need not be conducted at critical low flow or under other worst case conditions Second, biological surveys can detect problems such as habitat degradation that are not strictly water quality problems, but can prevent attainment of uses Third, biological surveys directly assess biological integrity, providing information needed to identify high quality waters deserving special protection or confirm instream impacts predicted by fate and transport modeling (e g , wasteload allocation) and toxicity testing (i e , bioassays)

The power of biological assessments is their ability to assess aquatic ecosystem health (i e , biological integrity) They can supplement, but not replace, chemical and toxicological methods that are necessary to predict risks (particularly to human health and wildlife) and to diagnose, model, and regulate problems once they are detected

USES OF THE DATA

Three major uses of the chemical and biological data derived from the BWQS and NAWQMN Programs have included

- improving water quality standards (including refinement of stream use classifications and development of biological criteria),
- identifying impaired waters and assessing attainment/nonattainment of beneficial uses
- evaluating the effectiveness of pollution controls

Use #1· Improving Water Quality Standards

A major use of BWQS data has been to improve Ohio's water quality standards by refining existing use classifications and developing numeric biological criteria to supplement existing chemical-specific and toxicity criteria The development of biological criteria required descriptions of the type and condition of aquatic life thought attainable in streams and rivers throughout the State Ohio recognized that biological criteria needed to account for intrastate differences in attainable quality due to regional variation in land surface form, land use, vegetation, soils, and climate, but realized that it was infeasible to develop site-specific criteria for each of the hundreds of waterbodies in the State Their solution was to monitor streams least affected by human activity in each of several regions of the State ('least disturbed streams") and analyze the data to establish criteria specifying attainable conditions within each region

Ohio EPA could not have developed biological criteria without first developing standardized biological assessment methods Ohio has accomplished both – the development of assessment methods and criteria – through an iterative process of monitoring, the development of initial criteria, additional monitoring, and the subsequent development of more rigorous criteria Ohio was fortunate to have a fairly extensive historical database dating back as far as 1979

The process began in 1980, when Ohio EPA used the available database of about 150 sampling locations and the experience of its biologists to develop biological criteria for two aquatic life uses (exceptional warmwater habitat and warmwater habitat) These early criteria included both narrative and numeric requirements (e g , a stream met the exceptional warmwater habitat use only if there were more than 30 taxa present and pollution-sensitive species were "abundant")

The process continued in 1983 and 1984, when Ohio EPA and USEPA's Environmental Research Laboratory in Corvallis, Oregon, carried out the Stream Regionalization Project The project involved delineating the five distinct ecological regions ("ecoregions") illustrated in Figure 1, identifying "least-disturbed" watersheds in each ecoregion, and conducting extensive field work to characterize the health of fish and macroinvertebrate communities (and water quality) in the least-disturbed watersheds Ohio chose fish and macroinvertebrates as its indicators of biological integrity because the

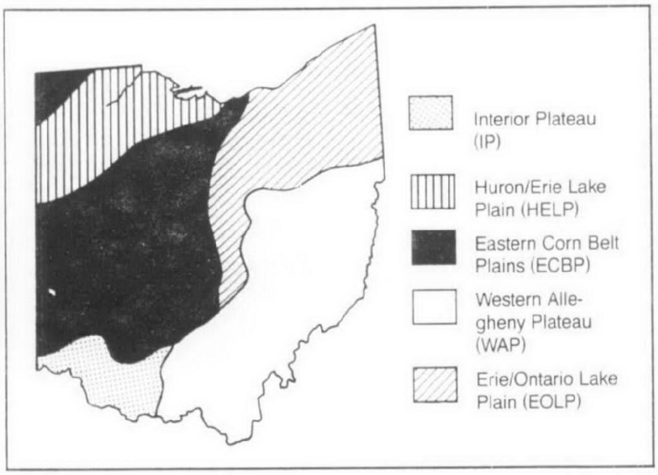
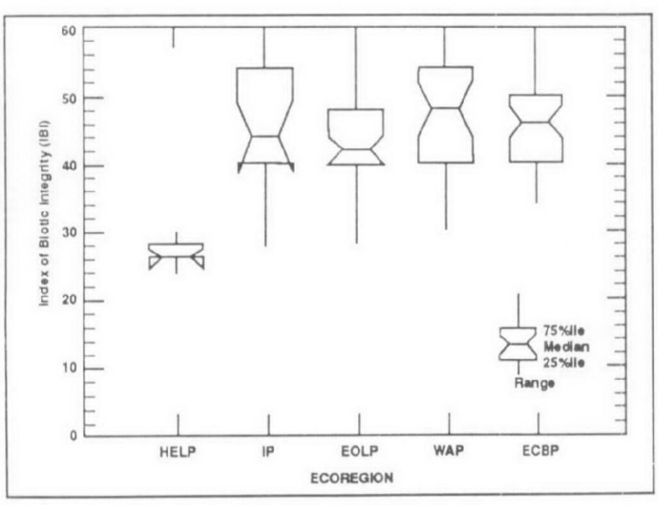


Figure 1. Ohio's Five Ecoregions.

distribution, environmental tolerance, and importance of these communities in lotic ecosystems were well known and because their health also reflects the health of lower trophic groups. More than 250 small stream sites and about 100 large river sites were sampled. These reference sites represent roughly the highest quality 5 percent of stream and river habitats in the State.

The field measurements were analyzed to determine various "metrics" of the health of the fish and macroinvertebrate communities such as species richness, trophic composition, diversity, the presence of pollution-tolerant individuals or species, abundance or biomass, and the presence of diseased or abnormal individuals. These metrics were in turn used to calculate values of three different biological indices: the Index of Biotic Integrity (IBI) for fish, the Modified Index of Well Being (Iwb) for fish, and the Invertebrate Community Index (ICI) for macroinvertebrates.

The next step in the analysis was to select values of each index thought attainable for each ecoregion. Figure 2 illustrates in a "box and whisker" plot the analysis conducted for one of the three indices: the IBI. The plot shows the distribution of IBI values calculated for least-disturbed streams in each of the five ecoregions. In the Huron/Erie Lake Plain ecoregion, for instance, IBI values for least-disturbed streams varied between 24 and 30. Ohio EPA established that a stream surpassing the 25th percentile value of the IBI scores of the reference streams in its ecoregion has attained the warmwater habitat use, in this case an IBI of 26. Ohio EPA established that a stream surpassing the 75th percentile value of the entire statewide reference site data set has attained the exceptional warmwater habitat use. These values serve as Ohio's numeric biological criteria. Generally, a waterbody is reported to fully attain its use only if all three index



Note: See Figure 1 for definition of acronyms.

Figure 2. Notched Box-and-Whisker Plot of Reference Site Results for the IBI (headwater streams).

scores (IBI, Iwb, and ICI) surpass the ecoregional criteria. Ohio reports partial use attainment if only one or two index values are met and nonattainment if none of the indices meet applicable criteria or if one organism group indicates poor or very poor performance.

Ohio has now established reference values for each of its three biological indices for each of the five ecoregions in three of its five aquatic life use categories. In addition, because attainable fish community characteristics vary with stream size and sampling method, reference values have been established separately for headwater streams (streams with drainage areas less than 20 mi^2), nonheadwater streams sampled by wading (drainage areas between 20 and 500 mi^2), and streams and rivers sampled by boat (drainage areas between 200 and 6,000 mi^2).

The five aquatic life uses included in Ohio EPA's refined water quality standards are: warmwater habitat, exceptional warmwater habitat, modified warmwater habitat, coldwater habitat, and seasonal salmonid habitat. Warmwater habitat is designated where waters are believed capable of supporting balanced reproducing populations of warmwater fish and associated organisms; exceptional warmwater habitat is designated where more sensitive and diverse biological communities, or rare species, are possible; coldwater habitat is designated in waters capable of supporting coldwater fish and associated organisms or where salmonids are regularly stocked; and seasonal salmonid habitat applies between October and May in tributaries to Lake Erie used by migrating salmonids. The modified warmwater habitat use designation is intermediate between the existing warmwater habitat and limited resource water categories. Limited resource waters are those that have extremely limited physical habitats due to natural limitations or extreme alterations of anthropogenic origin. The modified use was adopted after integrated assessments identified a number of stream segments where irreversible impacts precluded the attainment of the warmwater habitat use, but documented that these segments were able to sustain a semblance of a warmwater biological community. A use attainability analysis and USEPA approval are required prior to designating a stream as a modified warmwater habitat. There are, in addition, designations for aesthetics, water supply, and recreational uses, but the aquatic life use designations generally have the more stringent chemical criteria.

Ohio devoted a substantial fraction of its monitoring resources for 10 consecutive years to improving its water quality standards. Ohio expects in future years to sample about 10% of the reference sites each year to detect any broad-scale changes in background conditions that might prompt a recalibration of the biological indices, revisions of the biological criteria, or both.

Ohio EPA's approach to developing biological criteria is but one of several approaches used by State water quality agencies to define and measure achievement of biological integrity. States may choose to conduct crash efforts and monitor reference sites statewide in a year or two, or follow Ohio's example and spread the sampling over a 5- to 10-year period. The level of effort required to develop criteria varies from State to State—more ecologically homogeneous and sparsely populated States might find tens of reference sites sufficient; more heterogeneous and densely populated States might need more than the 300 or so sites monitored in Ohio. See the *Proceedings of the First National Workshop on Biological Criteria* (December 1988) for a discussion of other approaches.

Use #2: Identifying Impaired Waters

Biological assessments offer a powerful tool for identifying waters degraded by sources and causes of impairment that other approaches are likely to miss. In the middle segment of the Little Cuyahoga River, for example, fish and macroinvertebrate sampling indicated severe, but unexpected, impacts indicative of toxicity. These findings were unexpected because point source dischargers in the segment claimed to discharge only noncontact cooling water and small quantities of sanitary wastes. Accordingly, their permit did not require monitoring for toxic pollutants.

A followup investigation revealed that most of the dischargers in the river basin were involved in plastic and rubber manufacturing and therefore handled organic chemical products on the premises. Ohio EPA plans further work to identify the source of toxicity reaching the stream (e.g., spills, contaminated surface runoff, sewer system overflows, or unauthorized discharges).

In many other situations as well, Ohio EPA's increased reliance on biological methods has improved its ability to detect instream impacts (see Figure 3). The results of a survey of 431 stream segments found that instream chemical analyses for conventional pollutants, NH_3, and five heavy metals were in agreement with biosurvey results at 58% of the sites (at 17% of the sites both methods showed no impairment; at 41% of the sites both methods showed an impairment). At 6% of the sites, chemical data implied that there was an impairment while the instream biota showed no impairment. The most interesting finding, however, was that at 36% of the sites, instream chemical data implied no impairment while the instream biological communities showed impairment. The waters in this last category were degraded by "nonchemical" causes including sedimentation and/or habitat degradation (43%), subtle enrichment/dissolved oxygen impacts (31%), unknown toxicity (7%), and other causes (19%).

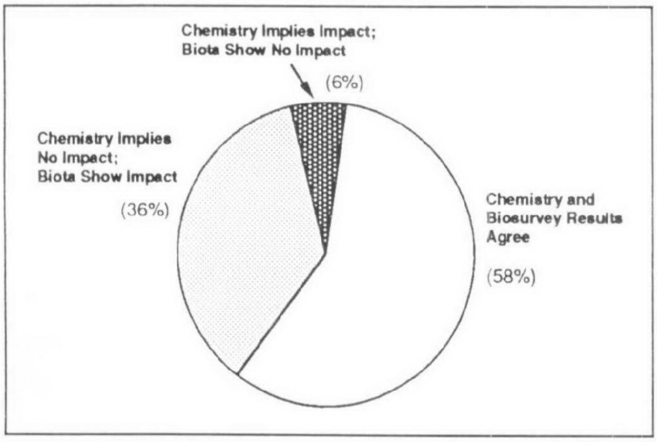


Figure 3. Biosurvey Results Usually Agree with Instream Chemistry or Reveal Unknown Problems.

An interesting consequence of Ohio EPA's improved ability to detect water quality problems is that the percentage of rivers and streams reported to fully support designated uses decreased between 1986 and 1988 from 61% to 32%. Ohio attributes this change to the adoption of revised biological criteria and more sensitive assessment methods, not to changes in water quality. Most of the waters newly designated in the 1988 §305(b) report as not supporting their uses experience "slight" to "minor" impairment, lending weight to Ohio's assertion that integrated assessments are capable of detecting increasingly subtle impacts.

Use #3: Effectiveness Evaluation

Ohio EPA also monitors a network of 36 NAWQMN sites to evaluate the effectiveness of selected projects. Each year, 10 of these sites are assessed for macroinvertebrate community health. When plotted versus time (which Ohio did for 11 rivers in its 1988 §305(b) report), the trends in ICI values from these sites present a meaningful indicator of environmental improvement. Where intensive survey data are also available to interpret observed trends (e.g., to correlate trends with program actions), these plots provide a measure of program success.

Figure 4 shows the results for two of the 36 sites, on the Mohican and Olentangy Rivers. At the Mohican site, four samples were collected between 1977 and 1987. Macroinvertebrate sampling shows an improving trend in biological condition since 1978. Warmwater habitat communities have been present in all years, with the most recent data suggesting that the site has the potential to achieve the exceptional warmwater habitat use. Ohio EPA attributes these improvements to industrial waste pretreatment requirements imposed in upstream cities and wastewater treatment improvements made by several industrial and municipal treatment plants.

At the Olentangy site, five samples were collected between 1977 and 1986. Biological condition at the site has steadily improved through this period. The most dramatic increase in ICI values occurred between 1977 and 1979 when an ICI value reflecting nonattainment of the warmwater habitat aquatic life use improved to an ICI value reflecting full attainment. The ICI improved further in 1983 when the macroinvertebrate community was scored exceptional or near exceptional, but this improvement may have been an artifact of moving the sampling location upstream. Construction of a new advanced treatment plant and improvements at several existing plants are the most likely explanations of the overall improvement.

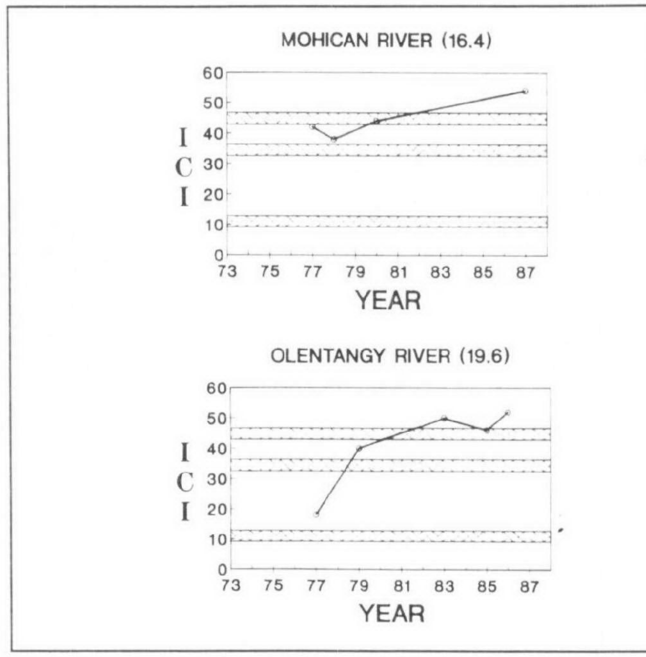


Figure 4. Long-term Trend of the Invertebrate Community Index (ICI) at Ohio EPA Annual Monitoring Stations.

DESIGN CONSIDERATIONS RELEVANT TO ALL USES OF MONITORING DATA

Ohio EPA conducts 12 to 15 intensive surveys per year during the June to October sampling season. Intensive surveys can be as short as 1 week, but usually last several months. They include chemical analyses of samples collected at between 3 and 80 sites at frequencies ranging from three times during the survey to once each week. They typically include fish sampling at each site between one and three times during the survey. Macroinvertebrate sampling is typically conducted at between 6 and 80 sites, with artificial samplers remaining instream for 6 weeks at each site sampled.

Where monitoring data are needed to calibrate and validate water quality models, more intensive sampling is done for selected physical/chemical parameters.

Ohio's biocriteria describe attainable conditions. In addition, one or more reference sites located upstream of all known sources of pollution are typically sampled to sort out the effects of multiple dischargers, but not as an arbiter of attainable condition. In a typical point source evaluation, one site is located upstream from the outfall, another site is located within the mixing zone, and additional sites are located at intervals downstream to determine the extent and severity of impact.

Fish Sampling Methods

The Ohio EPA has developed and documented standardized procedures for fish sampling. Pulsed DC electrofishing is used to obtain a representative sample of the fish community, either by wading into the stream or using a boat, depending on the size of the waterbody. In a survey, field personnel conduct repetitive sampling based on distance (rather than time) to avoid bias that would result where fish differ in spatial distribution due to differences in available habitat. Field personnel also weigh fish, identify each fish to the species level, and record external abnormalities. A three-person crew is required. Analysis of data collected at test sites indicates that spatial and temporal variability are low if standardized procedures are followed.

Macroinvertebrate Sampling Methods

Ohio relies primarily on a modified Hester-Dendy multiplate artificial substrate sampler for quantitative sampling of macroinvertebrates in streams and rivers The Ohio EPA uses a composite set of five samplers, supplemented with a qualitative sample from the natural substrate that provides a more complete inventory of all taxa present The Ohio EPA prefers artificial substrate samplers because they work in locations that cannot be sampled effectively by other means, require lower operator skill requirements, are nondestructive to the environment, and reduce the influence of the natural substrate Results collected over the past 15 years confirm that sampling variability is low if there is strict adherence to standardized procedures

Chemical Analyses

Ambient water samples (usually grab samples) are collected during integrated surveys These samples are analyzed for dissolved oxygen, nutrients, solids, oil and grease, total organic carbon (TOC), methylene blue activated substances (MBAS), fluoride, organics, metals, pesticides, cyanides and phenols, as appropriate Effluent and sediment samples are collected as necessary

Quality Assurance

Quality assurance is of paramount importance to the Ohio BWQS Program In September 1989, the Ohio EPA published an updated version of *Biological Criteria for the Protection of Aquatic Life* This document published in three volumes, details all aspects of sample collection and analysis of biological samples including

- minimum staff training in sample collection and species identification needed to ensure adequate data quality,
- methods for selecting and evaluating sampling sites,
- sampling procedures including the design and use of sampling equipment species identification, field counting and weighing procedures, sample preservation, and "chain-of-custody" procedures,
- habitat evaluation procedures,
- laboratory procedures for handling and identifying preserved specimens,
- data management and storage procedures,
- data analysis methods (including statistical tests and calculation of metrics)

Ohio EPA uses the USEPA's STORET database to manage its chemical data and its own Fish Information System (FINS) and Macroinvertebrate Data Gathering and Evaluation System (MIDGES) for its biological community data Personal computers are used extensively to analyze data and prepare reports

PROGRAM RESOURCE REQUIREMENTS

Out of an estimated 52 workyears available for Ohio EPA's monitoring activities in FY88 (field sampling, field and laboratory analyses data analyses, and reporting), 9 5 workyears (18 4%) went toward BWQS (surveys), 0 2 workyears (0 3%) went toward the biological portion of Ohio EPA's NAWQMN, and 0 8 workyears (1 6%) went toward the chemical portion of the NAWQMN The remaining monitoring program resources went toward wasteload allocation modeling/permitting, toxic contaminant monitoring, compliance/enforcement monitoring, water quality criteria, §401 certifications, and other needs

Collection of biological data has the reputation of being resource-intensive and too costly for routine application in State monitoring programs In 1989, Ohio EPA compared the cost of different approaches assumed to provide the same analytical and evaluative "power" Ohio EPA believes that, on a per-site basis, sampling fish and macroinvertebrate communities can be equal to or lower in cost than chemical sampling or toxicity testing More comprehensive chemical monitoring, such as priority pollutant scans and sediment analyses, further increases costs for chemical data

THE FUTURE

Improving the ability of its monitoring program to produce the type of monitoring information needed to support water quality program decisions has, in turn increased the demand for Ohio EPA's biological monitoring resources Managers of Ohio EPA's permits nonpoint source, hazardous waste and other environmental programs now compete for limited monitoring resources In its most recent 5-year monitoring strategy (Ohio EPA 1985), Ohio estimated that at current staffing levels it would take 13 years to satisfy its outstanding monitoring needs

Material for this report was furnished primarily by Chris Yoder, Ohio EPA Figures 1 and 3 were prepared using data from Ohio EPA's 1988 §305(b) report Figures 2 and 4 were taken from Biological Criteria for Protection of Aquatic Life, *February 28, 1988 Ohio EPA, Division of Water Quality Monitoring and Assessment, Surface Water Section Columbus, Ohio For more information, contact Chris Yoder*

This report is produced by EPA to highlight EPA and State monitoring activities Contributions of information for similar reports are invited Please contact Monitoring Branch, EPA AWPD WH-553 401 M Street S W Washington, DC 20460 (202) 382-7056

EPA
United States Environmental Protection Agency
Assessment and Watershed Protection Division
Office of Water
Washington, DC 20460
March 1991

Water Quality Program Highlights

Multimedia Toxics Study of the Calcasieu River Estuary, Louisiana

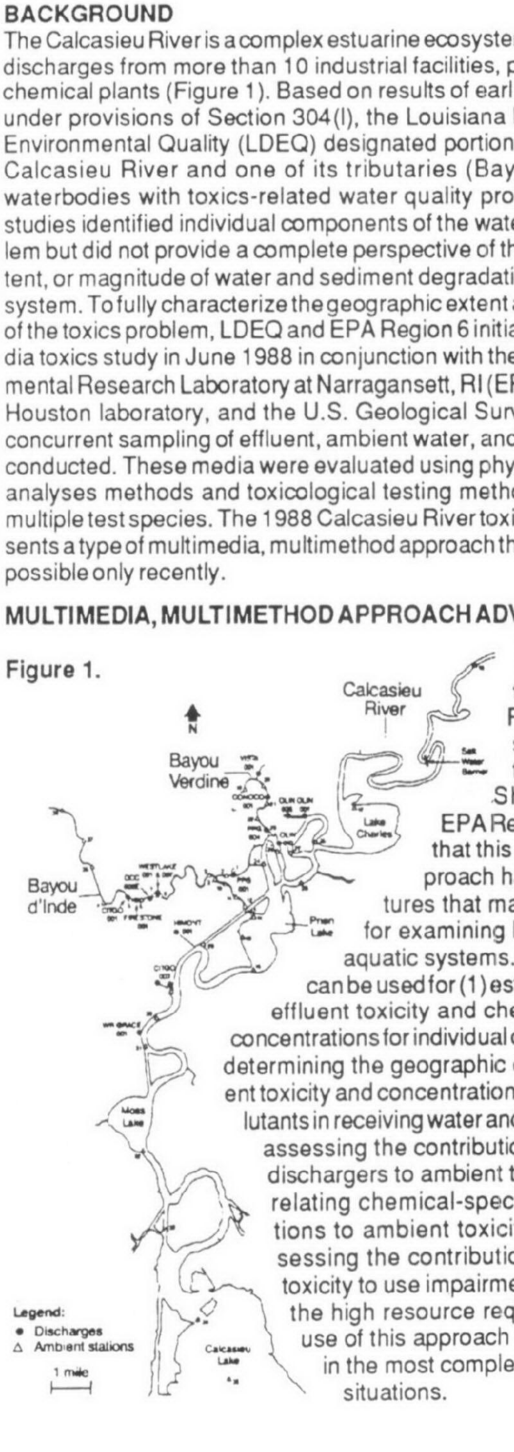
The Water Quality Act of 1987 reemphasizes the need to control toxic pollutants from point and nonpoint sources. In particular, Section 304(l) of the Act requires States and EPA Regions to identify waterbodies impacted by toxic pollutants; where known toxic problems exist due to point source discharges, Section 304(l) requires development and implementation of individual control strategies (ICSs) for dischargers. States are encouraged to collect additional information to characterize the nature and severity of these impacts.

BACKGROUND

The Calcasieu River is a complex estuarine ecosystem that receives discharges from more than 10 industrial facilities, primarily petrochemical plants (Figure 1). Based on results of earlier studies and under provisions of Section 304(l), the Louisiana Department of Environmental Quality (LDEQ) designated portions of the Lower Calcasieu River and one of its tributaries (Bayou d'Inde) as waterbodies with toxics-related water quality problems. Earlier studies identified individual components of the water quality problem but did not provide a complete perspective of the sources, extent, or magnitude of water and sediment degradation in the entire system. To fully characterize the geographic extent and magnitude of the toxics problem, LDEQ and EPA Region 6 initiated a multimedia toxics study in June 1988 in conjunction with the EPA Environmental Research Laboratory at Narragansett, RI (ERL-N), the EPA Houston laboratory, and the U.S. Geological Survey. Extensive concurrent sampling of effluent, ambient water, and sediment was conducted. These media were evaluated using physical/chemical analyses methods and toxicological testing methods employing multiple test species. The 1988 Calcasieu River toxics study represents a type of multimedia, multimethod approach that has become possible only recently.

MULTIMEDIA, MULTIMETHOD APPROACH ADVANTAGES

Figure 1.



Based on its experience in the Calcasieu River (and in a similar study in the Houston Ship Channel), EPA Region 6 believes that this monitoring approach has several features that make it desirable for examining large, complex aquatic systems. The approach can be used for (1) estimating whole-effluent toxicity and chemical-specific concentrations for individual dischargers, (2) determining the geographic extent of ambient toxicity and concentrations of priority pollutants in receiving water and sediments, (3) assessing the contribution of individual dischargers to ambient toxicity, (4) correlating chemical-specific concentrations to ambient toxicity, and (5) assessing the contribution of sediment toxicity to use impairment. Because of the high resource requirements, the use of this approach is feasible only in the most complex and critical of situations.

MONITORING APPROACH

The 1988 toxics study was designed to synoptically sample effluents, receiving waters, and sediments for both chronic toxicity and specific chemical contaminants. Water and sediment sampling was conducted at 38 stations, and effluent sampling was conducted at 15 industrial outfalls throughout the Calcasieu system (Figure 1). Monitoring activities were conducted during two 1-week intervals in a warm weather low-flow period. Effluents, receiving waters, and sediments for chemical-specific analyses were collected one time per location and shipped to the laboratory for appropriate chemical analyses. Some followup sediment testing was also conducted for Bayou d'Inde in April 1989 and July 1990. Effluents and receiving waters to be tested for toxicity were sampled three times during each week and sediments were sampled once at each station; all samples were shipped overnight to the laboratory.

Chemical Analyses—Chemical-specific analyses included the EPA-designated priority pollutant organic chemicals (extractable organics, volatile organics, and total phenolics) and selected toxic metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc). In addition, ammonia, alkalinity, hardness, chloride, turbidity, total suspended solids, total dissolved solids, total organic carbon (TOC), and sulfides were also assessed for ambient water and effluents. TOC was also analyzed for sediments.

Toxicity Testing—Effluents, receiving water, and sediment were tested using a battery of standard EPA bioassay tests. In addition to estimating toxicity, Region 6 was also interested in evaluating the sensitivity of EPA toxicity methods for aquatic life in an estuarine system. Chronic testing was conducted using four test species exposed in static renewal systems:

- Sheepshead minnow *(Cyprinodon variegatus)*— Larvae (<24 h old) were exposed for 7 days to effluent (LDEQ).
- Mysid shrimp *(Mysidopsis bahia)*— Juveniles (7 days old) were exposed for 7 days to effluent or ambient water (ERL-N).
- Inland silverside *(Menidia beryllina)*— Larvae (7-9 days old) were exposed for 7 days to effluent or ambient water (ERL-N).
- Benthic amphipod *(Ampelisca abdita)* — Juveniles were exposed for 10 days to sediment (ERL-N).

Growth and survival were the biological endpoints measured for all water and effluent tests; survival was measured in sediment tests.

STUDY RESULTS—BAYOU VERDINE

Results of chemical analyses and toxicity testing are summarized in Figure 2 for Bayou Verdine, the most degraded portion of the estuary. Results for each discharger are shown at the top of the figure, with the position of the outfall in relation to the ambient station indicated by an arrow. For each effluent, only those pollutants exceeding EPA criteria and/or State standards are identified. Exceedances of ambient criteria by dischargers for this bayou are based on simple dilution calculations; a 0% upstream dilution was assumed and tidal dilution was assumed to be negligible. The most sensitive biological endpoint, chronic value (ChV), is reported as percent effluent concentration for each of the three species tested. The ChV is an estimate of the presumably safe or no-effect concentration lying between the no-observed-effect concentration (NOEC) and the lowest-observed-effect-concentration (LOEC). The ChV is derived by calculating the geometric mean of the NOEC and LOEC values.

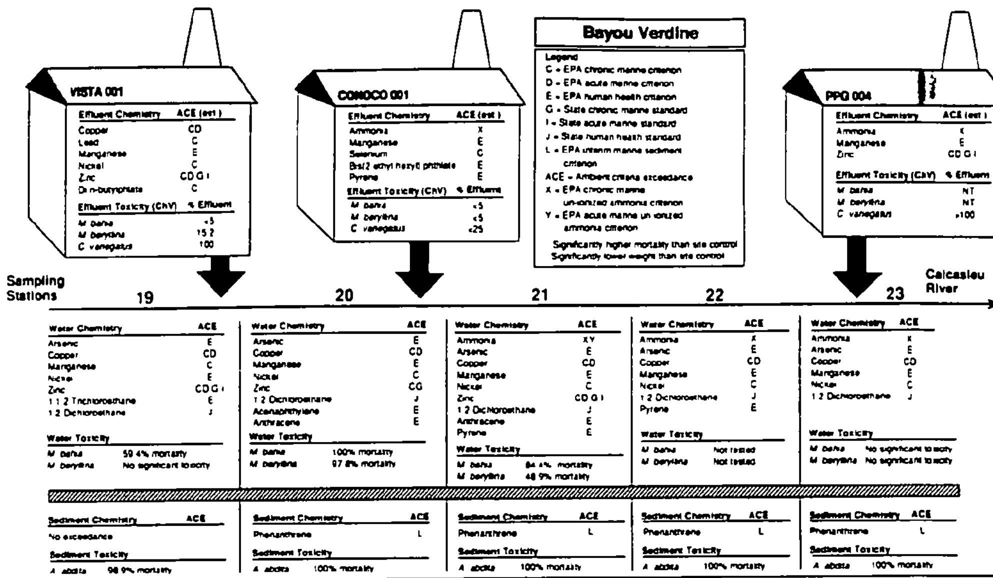


Figure 2. Chemical exceedances and toxicity results for Bayou Verdine.

Below the sampling station line, chemical exceedances and toxicity results are summarized for water and sediment.

Effluent — Chemical-specific data showed high concentrations of zinc in Vista 001 with lesser concentrations found in PPG 004 and Conoco 001. Zinc loadings were calculated to be 37, 5, and 1 lb/day for Vista 001, PPG 004, and Conoco 001, respectively. Nickel and copper appear to be contributed primarily by Vista 001. Vista 001 and Conoco 001 effluents were highly toxic, resulting in ChVs of <5% effluent for mysid shrimp and <5% to 15.2% effluent for silversides. Compared to mysids and silversides, the sheepshead minnow was relatively insensitive to these same effluents, exhibiting ChVs of <25 to >100% effluent.

Ambient Water — Water quality in Bayou Verdine was degraded by ammonia, several heavy metals, and organics. EPA criteria and/or State standards were exceeded at all five stations for arsenic, copper, manganese, nickel, and 1,2-dichloroethane and at several stations for zinc, ammonia, pyrene, and anthracene. Particularly noteworthy are those chemicals found in exceedance of EPA water quality criteria for protection of aquatic life that may contribute to ambient water toxicity. Nickel, copper, zinc, and ammonia exceeded EPA chronic marine criteria; copper, zinc, and ammonia exceeded EPA acute marine criteria at some stations. Several of these pollutants were detected in effluent of the bayou's three dischargers. Exposure to ambient water from stations 19, 20, and 21 produced a significant toxic response in at least one test species. Mysid shrimp exhibited the highest mortality—from 59 to 100%.

Sediment Quality — Sediment quality of Bayou Verdine was degraded by organic and metal pollutants. At four stations, the EPA interim marine sediment criterion was exceeded for phenanthrene. Currently there are no sediment criteria for metals. However, chromium, copper, lead, manganese, and zinc concentrations greater than 50 mg/kg were detected at several stations and a zinc concentration of 1,234 mg/kg was detected at station 20. Sediment metal concentrations were generally highest (>50 mg/kg) at stations 20 or 21, decreasing downstream. Chromium, copper, manganese, lead, nickel, and zinc were detected in the effluents of Vista 001, and zinc and manganese were also detected in effluents from the other dischargers. Exposure to sediment sampled from all stations produced high mortality (>98%) in the benthic amphipod.

STUDY CONCLUSIONS AND RECOMMENDATIONS

A primary finding was the identification of ambient water and sediment contamination and toxicity in Bayou Verdine. Analytical data reveal violations of EPA acute and chronic marine water quality criteria and State chronic marine standards for zinc, EPA chronic marine water quality criteria for nickel and copper, State human health standards for 1,2-dichloroethane and EPA human health criteria for arsenic and manganese, toxicological data indicate ambient toxicity of both receiving water and sediment at specific stations. Based on study results, EPA Region 6 included Bayou Verdine on the 304(l)(B) list and Vista Chemicals on the 304(l)(C) discharger list for nickel and zinc. Steps to control these pollutants are being taken through an ICS and modifications to the NPDES permit. No action has been taken concerning highly contaminated sediments.

Another finding was the detection of high sediment concentrations of hexachlorobenzene (HCB) and hexachlorobutadiene (HCBD) in Bayou d'Inde. The point source believed to be responsible for widespread bioaccumulation of these two compounds in the lower Calcasieu estuary was determined to be PPG 001. EPA Region 6 approved the State's listing of Bayou d'Inde, a portion of the Calcasieu River, and Prien Lake under Section 304(l)(B). PPG was listed under Section 304(l)(C) for discharges of halogenated aliphatic and aromatic priority pollutants, principally HCB and HCBD. EPA added bromoform and recommended more stringent controls for HCBD. Controls are being required through the ICS/permit modification process. Best available technology controls for volatile organic compounds (VOCs) will be implemented when the permit is reissued later in 1991 or 1992. The LDEQ is negotiating with PPG concerning cleanup of contaminated sediments.

EPA Region 6 believes periodic ambient toxicity testing at selected sites is warranted, particularly in Bayou Verdine and Bayou d'Inde. Mysids were the most sensitive test species, followed by silversides, sheepshead minnows were the least sensitive. The State supports use of the silverside in monitoring and permit requirements, and EPA Region 6 is incorporating this species in its whole effluent toxicity NPDES permit requirements.

Heavy metals, including zinc, copper, and arsenic, were detected in effluents discharged to the two bayous studied and the Calcasieu mainstem and were also found at relatively high concentrations in ambient water and sediments at some sites. Region 6 and the State recognize the need to investigate metal loading and impacts throughout the Calcasieu system. As a result of this study, Louisiana is currently establishing standards for copper, cadmium, lead, nickel, and mercury.

Material for this report was furnished by Philip Crocker, EPA Region 6 Water Management Division. The study was conducted with the support of EPA's AWPD and the State of Louisiana. "Toxics Study of the Lower Calcasieu River" is available from NTIS, #PB90226150/AS.

This report is produced by EPA to highlight monitoring and wasteload allocation activities. Contributions of information for similar reports are invited. Please contact EPA AWPD Monitoring Branch, 401 M Street, SW (WH-553), Washington, DC 20460, (202) 382-7056.

EPA
United States Environmental Protection Agency
Assessment and Watershed Protection Division
Office of Water
Washington, DC 20460
May 1991

Water Quality Program Highlights

Eutrophication Management in North Carolina

In North Carolina, several noteworthy nutrient management actions have resulted from eutrophication monitoring and assessments, including (1) development of a special classification, Nutrient Sensitive Waters (NSW), that both restores and protects designated waters; (2) development of a State water quality standard for chlorophyll *a*; (3) a ban on the manufacture, sale, and use of high phosphate detergents; and (4) initiation of a cost-sharing program for implementing agricultural best management practices (BMPs). Significant nutrient reductions have been achieved already because of the detergent ban. Further reductions will occur as effluent controls and BMPs continue to be implemented. This report discusses some of the tools the State has used to develop an integrated approach to eutrophication assessment and management.

THE EUTROPHICATION PROBLEM

Excessive discharge of nutrients (phosphorus and nitrogen) from wastewater treatment plants and nonpoint sources into lakes, reservoirs, rivers, and estuaries can cause undesirable blooms of microscopic algae and excessive growth of larger plants (macrophytes). Accelerated growth of plants frequently taxes the water's oxygen resources and disrupts the food chain. Eutrophication can therefore interfere with a waterbody's intended use, such as recreation. The objectives of managing nutrient inputs are to restore water quality in impaired eutrophic waters and to reduce the potential for future problems in unimpaired waters.

ASSESSING THE PROBLEM

Eutrophication in Coastal Rivers—The earliest documented eutrophic response to high nutrient concentrations in North Carolina waters occurred in the 1970s in a coastal plain waterbody, the Chowan River (Figure 1). The Chowan is a major alewife and herring nursery and fishery area and has recreational uses important to the local economy. Occurrence of massive blue-green algal blooms focused public attention on eutrophication and resulted in an intensive water quality monitoring effort. Biweekly monitoring of phosphorus, nitrogen, chlorophyll *a* (a measure of algal production), phytoplankton, and other water quality measurements was used to document the causes and severity of algal blooms in the river. Point source monitoring and land use data were used to develop estimates of point and nonpoint source contributors to nutrient loading. Subsequently, screening models relating phosphorus to chlorophyll *a* were developed to determine necessary reductions and to assess the probable effects of phosphorus control strategies.

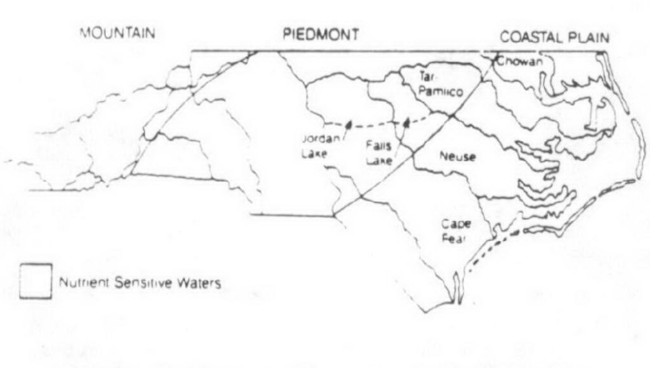


Figure 1. Nutrient sensitive waters in North Carolina.

During the early 1980s, surface blue-green algal blooms were also being documented on the lower Neuse River. Research supported by the State resulted in estimates of desirable nutrient reductions: for inorganic nitrogen, a 30% reduction in spring and summer concentrations; and for phosphorus, a 50% reduction. Developing these estimates involved innovative techniques using both laboratory and in situ algal assays focused on the phytoplankton species responsible for the worst blooms (*Microsystis aeruginosa*). Inorganic nutrients were added to enclosed "hydrocorrals" in the river to determine which nutrients were limiting phytoplankton growth. In a majority of cases, no enhanced growth was observed, indicating a hypereutrophic condition where nutrient supplies exceeded growth requirements. Therefore, a bioassay technique designed to address potential nutrient limitation was developed by diluting ambient water to determine the concentrations at which nutrients would become limiting to *Microcystis* growth. Using effluent and stream nutrient monitoring data and land use analyses, the NC Division of Environmental Management (DEM) determined the annual average contributions of nitrogen and phosphorus from point and nonpoint sources and assessed strategies to accomplish the necessary reductions.

In the Tar-Pamlico River basin, as in the Chowan and Neuse basins, heavy nutrient loads are delivered to the free-flowing river in the upper and middle basin before the river slows and broadens as it enters the Pamlico Sound. Unlike the other basins, blue-green algal blooms and excessive summer chlorophyll *a* levels have not occurred in the Tar-Pamlico basin. However, current nutrient levels, symptomatic ecological signs (dinoflagellate algal blooms, fish kills, loss of submerged aquatic vegetation), and land development patterns clearly suggest the probability of increasing degradation. The State thus developed a proactive strategy by requiring nutrient removal before severe signs of eutrophication appeared rather than taking the reactive stance required for the Chowan and Neuse basins.

Eutrophication in Piedmont Reservoirs—In addition to monitoring activities in coastal plain rivers, ongoing studies indicated that portions of two Piedmont reservoirs, Falls Lake (Neuse basin) and Jordan Lake (Cape Fear basin), were impacted by heavy nutrient loading. Falls Lake is currently the principal drinking water source for the City of Raleigh; Jordan Lake is a planned future water supply source. Although the intensity of surface algal blooms on the reservoirs has not matched that found on the coastal rivers, sampling at many lake stations has indicated that a majority of summer chlorophyll *a* values exceeded 40 μg/L. An additional concern is the observed dominance of blue-green algae.

DEVELOPING A SOLUTION

A State water quality standard for chlorophyll *a* (40 μg/L in the summer) was adopted during the Chowan study. While chlorophyll *a* standards have not been adopted by other States, DEM has found the standard to be an effective tool in nutrient management. The standard has been particularly useful in providing a decision criteria for models relating nutrients to chlorophyll *a*.

The Chowan River monitoring effort prompted the State to designate a new surface water classification—Nutrient Sensitive Waters—for surface waters "experiencing or subject to excessive growths of microscopic or macroscopic vegetation." The NSW classification allows the DEM to develop nutrient reduction strategies for individual waterbodies and basins. These strategies are based on existing data and model projections indicating use impairment in the absence of nutrient reductions. A Water Quality Management Plan for the Chowan basin was published in 1982.

The Chowan Management Plan provided a foundation for nutrient management efforts in other basins. As a result of the monitoring and algal studies described above, the Neuse River received the NSW classification in 1988, and a schedule for implementing nutrient controls was developed. The Falls Lake and Jordan Lake watersheds were designated NSW when they were impounded in 1983; a revised NSW strategy was adopted after a 5-year assessment in 1988. In September 1989 the Tar-Pamlico watershed received the NSW designation.

For the two Piedmont reservoirs, sufficient data were available to adapt nitrogen, phosphorus, and chlorophyll *a* loading/response models and to assess the impact of predicted population growth and changes in wastewater inputs and land use. A model developed at Duke University for southeastern lakes and reservoirs was used to predict the annual average lakewide phosphorus and nitrogen concentrations based on nutrient loading. A model developed by the Army Corps of Engineers for large reservoirs was used to predict the summer lakewide chlorophyll *a* concentrations based on the predicted phosphorus and nitrogen concentrations. Strategies for phosphorus reductions based on these two analyses were finalized in 1987; since then, DEM, in cooperation with EPA's Ecological Support Branch in Athens, Georgia, and the City of Durham, has completed intensive examinations of the impact of nutrient loading from several large municipal wastewater treatment plants on localized areas in both lakes. EPA's Athens laboratory provided support in completing algal tests to study the maximum potential algal growth, the biological availability of nutrients, and the limiting nutrient.

IMPLEMENTING A SOLUTION— NUTRIENT MANAGEMENT EFFORTS

Eutrophication assessments have also contributed to two major statewide nutrient management activities: agricultural BMP cost-sharing and a ban on phosphate-bearing detergents.

Point source controls—End-of-pipe nutrient controls required in NSW watersheds include limitations of 1 mg/L for phosphorus and 3 mg/L for nitrogen for all dischargers in the Chowan basin. In the other basins, a phosphorus limit of at least 2 mg/L is required for all significant dischargers. The stringent provisions of the Chowan Management Plan, for example, caused virtually all dischargers in this rural basin to construct land application systems for wastewater disposal.

BMP cost-sharing—The NSW classification also triggered a State-funded, voluntary agricultural cost-sharing program for implementing BMPs for waste, water, and fertilizer management and erosion control. This program has grown from 16 counties in NSW watersheds, funded by the State legislature at a level of about $2 million in 1984, to statewide funding in 1990 with an annual budget of $12 million guaranteed for 10 years. About 500,000 acres of land were treated with BMPs through the cost-sharing program between 1984 and March 1989. DEM estimates that this program could reduce phosphorus inputs from treated agricultural lands by roughly 30% and nitrogen inputs by 15-20%, with the additional benefits of pesticide and sediment reduction and long-term economic returns.

Detergent ban—Another major initiative to reduce phosphorus has been the adoption of a statewide ban on the manufacture, sale, and use of high phosphate detergents, effective January 1, 1988. DEM has evaluated the effect this law has had on the discharge of phosphorus from municipal wastewater (Table 1). Data from 23 major municipal facilities indicate that influent phosphorus loading has decreased by 10% to 58%, and effluent phosphorus loading has decreased by 25% to 85%. Municipalities are being polled to determine differences in treatment methods, which may explain the higher reductions in effluent phosphorus relative to influent phosphorus. It is estimated that phosphorus effluent loading has decreased by 4 million lb/year since the ban became effective. In the Neuse River, Falls Lake, and Jordan Lake watersheds, this reduction is equivalent to as much as one-quarter of the total loading. However, since reductions of about 50% or more are needed based on water quality models and algal assays, additional reductions are being sought through effluent limitations and nonpoint source controls.

Table 1. Nutrient Sensitive Waters: Annual Phosphorus (P) and Nitrogen (N) Reduction Goals and Achievements[a]

Waterbody	Target P Reduction[b]	Observed P Reduction[c]	Target N Reduction
Chowan River (NC portion)	35-40%	d	15-25%
Lower Neuse River	50% or greater	26%	30% spring/summer
Upper Neuse River (Falls Lake)	43%	21%	—
Upper Cape Fear River (Jordan Lake)	38%	24%	—
Pamlico River	e	13%	e

[a]29% P reduction has been documented in Chowan. N target reduction is being achieved. Target compliance dates for other basins range from 1990 to 1993.
[b]Additional P reduction needs are being studied.
[c]P reduction from P detergent ban.
[d]Municipal point sources are using nondischarging systems.
[e]No increase from point sources. Implement agricultural BMPs.

CURRENT AND FUTURE EFFORTS

In addition to monitoring the effect of management actions on NSW waters, DEM is currently involved in both screening and intensive eutrophication studies of other coastal and inland waters. The North Carolina Lakes Program focuses on screening level assessments of 144 public lakes greater than 100 acres. An algal bloom monitoring network, involving citizen and DEM staff investigation of bloom events, is being used for geographic tracking of bloom occurrence. The most notable management result of this monitoring network has been the identification of a coastal river (New River) with excessive blooms, resulting in intensive sampling and point-source phosphorus controls.

Material for the report was provided by John Dorney and Jim Overton of the Water Quality Section of the North Carolina Division of Environmental Management.

This report is produced by EPA to highlight monitoring and wasteload allocation activities. Contributions of information for similar reports are invited. Please contact EPA, AWPD, Monitoring Branch (WH 553), 401 M Street, S.W., Washington, DC 20460 (202) 382-7013.

EPA
United States
Environmental
Protection Agency
Assessment and Watershed Protection Division
Office of Water
Washington, DC 20460
June 1991

Water Quality Program Highlights

Florida's Method for Assessing Metals Contamination in Estuarine Sediments

Among the toxicants found in sediments, heavy metals (e.g., lead, cadmium, mercury, nickel) have been a continuing concern. These contaminants are frequently found in nonpoint source runoff, and elevated metals concentrations often signal the presence of other types of pollution. Metals are, however, a natural component of the coastal environment and, in small amounts, are necessary to the existence of marine and estuarine organisms. The EPA is currently working to develop sediment metal criteria that address the issue of bioavailability of sediment-bound metals to aquatic life. This is an important and complex issue because high concentrations of metals in sediment in and of themselves are not necessarily toxic–the metals may be tightly bound to sediment particles and / or organic matter thereby reducing their availability to be metabolized by aquatic organisms. Conversely, seemingly low concentrations of metals in some sediment types may be toxic to various aquatic organisms because the metals are more available for metabolism.

Florida's Department of Environmental Regulation (DER) has developed a method to identify sediments with elevated metals contamination using data on metals concentrations in sediments from unimpacted areas. The method does not identify sediments that are toxic (i.e., where benthic communities are impacted), but it permits targeting of areas of elevated metals concentrations for further chemical, toxicological, or biological assessments. This State's approach, which is based on natural relationships between metals in uncontaminated sediments, may be useful in other regions of the country where there is a need to investigate trends, manage cleanup efforts, or develop permits for dredging and disposal of sediments.

THEORETICAL BASIS FOR THE FLORIDA APPROACH

The background or "natural" concentration of metals in sediment can vary widely among marine waters, with concentrations generally being a function of watershed mineralogy, sediment grain size, organic content of the sediment, and the amount contributed by human activities. Such variability makes it difficult to define numerical criteria for sediment or compare sediment metals concentrations from different areas.

Florida's approach to interpreting sediment data is based on naturally occurring relationships between the sediment concentrations of various metals. Specifically, geochemists have found that several abundant crustal elements occur in a relatively constant relationship with heavy metals, which allows researchers to "normalize" or reference various metals to a single conservative element. This method offers the additional advantage of requiring data only on sediment metal concentration; other methods (sediment toxicity testing, partitioning, and benthic community structure) require data on numerous parameters.

Florida DER chose aluminum as the reference element because (1) it is highly refractory (i.e., it does not degrade or alter in form in the environment); (2) heavy metal/aluminum ratios are relatively constant in unimpacted estuaries; and (3) aluminum concentrations generally are not influenced by human activities.

DEVELOPING REFERENCE DATA

To set up their analyses, the DER sampled reference stations to document metals concentrations at 103 "unimpacted" (i.e., clean water) sites throughout the State of Florida. Duplicate samples were collected from the upper 5 cm of sediment for up to nine metals: aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. A total of 785 data points were obtained (all nine metals were not measured at each site).

Of the nine metals, mercury presented unique problems because (1) it is more volatile than the other metals; (2) natural background concentrations of mercury were near the analytical detection limit, where higher measurement error can be expected; and (3) an inverse mercury/aluminum ratio was observed. As a result, mercury was excluded from further analysis.

For the remaining eight metals, several steps were taken before statistical analyses were attempted. To satisfy the requirement that data exhibit a normal (i.e., bell-shaped) distribution, analyses were carried out using the logarithms of the raw data. In addition, probability plots were used to assist with decisions to discard some outlier values. This step was necessary to minimize the possibility of including data from sites with some enrichment and to satisfy statistical assumptions; a total of 18 out of the 785 data points were discarded. Finally, metal vs. aluminum regressions were completed, and 95% prediction limits were calculated.

Regression is a standard statistical method of fitting a line to data that describe the relationship between two variables; in this case, the dependent variable is the concentration of one of seven heavy metals, and the independent variable is the concentration of aluminum. The 95% prediction limit defines a range where the concentration of a metal can be expected to occur (with 95% confidence) under natural conditions. An example of the lead/aluminum relationship is shown in Figure 1. Similar plots showing a statistically significant relationship across the range of observed aluminum concentrations (47 to 79,000 ppm) were observed for all seven metals.

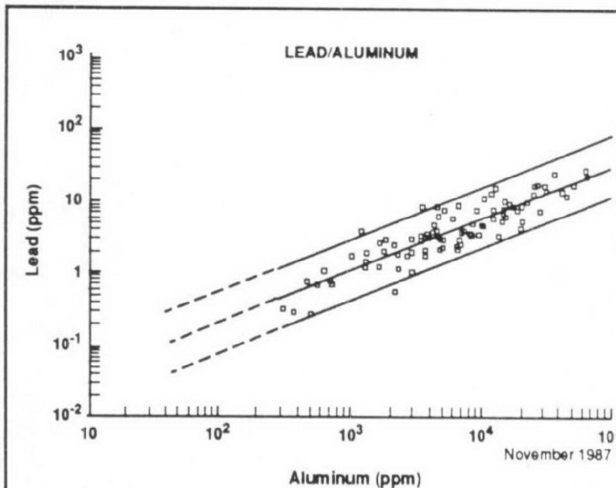


Figure 1. Lead/aluminum regression line (a) and 95% prediction limits (b). Dashed line indicates extrapolation beyond data range.

UTILITY OF THE METHOD

Florida DER has found the metal vs. aluminum plots to be useful in a number of ways. A key use is simply to flag stations where metal values may be in excess of naturally expected concentrations. An observation outside of the 95% prediction range should trigger closer investigation of possible pollutant sources. In addition, the method provides the ability to track trends in metal/aluminum ratios and has been used to determine where additional monitoring may be needed. For example, where sediment contamination is suspected, the State may perform sediment bioassays. Sediment bioassays involve exposing an organism to metal-contaminated sediments and measuring the effects of exposure on a biological endpoint (e.g., mortality, growth, or reproductive effects).

Experience gained in the studies of unimpacted coastal sites has enabled the DER to improve their sampling, laboratory, and interpretive activities. Key findings include the following:

- Duplicate or triplicate samples are crucial to reducing sampling variability.
- Total digestion of sediment samples in the laboratory is necessary to ensure release of metals that are tightly bound with the crystalline structure of sediment minerals.

THE BISCAYNE BAY STUDY

One application of the reference metal approach has been to assess toxicant levels in the Miami River-Biscayne Bay area of Miami. The river is a major tributary to the bay, is lined with ship berthing areas, and receives urban stormwater runoff from Miami. Sediment samples were taken at 11 stations in the river and bay (see Figure 2), and results were plotted over the regression lines and confidence intervals obtained from unimpacted areas. Of the seven heavy metals, arsenic and nickel fell within the expected natural ranges; chromium, copper, and lead concentrations were both within and above the predicted natural range, with most stations near the mouth of the river having the highest concentrations; and cadmium and zinc exceeded the predicted natural ranges at almost all the stations sampled.

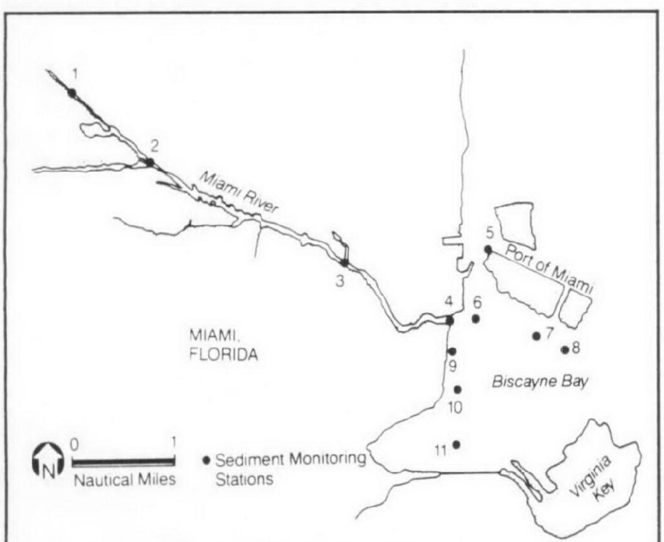


Figure 2. Sediment monitoring stations in the Miami River-Biscayne Bay area.

Figure 3 shows the sediment concentrations of lead at the 11 stations superimposed over the lines indicating the expected metals concentrations based on statewide sampling of unimpacted areas. The numbered data points indicate stations, with 1 representing the most upstream station and 11 representing the most downstream station. The increasing degree of enrichment with increasing aluminum concentrations is thought to be due to grain size effects. Fine-grain sediments (typical of the Miami River) more readily adsorb contaminant metals and generally have higher aluminum values. Similar conclusions could not have been reached using water column data alone.

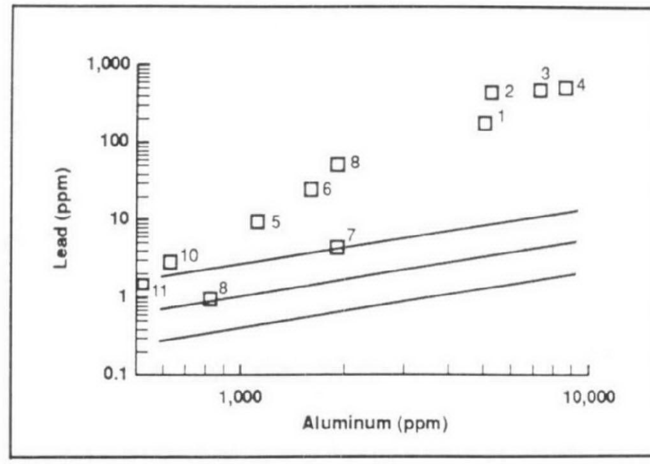


Figure 3. Lead concentrations in sediment from Miami River and Biscayne Bay. Regression line and 95% range from clean water sites are also shown.

The conclusion that the Miami River was contributing toxics to the sediments of the river and bay and that expansion in the area of contamination is likely in the absence of remediation has resulted in an increased commitment to reduce pollutant inputs to the system.

Similar studies have been completed successfully in other estuaries in Florida, including the Tampa Bay and Pensacola Bay systems. The approach has been found to be especially valuable in surveys of large systems, where it can be used to identify potential sources of pollution and assist in decisions regarding more intensive monitoring efforts. In addition to the quality of information obtained from the reference metal approach, the State has been pleased with the method's simplicity, cost-effectiveness, and the resulting improved consistency in regulatory decisions and reduction of regulatory delays.

Material for this report was furnished by Dr. Steven J. Schropp and Fred D. Calder, Florida Department of Environmental Regulation, Coastal Zone Management Section, Florida Department of Environmental Regulation, 2600 Blair Stone Road, Tallahassee, FL 32301.

This report is produced by EPA to highlight monitoring and wasteload allocation activities. Contributions of information for similar reports are invited. Please contact EPA, AWPD, Monitoring Branch (WH-553), 401 M Street, S.W., Washington, DC 20460 (202) 382-7013.