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Report to Congress

Water Quality Improvement Study

U.S. Environmental Protection Agency

REPORT TO CONGRESS
WATER QUALITY IMPROVEMENT STUDY

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Report to Congress on the Water Quality Improvement Study

EXECUTIVE SUMMARY

The objective of this report is to identify improvements in water quality attributable to the application of best available technology economically achievable (BAT). This study is required by Section 308(g) of the Water Quality Act of 1987. Section 308(g) also requires an evaluation of the water quality program (including Section 302(a) site-specific water quality determinations) and recommendations of methods for improving such program. This study does not include an evaluation of non-BAT aspects of the water quality program since this aspect is now the subject of a major concurrent effort mandated under Section 308(a) of the 1987 Water Quality Act [Section 304(l) of the Clean Water Act].

This Report to Congress presents the results and general conclusions of this study on the effectiveness of BAT effluent limitations for controlling pollutant discharges from industrial sources and the resulting improvements in chemical and biological quality of streams and rivers receiving discharges from these industrial sources. This study does not address the benefits of controls other than the national categorical effluent guidelines, such as "best professional judgment" or water quality-based controls implemented at the individual permit level, pretreatment requirements, nonpoint source controls, and treatment requirements for publicly owned treatment works. Nor does this study address the non-water quality impacts that have resulted from improved wastewater treatment (e.g., generation of solid wastes or increased air pollutant emissions due to volatization or stripping).

LEGISLATIVE HISTORY AND BACKGROUND

The Clean Water Act establishes as a national goal the restoration and maintenance of "the chemical, physical, and biological integrity of the

Nation's waters." As a primary means of achieving this goal, Congress prohibited "the discharge of any pollutant by any person" into the waters of the United States unless that discharge complies with the specific requirements of the Act Section 301 (a), 33 U.S.C. 1311(a). Compliance may be achieved by obtaining a permit issued pursuant to Section 402 of the Act. Permits must incorporate applicable technology-based effluent limitations guidelines promulgated by EPA on a nationwide, industry-by-industry basis under Sections 301(b) and 304, and if EPA has not promulgated guidelines, limitations are applied in individual permits on a case by case basis (Section 302). Effluent limitations are implemented in two stages. By July 1, 1977, dischargers to surface waters were required to achieve effluent limitations applicable to best practicable control technology currently available (BPT). For toxic pollutants and nonconventional pollutants, they are required, by 1984, to achieve effluent limitations applicable to best available technology economically achievable (BAT). Separate requirements were established for industrial facilities that discharged wastewaters to publicly owned treatment works (POTWs) and for new sources.

The development of categorical standards, including BPT and BAT regulations, has spanned a period of 16 years. Roughly half of the original BPT regulations promulgated in the mid-1970s have remained unchanged, despite additional regulatory activity for industrial categories. For some of these categories, the BPT effluent limitations have equaled BAT. Therefore, the technology basis for limitations for some industrial categories has been unchanged since the mid-1970s; for others, however, the statutory deadlines for compliance with BAT limitations have not yet passed.

"Technology-based" limitations are used by permitting authorities to set minimum pollution control requirements for all dischargers other than publicly owned treatment works. In some instances, however, additional controls may be necessary to meet water quality standards. Section 304(l) of the Clean Water

Act (added by the 1987 Amendments) requires States to identify waterbodies that are impaired by toxic discharges from point sources and develop strategies to control these discharges. States were to identify waterbodies and develop individual control strategies (ICSs) by February 4, 1989 and must achieve applicable water quality standards on or before June 4, 1992. EPA approved or disapproved the ICSs on June 4, 1989, and where EPA disapproved an ICS, the revised ICS must achieve applicable water quality standards on or before June 4, 1993.

METHODOLOGY

The limitations required under EPA's effluent guideline regulations have resulted in a significant reduction in the amounts of toxic, conventional, and nonconventional pollutants that are discharged to the nation's waters. While these reductions in themselves have improved water quality, the extent of such improvements has not been examined closely. This study attempts to determine the extent of these improvements, on a nationwide scale, through the examination and use of currently existing EPA data sources. However, this study does not attempt to quantify benefits which result from improved water quality. These include increased sport and commercial fishing, and improved recreational opportunities.

Three methods, or components, were used to identify and/or project the extent of improvements in water quality that can be attributed to the implementation of BAT effluent regulations. These are: (1) water quality modeling of pollutant discharges by industries regulated by the BAT limitations; (2) analysis of ambient water quality monitoring data for stream segments receiving discharges from BAT facilities; and (3) summarization of water quality improvement case studies relevant to the BAT regulations. For the purpose of this study, a water quality improvement, as it pertains to the first two components, was defined by the Agency as:

- Complying with EPA national ambient water quality criteria after the implementation of BAT, having exceeded (not complied with) water quality criteria prior to BAT.

- A decrease in in-stream pollutant concentration after implementation of BAT.

For the first component of the study, modeling was performed to project in-stream pollutant concentrations of ten selected pollutants (six heavy metals, cyanide, and three organic chemicals) for comparison with EPA ambient water quality criteria. These pollutants were selected because they are the most common toxic chemicals present in the wastewater discharges of BAT facilities. Although national water quality criteria are guidance and may be more or less stringent than applicable State water quality standards, national water quality criteria were selected as the basis for comparison for two reasons. First, national water quality criteria provide a nationally consistent measure for comparison and second, they account for the fact that many States have not yet adopted all necessary numerical water quality standards for toxic pollutants.

Only direct discharging industrial facilities in those categories having BAT regulations that specifically regulate toxic pollutants (i.e., those toxic, or priority, pollutants identified in the Clean Water Act of 1977) were included. Indirect dischargers (i.e., those that discharge to POTWs) were not evaluated in the model. The model focused on determining the impacts of these discharges on the unique stream segments (or reaches) that receive the wastewater discharges. No effort was made to determine downstream or cumulative effects. The model also evaluated only streams and rivers; lakes, estuaries, and shorelines were not included because of the difficulty involved in determining the dilution characteristics.

Two treatment levels were used to project the benefits of the categorical limitations: (1) raw, or untreated, discharge levels; and (2) levels representing compliance with BAT limitations. Industry-wide pollutant concentrations representing long-term average discharge levels were used.

In the second component of the study, ambient water quality monitoring data were analyzed for those reaches receiving discharges from the modeled BAT facilities. Since the methods available for analyzing these monitoring data are best suited for determining relative differences in concentrations over specific time frames, this evaluation focused on showing trends in the in-stream levels for the ten selected pollutants between two time periods selected to represent pre- and post-BAT conditions. The major assumptions and limitations that pertain to the first two components of this study are summarized in Table 1.

The last component of this study involved the presentation of actual case studies showing that the implementation of BAT resulted in improvements in the chemical and biological quality of the receiving waters. Most water quality improvement studies have focused on conventional pollutants discharged from municipal facilities, so few studies that target toxic pollutants from industrial discharges exist. Several studies, however, are pertinent to the BAT regulations and resultant improvements in water quality, and these are summarized below.

A special case study was developed by the Agency to evaluate the improvements resulting from BAT on a typical estuary. This study used a water quality model to project theoretical improvements, which were verified through the review of ambient monitoring data.

RESULTS OF THE STUDY

The results of the three methods indicate that water quality improvements have occurred as a result of the application of BAT. The model evaluated 2,490 individual BAT facilities, discharging to 1,546 unique reaches (totaling 24,289 river miles). On a pollutant-by-pollutant basis, pre-BAT compliance with water quality criteria ranged from 43 percent (copper) to 97 percent (toluene) in the river miles assessed under low flow conditions. Compliance with criteria after BAT increased by an average of 20 percent for each pollutant. Improvements under average flow conditions are less pronounced; compliance rates ranged from 75 (cyanide) to 100 (phenol, toluene, and benzene) percent prior to BAT and from 90 (mercury) to 100 (nickel, phenol, toluene, and benzene) percent after BAT.

TABLE 1
MAJOR ASSUMPTIONS AND LIMITATIONS

- Study is limited to only the reaches where BAT industries are located because of the uncertainty in modeling the fate and transport of pollutants without extensive site-specific information. Consequently, some reaches may have been excluded that benefited from BAT.

- Analysis focused only on direct dischargers. Indirect dischargers were not included. By not including indirect dischargers, BAT industry plant population was reduced and potential water quality improvements underestimated.

- Projection of BAT benefits is limited to the ten most frequently regulated and monitored pollutants instead of all priority pollutants to facilitate data collection and analysis. This approach was considered adequate to determine trends in water quality improvements while maintaining a manageable data base. However, it also excludes potential BAT benefits for overlooked pollutants.

- Water quality model used untreated treatment levels to represent industry's pre-BAT discharge levels due to the lack of representative data on treatment in place prior to the BAT. This approach appears reasonable because only limited toxics controls existed in 1970s. But some BAT benefits may have been overestimated by not considering existing treatment in-place. The BAT treatment levels were used to represent post-BAT conditions.

- Water quality model used industry-wide average pollutant concentrations for BAT industrial categories to represent individual facility discharge levels. This assumes every facility in a particular industry discharges the same pollutants at the same concentrations.

- The time period from 1970 to 1980 was selected to represent pre-BAT conditions; from 1985 to 1988 to represent post-BAT conditions (intervening years assumed as transition) based on the BAT promulgation dates (with an assumed 2-year implementation period) in our ambient water quality analysis. Consequently, the STORET monitoring data available for analysis were considerably reduced in scope. Also, full benefit of BAT promulgated in the mid-1980s is not yet fully reflected in monitoring data.

- Ambient monitoring data was collected for only those reaches receiving discharges from BAT facilities. The location of the individual monitoring stations in relation to the discharge(s) was not readily available.

- National water quality criteria were used rather than individual State standards because many States do not yet have numerical standards for many toxic pollutants, and EPA criteria provide a consistent basis for nationwide in-stream pollutant concentration comparison. Existing State criteria may be more or less stringent than EPA criteria.

Prior to the implementation of BAT, only 29 percent of the assessed river miles were projected to comply with all the criteria for the ten selected pollutants under low stream flow conditions (58 percent of the river miles were projected to comply under average flow conditions). After industries meet the discharge requirements of BAT, an additional 29 percent of the assessed river miles are projected to comply with criteria (at both average and low flow conditions). Individually, the pollutants most associated with noncompliance are mercury, copper, and lead. After the implementation of BAT, this study projects that 42 percent of the river miles assessed may not comply with criteria for one or more of the modeled pollutants under low flow (12 percent at average receiving stream flow). This projection, however, is not a precise measure of BAT derived improvements, since it is dependent on the number of pollutants evaluated. These river miles not complying with criteria may require further water quality-based toxic controls depending on State water quality requirements, including site-specific water quality criteria.

Ambient monitoring data were available for both time periods evaluated for at least one of the selected inorganic pollutants for 429 (8,434 river miles) of the 1,546 reaches evaluated by the model. Limited ambient data were available for the three selected organic pollutants (toluene, benzene, and phenol) but unfortunately, none of the reaches had monitoring data for both time periods for any of the organics. As a consequence, this monitoring data analysis was reduced in scope, as compared to the discharge model.

On an individual pollutant basis, the ambient monitoring data analysis found reductions in in-stream concentrations for each of the seven monitored pollutants. These reductions ranged in scope from 69 percent of the monitored river miles for zinc to 87 percent of the monitored river miles for mercury. In terms of overall pollutant reduction trends (considering all monitored pollutants), improvements were shown for 76 percent (6,397 miles) of the 8,434 river miles assessed.

However, ambient monitoring data also indicated that for 14 percent (1,147 miles) of the assessed river miles, overall pollutant concentrations increased between the two time periods. Eleven percent of the river miles (890) were found not to have a significant difference between the pre- and post-BAT average concentrations. Possible explanations for this deterioration or lack of progress include: variability in stream conditions; discharges from new sources; changes in upstream pollutant inputs; pre-BAT treatment may have been equivalent to BAT (thus not changing the overall performance); or sources that either met required limitation prior to ambient sampling or have not yet attained these limitations.

The six case studies included in this study present various types of water quality improvements that can be attributed to BAT. Three show reduced heavy metals concentrations, resulting from BAT-type limitations, in the receiving stream and the return of less pollutant-tolerant aquatic biota. Another case study presents data on oysters which shows a decrease in metal concentrations between samples collected in the 1970s and those collected in the 1980s (BAT controls on metal industries were implemented on upstream sources in the mid-1970s). Two studies show that reduced pollutant discharges from pulp and paper mills improved oxygen conditions, causing a return of indigenous fish species.

In addition, the special case study verified that toxic pollutant levels in the Delaware estuary have been reduced, at least partially as a result of BAT.

CONCLUSIONS OF THE STUDY

The three components of this study (e.g., water quality modeling, monitoring data evaluation and case study reviews) indicate that water quality has improved significantly as a result of the implementation of the BAT effluent limitation regulations.

The water quality model projects that during average stream flow conditions, compliance with WQC for each of the evaluated pollutants under BAT is 90 percent or higher. For four of the evaluated pollutants, compliance is 100 percent. In addition, 88 percent of all stream miles are projected to meet WQC for all 10 evaluated pollutants, compared to 59 percent prior to BAT.

During low stream flow conditions, compliance with individual pollutants ranges from 73 to 100 percent. The percentage of waters meeting WQC for all 10 pollutants is projected to be 58 percent with BAT, compared to 29 percent prior to BAT.

Under BAT, 12 percent of all river miles are projected to exceed WQC for one or more pollutants during normal stream flow; 42 percent of all river miles may exceed one or more WQC during low stream flow. Depending on individual States WQC, additional water quality controls for some pollutants may be necessary to bring those reaches completely into compliance.

Ambient monitoring data analysis also shows significant improvements, in terms of pollutant reductions trends. Seventy-six percent of river miles in the data base showed an overall decrease (improvement) in pollutant concentrations after BAT. At the same time, 14 percent of monitored river miles were shown to increase in concentrations from pre-BAT to post-BAT period. The overall reductions in pollutant levels, however, reflect not only the benefits of BAT controls but also the benefits from water quality-based limitations, municipal treatment improvements, controls on non-BAT industries and nonpoint sources, and, to an unknown extent, lower detection limits between the two time periods.

The full benefit of the implementation of the BAT regulations is not yet reflected in the ambient monitoring analysis. National categorical standards have recently been promulgated for one major industry, organic chemicals manufacturing, which will reduce the industry's toxic pollutant direct discharge loadings by an estimated 1.1 million pounds per year. Standards have yet to be promulgated for another industrial category (pesticides manufacturing). While the ambient data do reflect some of the benefits attributable to BAT, the full effect will not be evident until the early 1990s.

Actual cases where the implementation of BAT has resulted in water quality improvements present the best illustration of the effectiveness of the categorical standards; however, few such cases are available. Those studies that do exist have shown that the BAT regulations have had a positive impact on water quality of the receiving stream, both in terms of lower chemical concentrations and increased biological activity. In most instances, the streams/rivers assessed in these case studies were highly polluted prior to BAT, and even after the discharge levels had been reduced to BAT levels, additional water quality-based controls were and will continue to be necessary. In all cases, the implementation of BAT has resulted in considerable improvements in the chemical and/or biological quality (as measured by an increase in less pollution-tolerant aquatic life) of the receiving waters.

The site-specific modeling of the Delaware River estuary predicts BAT will achieve compliance with water quality criteria for the 10 modeled pollutants. Ambient monitoring data also show a decreasing pollutant concentrations trend. However, full benefits of BAT are not yet reflected in monitoring data because of the number of organic chemical facilities on this estuary. Organic chemical BAT guidelines were recently (11/87) promulgated, consequently many of these facilities may not yet be operating at BAT levels.

Considering the results of each component of this analysis, together with their respective assumptions and limitations, the BAT regulations have been an effective step toward improving the quality of our nation's surface waters. The extent of their effectiveness is difficult to assess, however, given the limits of existing EPA data sources and the fact that BAT controls have yet to be universally applied. Also, by not considering improvements resulting from the categorical pretreatment requirements, the extent of the improvements resulting from the overall national water quality program are underestimated. There may be a need for additional water quality-based controls beyond BAT in some cases to meet State water quality standards. In addition, as required by Section 304(m) of the Water Quality Act of 1987, the Agency will establish a schedule for: (1) the annual review and revision of promulgated effluent guidelines, and (2) the promulgation of regulations for industrial categories identified as sources of toxic and nonconventional pollutants for which guidelines have not previously been established.

Chapter One

INTRODUCTION

This report presents the findings of the Water Quality Improvement Study, conducted by the U.S. Environmental Protection Agency (EPA) as required by the amendments to the Federal Water Pollution Control Act (Clean Water Act). These amendments, known as the Water Quality Act of 1987 (PL 100-4), included several requirements for studies of the Nation's water quality and the regulations controlling pollutant discharges. Congressional intent was to determine the state of the Nation's water quality and to review the effectiveness of regulatory programs protecting or improving that water quality. Section 308 of the Water Quality Act requires the Administrator of the EPA to report to Congress on the effectiveness of the water quality improvement program, especially the application of best available technology (BAT) effluent limitations to control pollutant discharges from industrial sources. This report addresses the requirement for a Water Quality Improvement Study.

The specific areas to be addressed by the Water Quality Improvement Study, as specified in Section 308(g), are:

> "The Administrator shall study the water quality improvements which have been achieved by the application of best available technology economically achievable pursuant to Section 301(b)(2) of the Federal Water Pollution Control Act. Such study shall include, but not be limited to, an analysis of the effectiveness of the application of best available technology economically achievable (BAT) pursuant to such section in attaining applicable water quality standards (including the standard specified in Section 302(a) of such Act) and an analysis of the effectiveness of the water quality program under such Act and methods of improving such program, including site specific levels of treatment which will achieve the water quality goals of such Act.

> Not later than 2 years after the date of the enactment of this Act, the Administrator shall submit a report on the results of the study ... together with recommendations for improving the water quality program and its effectiveness to the Committee on Public Works and Transportation of the House of Representatives and the Committee on Environment and Public Works of the Senate."

EPA's Office of Water was directed by the Administrator to prepare this Report to Congress.

LEGISLATIVE HISTORY

The Clean Water Act established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." Under this program, industrial dischargers were required to achieve "effluent limitations requiring the application of the best practicable control technology currently available" (BPT) by July 1, 1977, and "effluent limitations requiring the application of the best available technology economically achievable (BAT) ... which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants," by July 1, 1984 (under Sections 301(b)(1)(A) and 301(b)(2)(A), respectively). New industrial direct dischargers were required to comply with Section 306 new source performance standards (NSPS) based on best available demonstrated technology; existing and new dischargers to publicly owned treatment works (POTW) were subject to pretreatment standards under Sections 307(b) and (c), respectively, of the Act.

The requirements for direct dischargers are incorporated into the National Pollutant Discharge Elimination System (NPDES) permits issued under Section 402 of the Act. Permits must incorporate applicable technology-based effluent limitations guidelines promulgated by EPA on a nationwide, industry-by-industry basis under Sections 301(b) and 304, and if EPA has not promulgated guidelines, limitations are applied in individual permits on a case by case basis (Section 302). Effluent limitations are implemented in two stages. By July 1, 1977, dischargers to surface waters were required to achieve effluent limitations applicable to best practicable control technology currently available (BPT). For toxic pollutants and nonconventional pollutants, they were required, by 1984, to achieve effluent limitations applicable to best available technology economically achievable (BAT). Separate requirements were established for industrial facilities that discharged wastewaters to publicly owned treatment works (POTWs) and for new sources. Pretreatment standards were made enforceable directly against dischargers to a POTW (indirect dischargers).

As a result of the Clean Water Act, BAT effluent limitation guidelines have been promulgated for 24 industrial categories (for one category, pesticides manufacturing, the BAT guidelines are currently being developed). The promulgation of the effluent limitation guidelines for these industries has occurred in two "phases." The first "phase" was prior to the passage of the Federal Water Pollution Control Act (PL 95-217), commonly referred to as the Clean Water Act of 1977, with the limitations focusing mostly on conventional pollutants. Many of the BAT limitations promulgated at this time were withdrawn or rescinded, while some of the BPT limitations remained in effect. The second "phase" regulations were promulgated after the 1977 amendments and reflect additional controls on toxic pollutants. Most of the second "phase" regulations were promulgated in the early 1980s (Table 1-1). However, these regulations for one major industry (organic chemicals manufacturing) were not promulgated until 1987, and one regulations for the pesticide manufacturing category are presently being prepared.

The effluent limitations specified under Section 301(b)(1)(A), (B) and (2) of the Act are "technology-based" limitations. These limitations are used by permitting authorities (EPA or the States) to set minimum pollution control requirements for all industrial dischargers without regard to the quality of

Table 1-1

Promulgation History of BAT Regulations

Industry Name	Promulgation Dates for BAT Regulations Phase I	Phase II
Aluminum Forming	- *	09/83 @
Battery Manufacturing	- *	02/84 @
Coal Mining	04/77	11/82 @
Coil Coating	- *	11/82 & 11/83 @
Copper Forming	- *	08/83 @
Electrical & Electronic Components	- *	03/83 & 11/83 @
Foundries	- *	10/85
Inorganic Chemicals	03/74	06/82 & 07/84
Iron & Steel	06/74	05/82 @
Leather Tanning	04/74	11/82 @
Metal Finishing	03/74	07/83 @
Nonferrous Metals	04/74	02/84 & 08/85 @
Nonferrous Metals Forming	-	07/85
Ore Mining	11/75	11/82
Organics/P&SF	04/74	11/87
Pesticides	11/76	WITHDRAWN 12/86
Petroleum Refining	05/74	09/82 @
Pharmaceuticals	11/76	09/83
Plastics Molding & Forming	-	12/84
Porcelain Enameling	- *	11/82 @
Pulp & Paper	05/74	10/82 @
Steam Electric	10/74	11/82 @
Textiles	07/74	08/82
Timber Products	04/74	01/81 @

KEY

* These categories represented a portion of the Machinery and Mechanical Products category during Phase I (no regulations promulgated).

@ Minor changes (amendments) have been made to these industries after promulgation as a result of litigation.

receiving waters. In some cases, however, technology-based standards are not enough. If water quality does not support the designated use even after every discharger meets his technology-based standards, additional controls must be applied. Section 301(b)(1)(C) of the Act requires "any more stringent limitations," including those necessary to meet water quality standards, whenever meeting the technology-based standards in Section 301 fail to attain or maintain the water quality called for in the river or stream (water quality-based limitations). Section 302(a) also authorizes the Administrator to establish effluent limitations more stringent than those necessary to meet quality standards in order to meet the water quality goals of the Act.

In the Water Quality Act of 1987, Congress added new Section 304(l), which requires States to develop lists of impaired waters, lists of point sources and amounts of pollutants causing toxic impacts and "individual control strategies" for such point sources. These new requirements should aid in the identification of waters that will need water quality-based standards. These provisions direct immediate attention to establishing controls where there are known impacts due entirely or substantially to point sources of Section 307(a) toxic pollutants. The identification of waterbodies and point sources and the development of control strategies is the subject of a separate Agency effort. The statutory deadline for identification of waterbodies and development of individual control strategies (ICSs) was February 4, 1989, and must achieve applicable water quality standards on or before June 4, 1992. EPA approved or disapproved the ICSs on June 4, 1989, and where EPA disapproved an ICS, the revised ICS must achieve applicable water quality standards on or before June 4, 1993.

GENERAL APPROACH AND ASSUMPTIONS IN THE WATER QUALITY IMPROVEMENT STUDY

The objective of this report is to identify improvements in water quality attributable to the application of best available technology economically achievable (BAT). This study is required by Section 308(g) of the Water Quality Act of 1987. Section 308(g) also requires an evaluation of the water quality program (including Section 302(a) site-specific water quality determinations) and recommendations of methods for improving such program. This study does not include an evaluation of the water quality program since it is now the subject of a major concurrent effort mandated under Section 308(a) of the 1987 Water Quality Act [Section 304(l) of the Clean Water Act].

Because of the implementation of BAT by industrial dischargers and the subsequent reduction in pollutant loadings, it can be inferred that the water quality in the nation has improved. As illustrated in Table 1-2, the Agency estimates that, the result of treatment including BAT, organic priority pollutant discharges have been reduced by 99 percent from untreated levels and that inorganic priority pollutant discharges have been reduced by almost 98 percent. These estimates of pollutant reductions do not account for treatment in-place prior to the implementation of BAT, and therefore, may overestimate BAT benefits. However, the extent of these pollutant reductions and their contribution to attaining the goals of the national water pollution control program have not been determined. This study attempts to determine the extent of these improvements on a national scale, through the examination and use of currently existing data sources. However, this study does not attempt to quantify benefits which result from improved water quality. These include increased sport and commercial fishing, and improved recreational opportunities.

For purposes of this study, "water quality improvement" was defined as one of the following:

- Compliance with EPA national water quality criteria (WQC) after BAT, having not complied with WQC prior to BAT.
- A decrease in in-stream pollutant concentration after implementation of BAT.

Table 1-2 Comparison of RAW and BAT Pollutant Loadings for BAT Industries

INDUSTRIAL INFORMATION				TOTAL SUSPENDED SOLIDS LOADINGS (lb/day)		BIOCHEMICAL OXYGEN DEMAND LOADINGS (lb/day)		PRIORITY POLLUTANT LOADINGS (lb/day)			
		PROCESS WASTEWATER FLOW (MGD)						ORGANICS		INORGANICS	
INDUSTRIAL CATEGORY	NUMBER OF PLANTS	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT
ALUMINUM FORMING	42	10.6	7.3	4,059	727	--	--	9	--	2,943	63
BATTERY MANUFACTURING	15	1.2	0.1	7,544	11	--	--	--	--	1,109	31
COAL MINING	10,375	6,417.0	6,417.0	224,811,488	1,672,004	--	--	400	133	134,373	7,401
COIL COATING	32	3.3	1.1	2,978	113	--	--	16	--	968	7
COPPER FORMING	37	15.1	2.2	24,108	223	--	--	858	11	41,813	34
ELECTRICAL COMPONENTS	84	12.8	12.8	4,292	1,282	--	--	409	75	250	152
FOUNDRIES	301	177.3	7.0	1,151,113	197	--	--	2,248	21	51,307	64
INORGANIC CHEMICALS	149	197.8	166.1	7,255,677	60,883	--	--	--	--	166,723	12,616
IRON & STEEL	738	5,199.2	1,497.7	5,141,618	135,470	--	--	105,296	262	917,027	2,551
LEATHER TANNING	17	4.2	4.2	87,277	1,944	53,901	1,173	303	6	3,595	67
METAL FINISHING	2,800	365.9	365.9	2,059,357	54,348	--	--	9,343	162	240,178	6,555
NONFERROUS METALS	112	55.0	8.7	62,457	199	--	--	495	3	3,033	132
NONFERROUS METALS FORMING	51	2.1	0.3	793	18	--	--	6	--	2,525	2
ORE MINING	506	1,359.6	1,359.0	178,579,200	95,845	--	--	--	--	2,265	2
ORGANIC CHEMICALS *	301	394.3	394.3	398,349	--	245,956	--	483,546	1,097	83,304	794
PESTICIDES MANUFACTURING	42	4.6	4.6	--	--	--	--	--	--	--	--
PETROLEUM REFINING	164	312.0	312.0	239,804	67,957	346,817	35,150	17,119	103	4,077	796
PHARMACEUTICALS **	52	24.9	24.9	125,693	13,603	237,825	16,573	6,425	232	229	81
PLASTICS MOLDING & FORMING	810	88.5	88.5	63,775	3,593	8,635	2,604	141	124	135	95
PORCELAIN ENAMELING	28	2.2	1.8	76,629	179	--	--	--	--	--	--
PULP & PAPER	355	3,746.4	3,746.4	10,847,704	889,338	8,014,703	541,732	32,794	3,355	8,501	8,166
TEXTILES	229	177.7	177.7	171,521	72,842	489,032	33,273	3,656	691	2,358	1,438
BAT INDUSTRIES TOTAL:	17,240	18,571.6	14,599.5	431,115,436	3,070,776	9,396,869	630,505	663,064	6,275	1,666,713	41,047

SOURCE: USEPA (1988).

To determine water quality improvements, the approach used had three major components: (1) projecting in-stream concentrations of selected pollutants by modeling pre- and post-BAT effluent discharges of industries regulated by BAT to determine theoretical improvements based on compliance with water quality criteria; (2) reviewing available ambient water quality monitoring data to determine trends in chemical water quality; and (3) providing actual case studies on the implementation of the national effluent regulations for industrial dischargers and a discussion of any improvements in either the chemical or biological quality of specific waters as a result of such implementation.

The modeling and ambient data review effort primarily focused on: (1) facilities discharging directly to surface waters that are required, under the BAT regulations, to control toxic pollutants; and (2) nationwide improvements. Indirect facilities (i.e., those that discharge their wastewater to POTWs), which are controlled by pretreatment standards, were excluded for two reasons: (1) there was insufficient information on indirect facilities within the EPA national data bases, and (2) these facilities are not controlled by State or EPA-issued permits (NPDES), but rather by local limits developed by the POTW receiving the discharge. This study also excludes industries which are not regulated by the national categorical (technology-based) effluent limitation guidelines, but rather by "best professional judgment" permits. By not considering indirect facilities and improvements in water quality resulting from pretreatment requirements or controls on industries without additional categorical effluent limitation regulations, this study underestimates the extent of the improvements resulting from the national water quality program. The effectiveness of the BAT regulations in improving water quality can be addressed on a national level because site-specific and/or regional factors are not taken into account in establishing these technology-based effluent limitations. The site-specific nature of water quality-based limits prevents a theoretical estimate of their effectiveness. Specific instances where water quality improvements are attributable to indirect facilities will be discussed, when applicable, in the case studies.

The first two components (or analyses) of this study made use of existing EPA computerized information to expedite the nationwide study. Ideally, such information sources would have historical information available for each of the industrial facilities affected by the BAT regulations. Ideally, this information would include pollutant loading information prior to, and after, implementation of BAT treatment technologies; the date when BAT treatment was implemented; and in-stream ambient monitoring data specific to each facility. Unfortunately, existing data bases were developed primarily for the purpose of and tracking ambient water quality for localized pollution control purposes and not specifically for performing a nationwide water quality improvement study. Thus, the ideal data base described above is not available.

Other factors also need to be considered, including the long time frame over which BAT regulations have been implemented. In addition, for a number of years some States have been writing water quality-based permits for industrial dischargers that are generally more stringent than the treatment requirements of BAT. Differentiating between the time periods that represent pre- and post-BAT and which facilities have effluent limitations based on technology or water quality is not feasible using these sources of data.

Several assumptions were necessary in order to complete the first two components of this study using the available EPA information:

1. All industrial facilities covered by the BAT regulations will be evaluated assuming that technology-based limitations are the basis for their respective discharge levels.

2. Pre-BAT effluent discharges will be represented by untreated, or raw, levels as determined by EPA sampling programs.

3. The pre-BAT period for evaluating ambient monitoring data is from 1970 to 1980.

4. The post-BAT period is from 1985 to the present.

5. Ten pollutants were selected to represent toxic pollutant discharges from BAT-regulated facilities. These selected pollutants are the most frequently discharged and regulated priority pollutants.

6. Only stream segments receiving direct discharges for BAT facilities were evaluated.

One limitation of this study is that it is not currently feasible to determine which BAT industrial facilities actually have and meet permit limitations based on the national effluent guideline (technology-based) regulations. However, by not considering more stringent controls imposed by water quality-based permits and assuming that all BAT industries meet the requirement of the technology-based limitations only, the overall need for the more stringent controls can be more accurately assessed on a national level. This is one of the requirements of the water quality improvement study.

In evaluating the improvements resulting from the BAT regulations, the ideal scenario would consider discharge levels prior to the implementation of treatment requirements mandated by the Federal water quality program (i.e., pre-BAT), which began in 1972. Unfortunately, no accurate method exists to determine or estimate these discharge levels, especially in the area of toxic pollutant discharges. In some instances, facilities had treatment of their wastewater discharges. In others, untreated wastewaters were discharged directly to receiving waters. In addition, EPA's initial sampling of industrial facilities in the mid-1970s to define effluent characteristics focused on conventional pollutants and a few toxic metals. Only later, in response to the NRDC Settlement Agreement and subsequent amendments to the Clean Water Act, did the Agency focus its regulatory efforts on the toxic, or priority, pollutants referenced in the Act. For this reason, and because it is Agency policy when determining benefits of BAT guidelines, untreated wastewater was used as the basis for determining the improvements. This assumption will overestimate the actual benefits of the technology-based program, but the extent of this overestimate is uncertain.

It was difficult to select appropriate time periods for comparing pre- and post-BAT ambient water quality monitoring data because BAT treatment levels for some industries (such as metal finishing/electroplating, pulp and paper, and textiles) have remained essentially the same since the mid-1970s, while for others, BAT limitations have yet to be fully implemented or promulgated (organic chemicals and pesticide manufacturing, respectively). Taking into consideration, however, the fact that monitoring for toxic pollutants was not as common prior to the mid-1970s as it is today and that detection limits for individual chemical parameters have changed as technology has improved, the years from 1970 to 1980 were selected to serve as the pre-BAT period. During this period some reductions in ambient pollutant concentrations would be reflected in the monitoring data, but the overall average for that period should tend to be representative of levels prior to the implementation of technology-based regulations. To reflect post-BAT levels, 1985 was selected as the start date. A majority of the "Phase II" BAT regulations for the industrial categories were promulgated in the early 1980s (Table 1-1), so the period from 1981 to 1984 was considered a transition period and was not evaluated.

By using only a select group of toxic pollutants, the overall trends in water quality can be identified without the need for voluminous amounts of data. However, by not considering improvements resulting from reductions of other toxic pollutants, the full benefits of BAT are underestimated.

Only those stream segments receiving discharges from BAT-regulated facilities were included in the first two components of this study. Because of difficulty in modeling the fate and transport of these pollutants, no impacts to downstream stream segments were considered, thus reducing the scope of potential improvements.

The first two components of this study project and estimate improvements in water quality resulting from the application of BAT. While these analyses provide a good picture of overall national trends, case studies best present water quality improvements since such improvements are "real life," not projected or estimated. Case studies reviewed for this study had to show a direct benefit in water quality (either chemical or biological) as a result of facilities implementing limitations set forth by BAT. The focus of such improvements or benefits was the reduction of toxic pollutants. However, other aspects of technology-based limitations, such as reductions in conventional pollutant discharges for industrial sources were also considered, as well as the beneficial results of the implementation of pretreatment program for indirect dischargers to publicly-owned treatment works. However, this study does not attempt to quantify benefits which result from improved water quality. These include increased sport and commercial fishing, and improved recreational opportunities.

Report Organization

The remainder of this report consists of four chapters that address the objective of Section 308(g) of the Water Quality Act of 1987 relevant to the BAT regulations. Chapter 2 presents a general discussion of the data sources and methodology used to identify water quality improvements. Chapter 3 summarizes the results of the analyses. Chapter 4 addresses the study findings and the evaluation of the effectiveness of the BAT regulations. Chapter 5 lists the various references used in this study. Volume II of this report contains the technical appendices, providing the backup material and outputs from the water quality model and ambient data evaluation. Volume II is available under a separate cover.

Chapter Two

METHODOLOGY

OVERVIEW

Three different components were used to identify water quality improvements resulting from the application of best available technology economically achievable (BAT): (1) projection of theoretical improvements in water quality for stream reaches with BAT industries (those industries covered by the BAT regulations) using water quality modeling; (2) review of ambient water quality data for pre- and post-BAT time periods; and (3) summary of specific instances (case studies) where water quality has improved because of BAT. Specifically, this methodology included the following:

Water quality modeling of industrial facilities with BAT effluent limitations to control toxics. The model predicted in-stream concentrations of ten selected pollutants at pre-BAT and post-BAT treatment levels at low and average receiving stream flow conditions. Concentrations were then compared to EPA water quality criteria to determine the potential/theoretical water quality improvements.

Analysis of STORET ambient water quality monitoring data, for the same ten selected pollutants, for stream segments receiving BAT industrial discharges for time periods assumed to reflect pre-BAT (1970 to 1980) and post-BAT (1985 to 1988) conditions. The average values for these two time periods were used to determine trends in ambient pollutant levels.

Summary of case studies that associate the implementation of national technology-based effluent limitations with improvements in the chemical and/or biological quality of the receiving waters. All improvements that can be attributable to BAT regulations are considered, primarily reductions in toxic pollutant discharges but also including controls on conventional pollutants and indirect dischargers. A special case study was developed by the Agency to evaluate the benefits of BAT regulations in estuaries.

The ten pollutants selected to be evaluated were representative of toxic pollutants regulated by BAT and could be considered "indicator" pollutants. These pollutants are the most frequently discharged and regulated priority pollutants found in the wastewater of the BAT facilities and include six heavy metals (cadmium, mercury, copper, lead, nickel, and zinc), cyanide, and three organic chemicals (phenol, toluene, and benzene). Table 2-1 lists these pollutants and their frequency of occurrence in the BAT industries effluent. Also shown are the industries in which these pollutants are regulated. In addition, limiting the number of pollutants also reduced the modeling effort to a manageable size.

The modeling and ambient data analyses are limited to only those reaches receiving BAT industrial discharges. (Reaches are unique segments of streams and rivers that have been delineated by EPA for the purpose of integrating water quality and facility information.) It was beyond the scope of this study to address the effects of the discharges on reaches downstream of the industries, even though the downstream reaches are likely to be directly affected.

The methodology used to identify water quality improvements is presented in the following sections: (1) Information Sources, which presents a brief description of all the EPA information sources used for the first two components of the study; and (2) Description of Methods to Assess Improvements, which presents general discussions of the components of this study - the water quality modeling analysis, the ambient water quality data evaluation, and site-specific case studies. The latter section also provides, for each

Table 2-1

Frequency of Occurrence of Selected Priority Pollutants
in BAT Industrial Category Wastewater Discharges

Industrial Category	Occurrence of Pollutant in Industrial Category									
	Cadmium	Mercury	Copper	Lead	Nickel	Zinc	Cyanide	Phenol	Toluene	Benzene
Aluminum Forming	1		1	1	1	R	R	1		
Battery Manufacturing	R	R	R	1		R	R			
Coil Coating	1	1	R	1	1	R	R	1	(R)	
Copper Forming	1		R	R	R	R	1		1	1
Electrical & Electronic Components	1	1	1	1	1	1	1	(R)	(R)	
Metal Molding & Casting (Foundries)	1	1	R	R	1	R		1	1	1
Inorganic Chemicals	R	R	R	R	R	R	R			
Iron & Steel	1	1	1	R	R	R	R	1	1	R
Leather Tanning & Finishing	1	1	1	1	1	1	1	1	1	1
Metal Finishing	R		R	R	R	R	R	(R)	(R)	(R)
Nonferrous Metals	1	1	R	R	R	R	R	1		
Nonferrous Metals Forming	R		R	R	R	R	R		1	
Ore Mining & Dressing	R	1	R	R	R	R	1			
Organic Chemicals, Plastics, & Synthetic Fibers			R	R		R	R	R	R	R
Petroleum Refining	1	1	1	1	1	1	1	1	1	1
Pharmaceuticals Manufacturing		1	1	1	1	1	R	1	1	1
Porcelain Enameling	1		1	R	R	R				
Pulp & Paper		1	1	1	1	R	1	1	1	1
Textiles	1	1	1	1	1	1	1	1	1	1
Total Occurrences	16	13	19	19	17	19	17	13	13	10
Total Regulated	5	2	10	10	8	14	10	1(2)	1(3)	2(1)

KEY

R - Regulated pollutant in industrial category.
1 - Detected, but not regulated, in wastewater of industrial category.

Values in parentheses denote when pollutant is regulated as part of "Total Toxic Organics."

SOURCE: U.S. EPA, 1986.

component, a summary of the approach and purpose of the analysis, assumptions used and limitations in performing the analysis, and the actual analysis conducted. Outputs from the water quality model and the ambient water quality monitoring data analyses are included in the technical appendices (Volume II).

INFORMATION SOURCES

To perform the first two components of this study, readily available and accessible information contained in the following EPA data bases were used: Permit Compliance System (PCS), Industrial Facilities Discharge (IFD) file, GAGE file, REACH file, and STORET Water Quality file. A brief description of each data base and how it was used is presented below:

- **Permits Compliance System (PCS)** - PCS is a computerized management information system for tracking permit status data for the National Pollutant Discharge Elimination System (NPDES). This system was used to identify BAT facilities by SIC code and to determine their discharge status (active or inactive).

- **Industrial Facilities Discharge (IFD) file** - The IFD file provides a comprehensive data base of industrial and municipal point source dischargers, including discharge flow and location information, standard industrial classification (SIC) codes, and categorization of discharge types. This file was used to locate the BAT facilities, identified by PCS, on specific reaches and to provide wastewater discharge flows for the water quality model.

- **GAGE file** - The GAGE file stores data from stream gaging stations, including: station location, types and frequency of data collected, and stream flow data (mean, annual, and low flow). The GAGE file was used to provide stream flows (both average and low) for the water quality model.

- **REACH file** - The REACH file is a digital data base of streams, rivers, reservoirs, lakes, and estuaries in the contiguous U.S. divided into unique segments called "reaches." The reaches allow EPA (and other system users) to integrate data from different files and data bases by assigning unique reach numbers to individual water body segments. This file identified the type of reach (stream or nonstream).

- **STORET Water Quality file** - STORET is a data base composed of several individual, but related, files, and includes data on: stream flow; physical and chemical characteristics of streams, fish tissue, and sediment; municipal waste sources and disposal systems; and pollution-caused fish kills. STORET was used to obtain ambient water quality information for the ten selected pollutants.

All information contained in these data bases was retrieved during December 1987, with the exception of the STORET data, which was retrieved in July 1988.

Screening and Evaluation

Data were retrieved from the EPA data bases and subsequently compiled and analyzed using a computerized software system. The files were then screened to select only those facilities that would be covered by the BAT regulations and could be evaluated by the water quality model. All currently active facilities were also assumed to be active prior to BAT implementation, therefore neglecting the impacts on water quality for new sources and plant closings. The reaches identified as receiving BAT discharges in water quality model will serve as the basis of retrieving ambient monitoring data. The following is a brief description of the screening process:

1. The EPA data bases contain information on 120,992 industrial dischargers and roughly 68,000 reaches. Of these dischargers, 46,467 are inactive (e.g., closed) or their discharge status is unknown, and 53,621 reaches do not have any assigned dischargers on them. All inactive/unknown facilities and reaches without dischargers were excluded from this study.

2. Of the 74,525 active dischargers, 59,338 facilities are not covered by the BAT regulations and were not included in this study. This also removed 8,556 reaches from consideration.

3. Five BAT industrial categories (coal mining, steam electric, plastics molding and forming, timber products, and pesticide manufacturing) were not evaluated in this study because their effluent regulations either: (1) do not specify toxic pollutants; (2) control only a small volume of the total discharge; or (3) have been rescinded. Therefore, an additional 8,353 dischargers and 1,593 reaches were excluded from the model/ambient analyses.

4. Because it is necessary to correlate dischargers with stream locations (i.e., reach numbers), those facilities in the EPA data bases without assigned reach numbers were excluded, resulting in the removal of 1,837 facilities from the study. This step also removed all facilities in Hawaii, Alaska, and the U.S. Territories, since streams in these areas are not currently hydrologically linked.

5. The water quality model can evaluate only facilities located on hydraulic transport ("stream") type reaches; therefore, all reaches that are nonhydraulic or boundaries (e.g., coastlines, estuaries, lakes, and shorelines) were excluded. This screening step eliminated 683 facilities and 322 reaches from consideration in the study.

6. The remainder of the facilities and reaches were then screened to determine if flow data were available. One hundred and forty-four reaches were excluded because they did not have both average and low flows (which also eliminated 484 facilities) and 1,232 industrial facilities did not have process flows (which removed 497 reaches from consideration). The final step eliminated facilities that may have erroneous process flows stored in the data base. If the process flow exceeded the 95th percentile flow for a particular industrial category, the facility and its corresponding reach were excluded. This step removed 108 facilities and 53 reaches because of possible erroneous process flows.

This screening process, summarized in Table 2-2 and Figure 2-1, identified 2,490 facilities and 1,546 reaches (representing 24,289 river miles) to be evaluated in the water quality modeling component of the Water Quality Improvement Study (WQIS). The 1,546 reaches were also used as the basis for retrieving ambient monitoring data for the second component of this study.

Additional Sources

Additional EPA sources of information (for the model and ambient analysis) include (1) industry-wide effluent characteristics by industrial category and (2) EPA ambient water quality criteria.

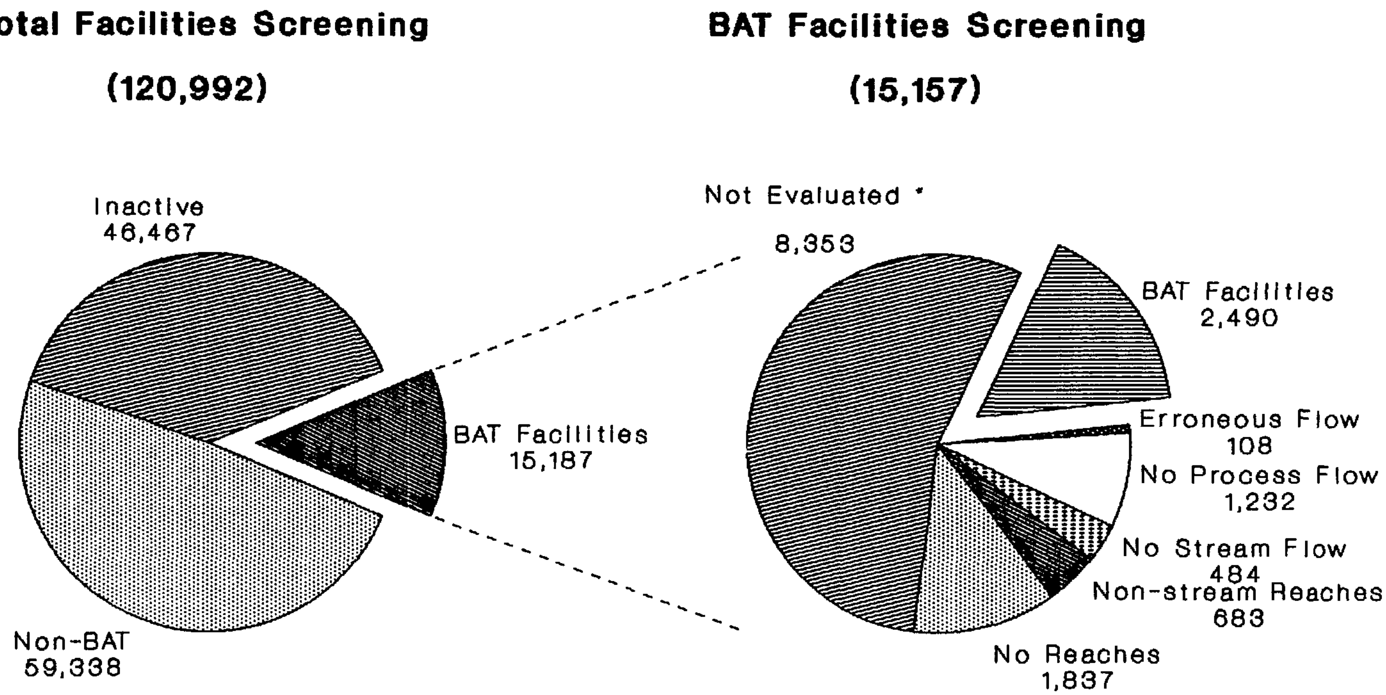
The industry-wide effluent characteristics were used in the water quality modeling effort to determine the pollutant concentrations discharged by each of the facilities evaluated. The source of these concentrations was the Monitoring and Data Support Division (MDSD) report, Summary of Effluent

Table 2-2

Summary of Screening Process
Used to Select BAT Facilities and Reaches
for Inclusion in the Water Quality Improvement Study

Description of Screening Step	No. of Facilities	No. of Reaches
Total facilities/reaches in EPA data bases	120,992	~68,000
No. of reaches without assigned facilities	0	~53,621
No. of inactive facilities excluded	46,467	1,668
No. of non-BAT facilities/reaches excluded	59,338	8,556
No. of BAT facilities/reaches not evaluated*	8,353	1,593
No. of BAT facilities not assigned reaches	1,837	0
No. of BAT facilities/reaches excluded because of non-steam reach type**	683	322
No. of BAT facilities/reaches excluded because of unavailable reach flow	484	144
No. of BAT facilities/reaches excluded because of unavailable process flow***	1,232	497
No. of BAT facilities/reaches excluded because of "erroneous" process flow	108	53
No. of BAT facilities/reaches evaluated	2,490	1,546

*Coal/steam/plastics molding and forming/timber products/pesticides manufacturing categories.
**Lakes/coast-shoreline/estuary/artificial/etc.
***Includes "zero discharge" facilities (those facilities that do not discharge process wastewater).



* Contains the 4 subcategories not evaluated.

Figure 2-1.

Summary of Facilities Screening Process

Characteristics and Guidelines for Selected Industrial Point Source Categories: Industry Status Sheets (U.S. EPA, 1986). For direct dischargers, pollutant concentrations are provided for four treatment levels: RAW (untreated wastewater), CURRENT (the average level of discharge determined by sampling during the second phase of the BAT rulemaking process), BPT, and BAT (the expected BPT and BAT discharge levels based on the required treatment technology specified in the effluent limitations). These industry-wide effluent concentrations, developed by EPA's Industrial Technology Division, were used to provide a consistent source of data for the selected treatment levels and represent long-term averages. RAW and BAT levels were used in the water quality model analysis.

The calculated in-stream pollutant concentrations from the water quality model analysis were compared to EPA ambient water quality criteria (either chronic freshwater aquatic life or human health ingestion of organisms only criteria) for the ten selected pollutants. The more stringent human health ingestion of water and organisms criteria were not used because exposures due to drinking untreated surface waters (most surface water sources are treated) are not as likely.

The human health criterion for benzene (a human carcinogen) represents a risk level of 10^{-6} (1 excess cancer death per 1,000,000 people exposed over a 70 year period). For each pollutant, the lower of the two criteria was used. Table 2-3 shows the criteria used in this study. Four of the metals have hardness-specific criteria. For these metals, the median hardness value (as determined through a separate STORET analysis) for each State was used to calculate State-specific criteria.

The study used EPA criteria rather than individual State water quality standards because: (1) most States do not yet have numerical standards for toxic pollutants; and (2) EPA criteria provided a consistent basis for comparison with in-stream pollutant concentrations, even though some existing State standards may be more or less stringent than EPA criteria.

Table 2-3

EPA Ambient Water Quality Criteria
Used in the Water Quality Improvement Study

Pollutant	Criteria (ug/l)	Type
Cadmium	Hardness-specific*	Freshwater aquatic life-chronic
Mercury	0.012	Freshwater aquatic life-chronic
Copper	Hardness-specific*	Freshwater aquatic life-chronic
Lead	Hardness-specific*	Freshwater aquatic life-chronic
Nickel	100	Human health-ingesting organisms only
Zinc	Hardness-specific*	Freshwater aquatic life-chronic
Cyanide	5.2	Freshwater aquatic life-chronic
Phenol	750	Freshwater aquatic life-chronic**
Toluene	650	Freshwater aquatic life-chronic**
Benzene	40	Human health-ingesting organisms only

* Hardness-specific criteria are calculated as follows:

Cadmium $e^{(0.7852[\ln(\text{hardness})]-3.49)}$

Copper $e^{(0.8545[\ln(\text{hardness})]-1.465)}$

Lead $e^{(1.273[\ln(\text{hardness})]-4.705)}$

Zinc $e^{(0.8473[\ln(\text{hardness})]+0.7614)}$

** Lowest Reported Toxic Concentration:

SOURCE: EPA Ambient Water Quality Criteria Documents (various dates).

Description of Methods to Assess Improvements

The following section contains brief descriptions of the three methods used to assess water quality improvements that have resulted from the implementation of BAT treatment technologies.

Water Quality Modeling Analysis

Water quality modeling was performed to identify theoretical water quality improvements by pollutant, as well as by reach. The analysis consisted of modeling industrial facilities with BAT effluent limitations that directly control toxic (priority) pollutants. The model calculated theoretical in-stream concentrations of the ten selected pollutants at pre- and post-BAT treatment levels under low and average receiving stream flow conditions. The in-stream concentrations were then compared to applicable water quality criteria to identify improvements in meeting these criteria. Of the 6,834 BAT facilities with toxic limitations (not including the 8,353 facilities in the coal mining, steam electric, timber products, pesticides manufacturing, and plastics molding and forming categories) identified in the EPA data bases, 2,490 were evaluated in the modeling procedure.

Assumptions and Limitations

In conducting the water quality modeling, a number of assumptions were made. These assumptions, together with their limitations, are as follows:

1. Industry-wide pollutant concentrations for the BAT industrial categories were used to represent individual facility discharge levels. This approach assumes that every facility in a particular industrial category discharges the same pollutants at the same concentrations; the only difference between facilities in the same category is the volume of wastewater discharged. This assumption does not reflect "real life" conditions, since each facility is different and effluent levels vary across categories. Since this is a national study, however, the differences in levels (some higher, some lower) will tend to cancel each other out.

2. Two treatment levels from U.S. EPA (1986) were used in the water quality model: RAW and BAT. The RAW treatment level was used to represent a particular industry's discharge level prior to the promulgation of BAT. The use of RAW as the pre-BAT discharge level overestimates the actual pre-BAT (1972) discharge levels because it does not credit industry with treatment in place at that time. Since it is not known how much treatment was occurring prior to BAT, RAW levels were used. The BAT treatment level was used to represent the levels at which an industry should be discharging after the implementation of the BAT regulations (post-BAT).

3. Process wastewater flows contained in the IFD data base were used to represent pre-BAT (RAW) flows. Where flow reduction was required by the BAT limitations, this was taken into account by reducing the pollutant concentration by a proportional amount. Flow reduction was required for the following industrial categories: aluminum forming, battery manufacturing, coil coating, copper forming, foundries, inorganic chemicals, iron and steel, nonferrous metals, nonferrous metals forming, and porcelain enameling.

4. BAT treatment levels were assumed to be the only effluent limitation imposed on the industries. Water quality-based limitations were not considered since the site-specific nature of such limitations prevents a theoretical estimate of their effectiveness.

5. The model assumed the pollutant was completely mixed in the receiving stream and that no fate-related removal (e.g., sedimentation, biodegradation, volatilization) occurred. While fate-related removal could be significant (especially for the organics), this assumption is partially offset by not considering background concentrations.

6. The model assumed that all currently active BAT facilities (as designated in PCS) were also active prior to BAT (i.e., plant closings and new sources were not accounted for).

<u>Analysis</u>

The objective of the water quality modeling was to project pre- and post-BAT in-stream pollutant concentrations for each reach in the contiguous U.S. that received wastewater discharges from BAT industries. There are currently 24 major industrial categories for which BAT effluent limitation guidelines have been promulgated (as presented in Table 1-1). The effluent discharge water quality modeling was performed for 19 of the 24 industries using industry-wide concentrations for the ten selected pollutants. Five of the 24 industries were excluded because their effluent regulations either did not specifically regulate toxic pollutants (coal mining, timber products, and plastic molding and forming); controlled toxics discharge only for a small volume of the total discharge (steam electric); or have been rescinded (pesticide manufacturing).

For each of the facilities identified as BAT facilities from the EPA data bases, individual plant loadings were calculated (the product of industry-wide effluent concentrations and process wastewater flows) for each of the ten pollutants. To calculate in-stream concentrations, the individual plant loadings were summed for each pollutant for all facilities on a particular reach. These total loadings were then divided by the stream flow (either low or average, depending on the analysis) and sum of the plant flows. The following equation illustrates this procedure:

$$C_i = \frac{\Sigma\ (C_e \times Q_e)}{Q_s + \Sigma\ (Q_e)}$$

where: C_i = In-stream pollutant concentration (ug/l)
C_e = Effluent pollutant concentration (ug/l)
Q_e = Process wastewater flow (MGD)
Q_s = Receiving stream flow (MGD).

This procedure was followed for each pollutant on each reach for the pre- (RAW) and post-BAT (BAT) effluent levels and summarized on a reach-by-reach basis (included in Volume II). The resulting in-stream pollutant concentrations were also compared to water quality criteria (WQC) to determine compliance.

Ambient Water Quality Monitoring Data Analysis

An analysis of ambient water quality monitoring data for those reaches identified as having BAT discharges was also conducted to determine water quality improvements. Ambient water quality monitoring data (from STORET) for the ten selected pollutants for time periods reflecting pre-BAT (1970 to 1980) and post-BAT (1985 to 1988) were used to determine trends in ambient pollutant concentrations. Corresponding monitoring data (i.e., data from both time periods) was available for at least one pollutant for 429 of 1,546 reaches receiving BAT discharges.

Assumptions and Limitations

The following is a brief discussion of the specific assumptions, and their limitations, made in performing the ambient water quality monitoring analysis:

1. The monitoring period from 1970 to 1980 represents pre-BAT conditions and the period from 1985 to 1988 represents post-BAT conditions. The intervening years were considered a time of transition and were not addressed. All monitoring data for the individual time periods were averaged together. Improvement trends within each time period are not considered as well as trends during the transition period.

2. Monitoring data reported below detectable levels were included only where detected levels were also available. In those instances, the monitored values were set equal to one-half the detection limit. It can not be determined whether or not this practice overestimates or underestimates the actual pollutant concentration.

3. The STORET water quality monitoring data should be used with some caution, in that:

   - The origins of the pollutants monitored include all upstream sources, including facilities and sources not evaluated in this study (e.g., POTWs, non-BAT industries, natural and nonpoint sources);

   - Information on the location of the monitoring station(s) in relation to the BAT industrial facilities (i.e., upstream or downstream) was not readily available; and

   - The flow conditions during sampling were unknown.

Analysis

To aid in the determination of the water quality improvements attributable to the BAT guidelines, ambient in-stream water quality monitoring data for the ten selected pollutants were analyzed for two monitoring periods - pre-BAT and post-BAT. The ambient pollutant data were obtained from EPA's STORET Water

Quality file. Monitoring data that were "unremarked" (i.e., pollutant concentration was quantifiable) and data "remarked" (pollutant concentration less than the detection limit) were used in this analysis. The individual monitoring values were retrieved from STORET and aggregated on a reach basis. The average concentration for a particular pollutant for each of the two time periods was calculated by using both the unremarked and the remarked data (which was set to one-half the detection limit). This averaging procedure was used only when there was at least one unremarked value.

In order to compare the two time periods, it was necessary to exclude average values where data were available for only one of the two time periods. Of the 1,546 BAT reaches, 429 had ambient water quality monitoring data available for at least one pollutant for both time periods. The average concentration for the two time periods were used to determine trends in chemical water quality. Three different classifications were used to define pollutant concentration trends: improved, deteriorated, and no change. An "improved" trend signifies that the pollutant concentration decreased by more than 10 percent between the two time periods. Likewise, a "deteriorated" trend denotes an increase in the post-BAT concentration of more than 10 percent. A "no change" designation signifies that the pollutant concentration did not change by more than 10 percent between the two periods.

Water Quality Improvement Case Studies

The third approach to determining ambient water quality improvements was to identify actual improvements (case studies) that can be attributed to the implementation of BAT requirements. The focus of this effort was different from that used for the water quality and ambient monitoring data analyses since all types of improvements would be applicable, not just improvements from direct dischargers of toxic pollutants. Such improvements could include reductions in conventional (suspended solids or biochemical oxygen demand) or nonconventional (ammonia and chlorine) pollutants and reductions in toxic pollutants discharged from POTWs as a result of the implementation of pretreatment programs. Improvements could be shown through reduced in-stream pollutant concentrations, attainment of designated water use, or improved biological integrity of the receiving stream.

In order to identify possible case studies, the 1988 State Water Quality Assessment [305(b)] Reports were reviewed. From these reports, potential case studies were selected for further investigation. Of the thirty-six 305(b) reports reviewed, nine States were identified as having potential case studies. Based on contacts with these nine States, five case studies were selected to illustrate water quality improvements attributed to the application of BAT regulations. An additional case study was provided by EPA Region X. The summary of these case studies are presented in Chapter 3.

A special case study was developed by the Agency to represent improvements resulting from BAT on a typical estuary. This case study used a water quality model to project theoretical improvements (similar to the nationwide model) and analyzed ambient monitoring data to verify these projected improvements. This special study is also discussed in Chapter 3.

Chapter Three

RESULTS

The overall results of the three methods used to identify water quality improvements that are attributable to BAT are presented in this chapter. For the water quality model and ambient monitoring data, water quality improvements are presented in terms of river miles that (1) complied with water quality criteria or (2) showed a decrease in ambient pollutant concentrations, respectively. Only nationwide summaries are presented here, along with summaries of specific cases studies in which the implementation of the BAT regulations have resulted in water quality improvements. The results of the model/ambient analyses, on a reach-by-reach/State basis, are provided in Volume II, Technical Appendices.

IMPROVEMENTS IN WATER QUALITY - WATER QUALITY MODEL

As defined in Chapter 1, a water quality improvement can mean either (1) compliance with water quality criteria after implementation of BAT treatment technology when criteria had been exceeded prior to BAT, or (2) a reduction in in-stream pollutant concentrations after BAT. The water quality model addresses improvements only in water quality criteria compliance, since theoretically all reaches receiving discharges from BAT facilities have improved in terms of pollutant concentration reductions (e.g., all industrial categories evaluated in this study reduced their discharge levels from pre-BAT to post-BAT).

The model assessed 2,490 BAT facilities on 1,546 reaches (totaling 24,289 river miles). The model calculated theoretical in-stream concentrations for the ten selected pollutants using industry-wide effluent concentrations, process wastewater discharge flows, and low (7-Q-10) and average receiving stream flows. The results of the water quality model are presented on both an individual pollutant basis and a reach basis (to determine if all modeled pollutants comply with their respective criteria).

Pollutant-by-Pollutant

Nationwide summaries of the river miles complying (instream concentration below criteria) and not complying (instream concentration at or above criteria) with water quality criteria (WQC) for the individual pollutants, based on pre- and post-BAT discharge levels, using low and average receiving stream flow are shown in Tables 3-1 and 3-2, respectively. Under low flow conditions, pre-BAT discharges are projected to result in less than half of the river miles complying with the WQC for copper (43 percent), lead (47 percent), and cyanide (47 percent). No pollutant had 100 percent compliance under low flow conditions prior to BAT. After BAT, compliance ranged from 73 (mercury) to 100 percent (phenol, toluene, benzene). The average increase in compliance was 20 percent. On a pollutant-by-pollutant basis, the additional percentage of river miles complying with WQC after BAT is shown below:

Pollutant	Additional Percentage of River Miles Complying with WQC After BAT (Low Flow)
Cadmium	25
Mercury	7
Copper	33
Lead	28
Nickel	22
Zinc	30
Cyanide	34
Phenol	8
Toluene	3 *
Benzene	9

* 97 percent compliance prior to BAT.

Table 3-1

Summary of Water Quality Modeling Results:
Compliance with Criteria (at Low Stream Flow)

		Pre-BAT		Post-BAT		
		Not Complying w/WQC	Complying w/WQC	Not Complying w/WQC	Complying w/WQC	Total River Miles Assessed
Cadmium	River Miles	9,030.2	15,258.5	3,038.2	21,250.5	24,288.7
	Percent	37%	63%	12%	88%	
Mercury	River Miles	8,176.4	16,112.3	6,523.8	17,764.9	24,288.7
	Percent	34%	66%	27%	73%	
Copper	River Miles	13,791.9	10,496.8	5,752.0	18,536.7	24,288.7
	Percent	57%	43%	24%	76%	
Lead	River Miles	12,864.3	11,424.4	6,174.2	18,114.5	24,288.7
	Percent	53%	47%	25%	75%	
Nickel	River Miles	6,265.7	18,023.0	1,043.2	23,245.5	24,288.7
	Percent	26%	74%	4%	96%	
Zinc	River Miles	9,748.1	14,540.6	2,469.0	21,819.7	24,288.7
	Percent	40%	60%	10%	90%	
Cyanide	River Miles	12,916.3	11,372.4	4,562.1	19,726.6	24,288.7
	Percent	53%	47%	19%	81%	
Phenol	River Miles	1,836.1	22,452.6	0.0	24,288.7	24,288.7
	Percent	8%	92%	0%	100%	
Toluene	River Miles	730.3	23,558.4	0.0	24,288.7	24,288.7
	Percent	3%	97%	0%	100%	
Benzene	River Miles	2,283.8	22,004.9	37.5	24,251.2	24,288.7
	Percent	9%	91%	0%	100%	

Table 3-2

Summary of Water Quality Modeling Results:
Compliance with Criteria (at Average Stream Flow)

		Pre-BAT		Post-BAT		
		Not Complying w/WQC	Complying w/WQC	Not Complying w/WQC	Complying w/WQC	Total River Miles Assessed
Cadmium	River Miles	2,807.4	21,481.3	332.9	23,955.8	24,288.7
	Percent	12%	88%	1%	99%	
Mercury	River Miles	4,704.3	19,584.4	2,488.8	21,799.9	24,288.7
	Percent	19%	81%	10%	90%	
Copper	River Miles	5,421.6	18,867.1	923.1	23,365.6	24,288.7
	Percent	22%	78%	4%	96%	
Lead	River Miles	5,764.3	18,524.4	1,007.6	23,281.1	24,288.7
	Percent	24%	76%	4%	96%	
Nickel	River Miles	1,328.7	22,960.0	2.6	24,286.1	24,288.7
	Percent	5%	95%	0%	100%	
Zinc	River Miles	2,915.2	21,373.5	338.7	23,950.0	24,288.7
	Percent	12%	88%	1%	99%	
Cyanide	River Miles	6,059.2	18,229.5	436.2	23,852.5	24,288.7
	Percent	25%	75%	2%	98%	
Phenol	River Miles	115.0	24,173.7	0.0	24,288.7	24,288.7
	Percent	0%	100%	0%	100%	
Toluene	River Miles	50.3	24,238.4	0.0	24,288.7	24,288.7
	Percent	0%	100%	0%	100%	
Benzene	River Miles	44.5	24,244.2	0.0	24,288.7	24,288.7
	Percent	0%	100%	0%	100%	

Improvements in meeting WQC are less pronounced under average receiving stream flow conditions. Prior to BAT, between 75 (cyanide) and 100 (phenol, toluene, and benzene) percent of the river miles assessed complied with WQC. After the implementation of BAT, compliance ranged from 90 (mercury) to 100 (nickel, phenol, toluene, and benzene) percent. The average increase in compliance as a result of the implementation of BAT, at average flow, was 10 percent. Individually, the additional percentage of river miles complying with WQC as a result of BAT for each of the pollutants, is shown below:

Pollutant	Additional Percentage of River Miles Complying with WQC After BAT (Average Flow)
Cadmium	11
Mercury	9
Copper	18
Lead	20
Nickel	5
Zinc	11
Cyanide	23
Phenol	0 *
Toluene	0 *
Benzene	0 *

* 100 percent compliance prior to BAT.

Overall Reach

The second method of evaluating the water quality improvements attributable to BAT, based on the water quality model, examines the reach as a whole. If the reach is to meet WQC, then all modeled pollutants on that reach must comply with their respective criteria. These "overall" reach evaluations, therefore, assess the effects of BAT on individual reaches for all the selected pollutants. The results of assessing water quality improvements using this methodology, under low and average flow conditions, are shown in Figure 3-1.

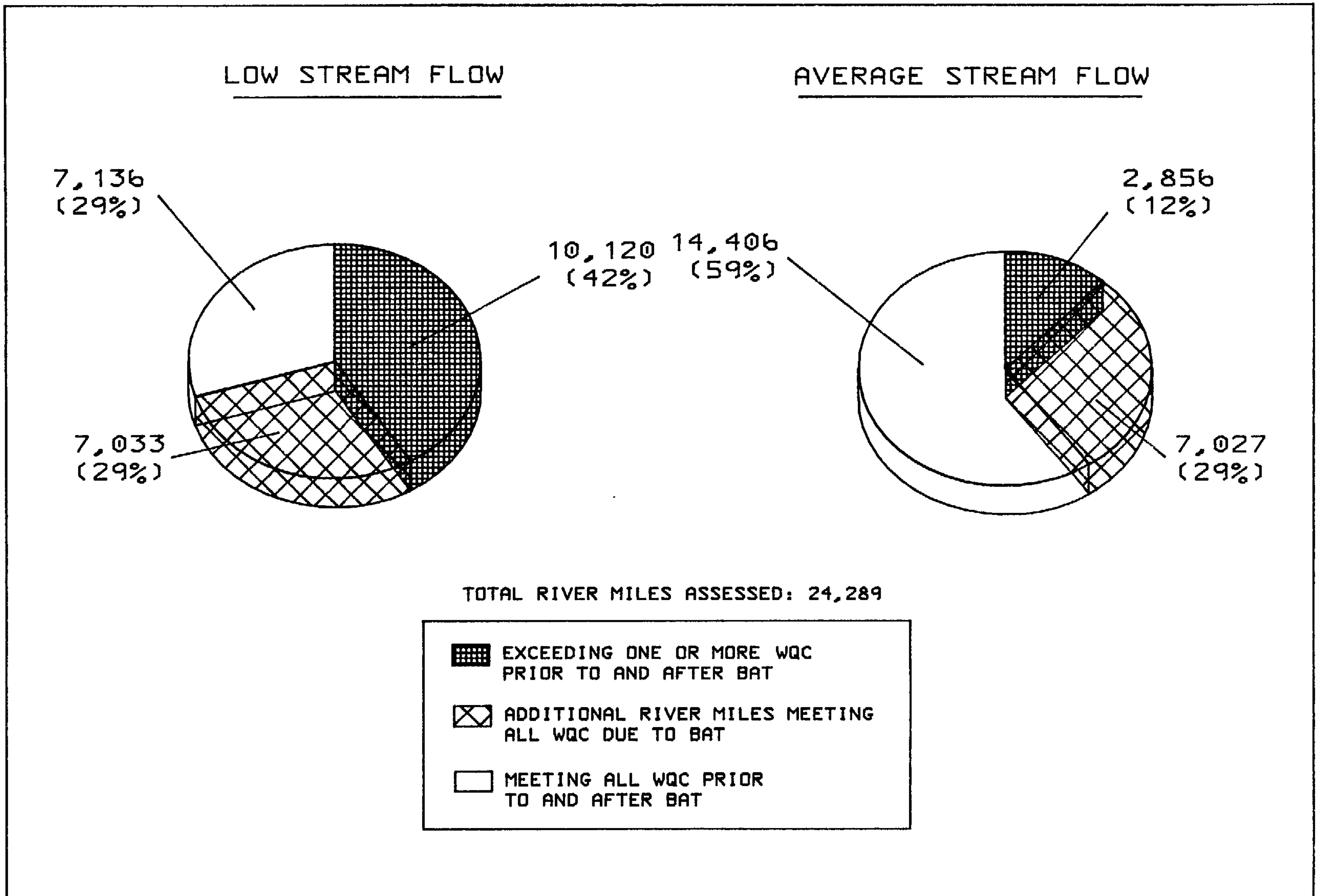


Figure 3-1. Summary of Water Quality Modeling: Overall Results.

Under low flow conditions, only 29 percent of the river miles were projected to meet all WQC prior to the implementation of BAT controls. After attaining discharge levels required under the BAT regulations, the model predicts that 58 percent of the river miles would meet criteria, that is, an additional 29 percent of the river miles would be in compliance. Even after BAT, 42 percent of the river miles assessed are projected to exceed criteria for one or more of the ten pollutants. Under this scenario, mercury and lead are the main causes of noncompliance.

At average stream flow, only 59 percent of the river miles were projected to comply with WQC for all the modeled pollutants prior to the implementation of BAT. After the implementation of BAT, an additional 29 percent of river miles would comply with WQC; 12 percent will still not comply with criteria. The major cause of noncompliance after BAT is mercury.

IMPROVEMENTS IN WATER QUALITY - AMBIENT MONITORING DATA

Improvements in water quality, as determined through analysis of ambient monitoring data, focus on trends in pollutant concentrations (both on an individual and on a reach basis) as opposed to comparison with water quality criteria. The primary reasons for this approach center on the general lack of monitoring data for reaches evaluated using the water quality model and the method of determining average pollutant concentrations for the pre- and post-BAT time periods.

Of the 1,546 reaches (24,289 river miles) assessed by the water quality model, 429 (totaling 8,434 river miles) had monitoring data for at least one of the selected pollutants for both time periods. None of the evaluated reaches, unfortunately, had monitoring data for both the pre-BAT and post-BAT time periods for the selected organic chemicals (phenol, toluene, and benzene).

Pollutant-by-Pollutant

Table 3-3 presents a summary of the in-stream concentration trends for each of the seven monitored pollutants. Between the pre-BAT (1970 to 1980) and post-BAT (1985-1988) time periods, each of the pollutants showed a marked decrease in in-stream concentration. On the average, each of the pollutant concentrations decreased in 78 percent of the monitored river miles. Cadmium and mercury showed the greatest concentration decreases (or improvement) in monitored levels (84 and 87 percent of the river miles improved). Zinc levels reflected the least improvement (69 percent improvement). The extent of no significant change in monitored pollutant concentrations between the two time periods ranged from 1 percent of the river miles (for mercury) to 11 percent of river miles (for copper). A deterioration, or increase in concentration, occurred along some reaches for each pollutant. The extent of deteriorations ranged from 11 percent of the river miles (for cadmium) to 25 percent of river miles (zinc).

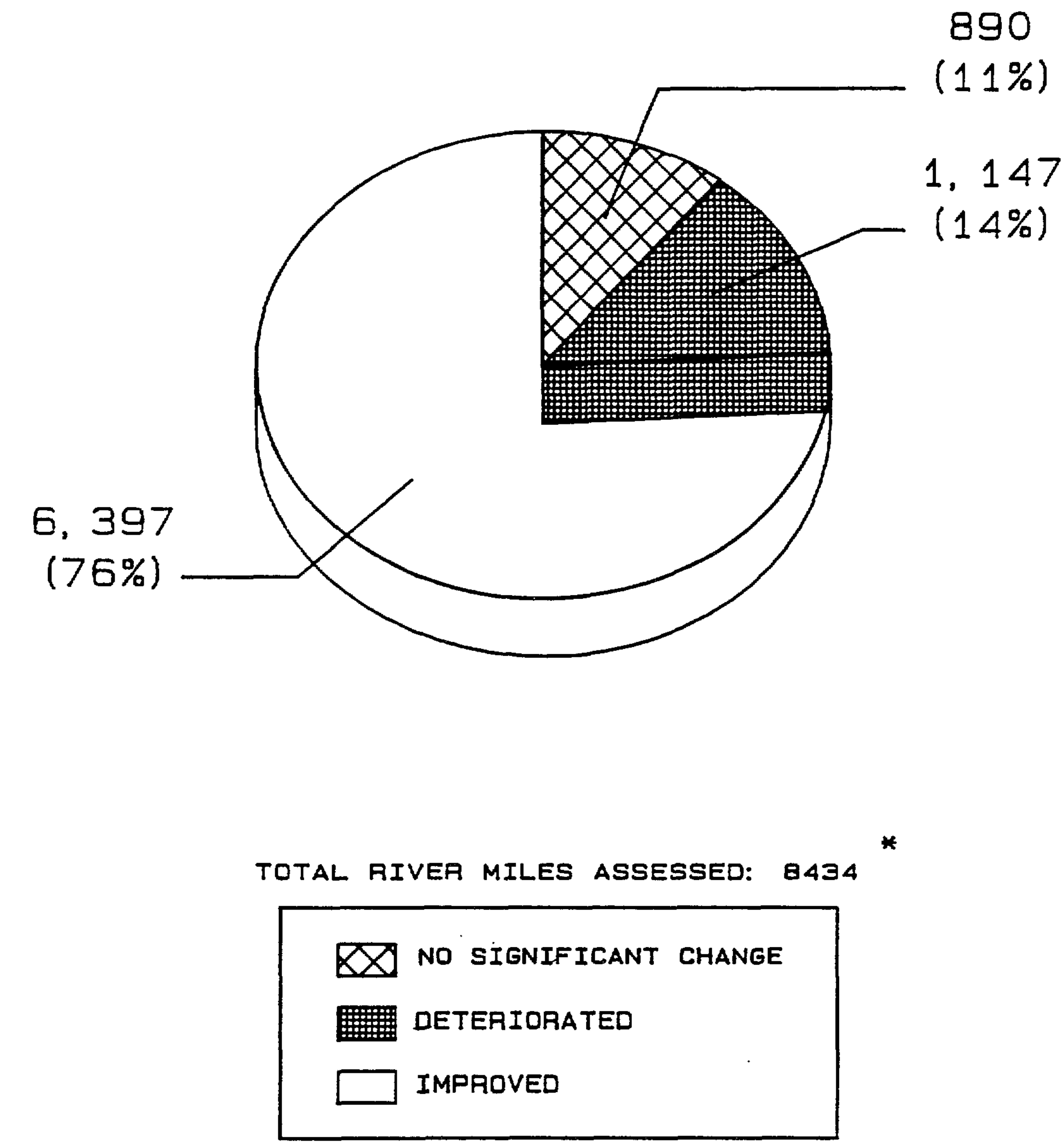
Overall Reach

Using a method to show overall trends on a reach basis (similar to the method used in presenting the results of the water quality model for overall compliance with WQC), the ambient monitoring data were analyzed to determine overall trends in pollutant concentrations for the monitored pollutants. Using this method, about 76 percent of the river miles with monitoring data available showed an overall improvement (or net decrease in pollutant concentrations). Roughly 14 percent of the river miles showed a net increase (deterioration) in monitored concentrations and 11 percent showed no significant change. Figure 3-2 illustrates these overall trends based on the ambient monitoring data analysis.

Table 3-3

Summary of Ambient Monitoring Data Analysis:
Pollutant Trends

		Improved	No Change	Deteriorated	Total Monitored
Cadmium	River Miles	3,822.6	193.0	519.5	4,535.1
	Percent	84%	4%	11%	
Mercury	River Miles	2,807.4	31.5	375.6	3,214.5
	Percent	87%	1%	12%	
Copper	River Miles	4,349.9	667.3	1,238.2	6,255.4
	Percent	70%	11%	20%	
Lead	River Miles	4,659.7	279.3	766.1	5,705.1
	Percent	82%	5%	13%	
Nickel	River Miles	3,590.4	229.8	1,172.9	4,993.1
	Percent	72%	5%	23%	
Zinc	River Miles	5,296.2	498.1	1,889.7	7,684.0
	Percent	69%	6%	25%	
Cyanide	River Miles	1,228.2	110.7	205.3	1,544.2
	Percent	80%	7%	13%	



* River miles for reaches with BAT facilities and monitoring data for one or more of the ten toxic pollutants.

Note: Percentages add up to more than 100 percent due to rounding.

Figure 3-2. Summary of Ambient Monitoring Data Analysis: Overall Trends for BAT Reaches.

IMPROVEMENTS IN WATER QUALITY - CASE STUDIES

Potential case studies screened for this study could represent any improvement in water quality attributable to the implementation of BAT regulations, including controls on conventional pollutants and regulations applicable to indirect dischargers. However, the focus was on toxic pollutant controls for direct discharging facilities. After a review of a number of State 305(b) reports as well as conversations with State officials, it appears that the focus of case studies have been on municipal discharges, where controls on oxygen-demanding pollutants and nutrients have resulted in improved oxygen levels in streams. The major concern with toxic chemicals, as evidenced by the 305(b) reports, is sediment contamination, primarily because of PCBs and pesticides. Little information is available concerning improvements that have resulted from toxic pollutant discharges, especially instances involving technology-based (i.e., BAT) controls. However, six studies have been reported that indicate improvements in water quality resulting from BAT or BAT-type controls.

In addition to the above case studies, a detailed water quality model and ambient monitoring data analysis was performed by the Agency on an estuary (Delaware River Estuary) to highlight the effects of BAT regulations on these types of waterbodies.

Long Island Sound - Connecticut

In 1985, the Connecticut Department of Environmental Protection (CT DEP) initiated a study to collect current fish tissue contaminant data for comparison with historical data in order to show temporal trends. Of the many sites and organisms selected for testing, oyster data obtained from Bridgeport Harbor and the Housatonic River areas indicated that these contaminated areas had improved over the past decade. Both Bridgeport Harbor and the Housatonic River have a heavy concentration of metals-related industries (metal finishing, copper forming, and foundries). The comparison of 1972-1974 oyster metal concentrations to the data collected in 1985-1986, shown in Figure 3-3, indicates that the "levels of cadmium, chromium, copper, mercury and zinc were currently lower than the lowest concentrations observed in an intensive study from the early 1970s. Although the 1985-1986 survey was not detailed enough to permit rigorous statistical analysis, the disparity in metals levels strongly suggests a reduction in metals contamination of oyster tissues in the Bridgeport and Housatonic Rivers" (NY DEC, 1988). Since Connecticut currently does not write water quality-based permit limitations, but instead bases its industrial discharge levels on BAT-type standards, the improvements in metals concentrations can be at least partially attributed to reductions in discharge levels from the metal industries located in these areas.

Naugatuck River - Connecticut

Another example of water quality improvements in Connecticut is the Naugatuck River. According to CT DEP (1988), the Naugatuck was once considered one of the most polluted rivers in the nation. From 1973 to 1976, CT DEP issued abatement orders to 77 industrial dischargers along the river. Metal finishers, the most prevalent type of industry on the river, were required to neutralize acids, destroy cyanide water, and precipitate heavy metals (BAT-type treatment technologies). "Monitoring data has shown a marked reduction in heavy metals, such as copper and zinc, and improved pH levels. While the river was virtually devoid of aquatic life in 1970, water quality has now improved to the point where the upper 22 miles ... have been stocked with trout on an experimental basis. The river has been identified by CT DEP Fisheries Unit as a potentially valuable resource for cold water and anadromous fisheries" (CT DEP, 1988). Water quality problems still exist on the lower portions of the river, which will require more stringent (e.g., water quality-based) permits in order to achieve water quality goals.

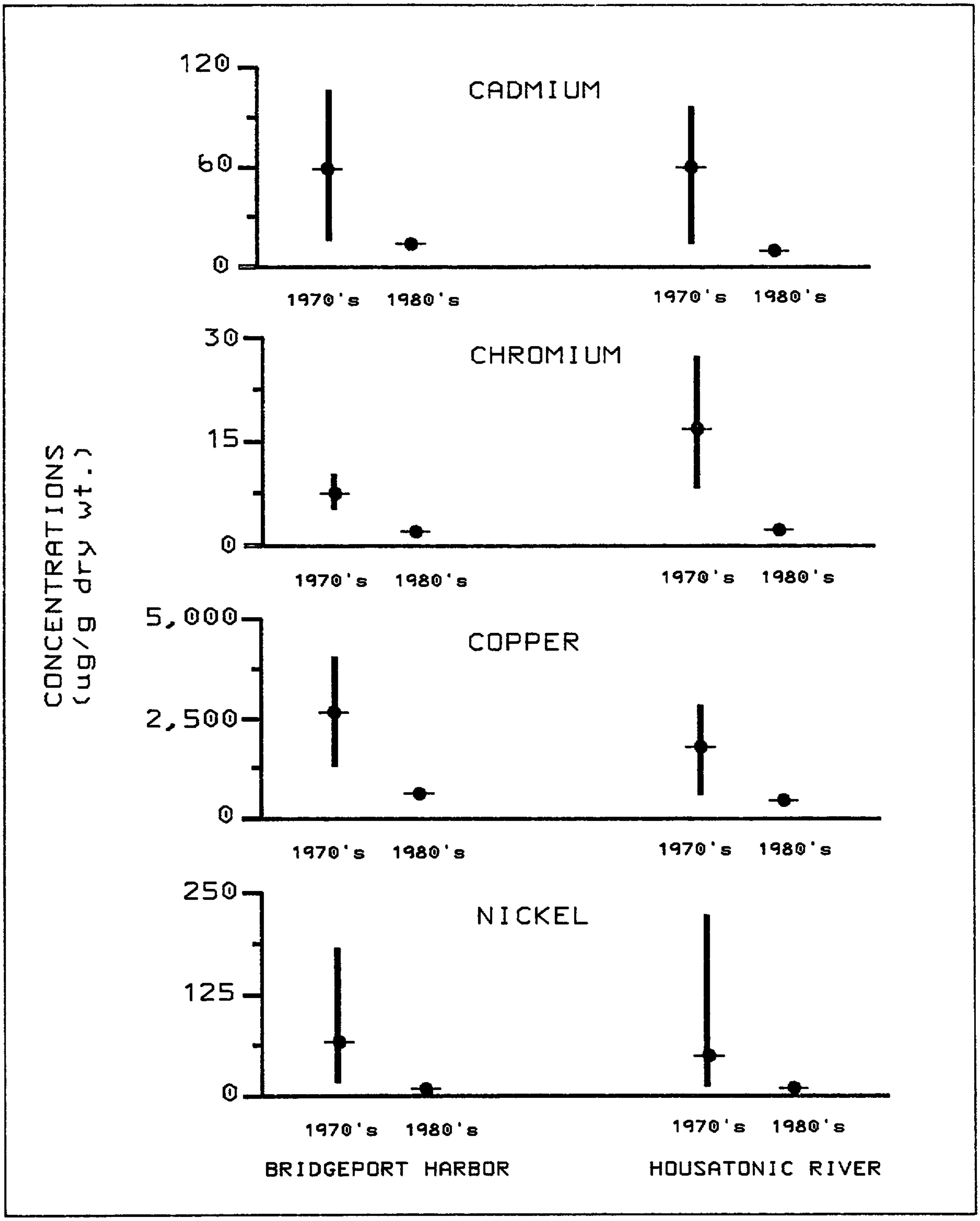


Figure 3-3. Trends in Metal Concentrations in Oysters - Long Island Sound.

Source: NY DEC, 1988.

South Fork Coeur d'Alene River - Idaho

The South Fork Coeur d'Alene River has had serious pollution problems for many decades, which were the result of ore mining and related activities. At the time of the enactment of the Federal Water Pollution Control Act of 1972, heavy metals concentrations in the river reached 23,000 ug/l for total zinc, 200 ug/l for total cadmium, and more than 500 ug/l for total lead during the summer low flow periods. These levels are roughly two orders of magnitude higher than EPA's acute (short-term) water quality criteria for protection of aquatic life. As a result of the 1972 Act, effluent limits for industrial dischargers were required. EPA's Region X Office initiated a monitoring program in 1972 to document the improvements in the South Fork Coeur d'Alene River and identify any remaining sources of heavy metals. Figure 3-4 shows the trends in zinc, cadmium, and lead at the mouth of the South Fork Coeur d'Alene River from 1972 to 1986 (USEPA, 1987). Each metal shows a decrease of roughly 90 percent during this period. While metal concentrations still exceed criteria levels, conditions of the South Fork are now suitable for many of the less sensitive indigenous species of aquatic biota, and conditions of the mainstream are enabling game fish to return downstream of the South Fork confluence. Data now indicate that nonpoint sources are responsible for 50 to 90 percent of the metals.

Lower Fox River - Wisconsin

The Fox River Valley is heavily industrialized, especially with paper mills, and 50 percent of all point source discharges occur in the lower portion (from Depere to Green Bay). High pollutant loadings from the paper mills have contributed greatly to the historically low dissolved oxygen levels in the Lower Fox River. As a result of the Clean Water Act of 1972, improved wastewater treatment systems, which began operation in the 1970s, have resulted in the attainment of the 5 mg/l dissolved oxygen standard for much of the time period after the treatment systems became operational. Permitted effluent levels for the paper mills have been set at the limits established by

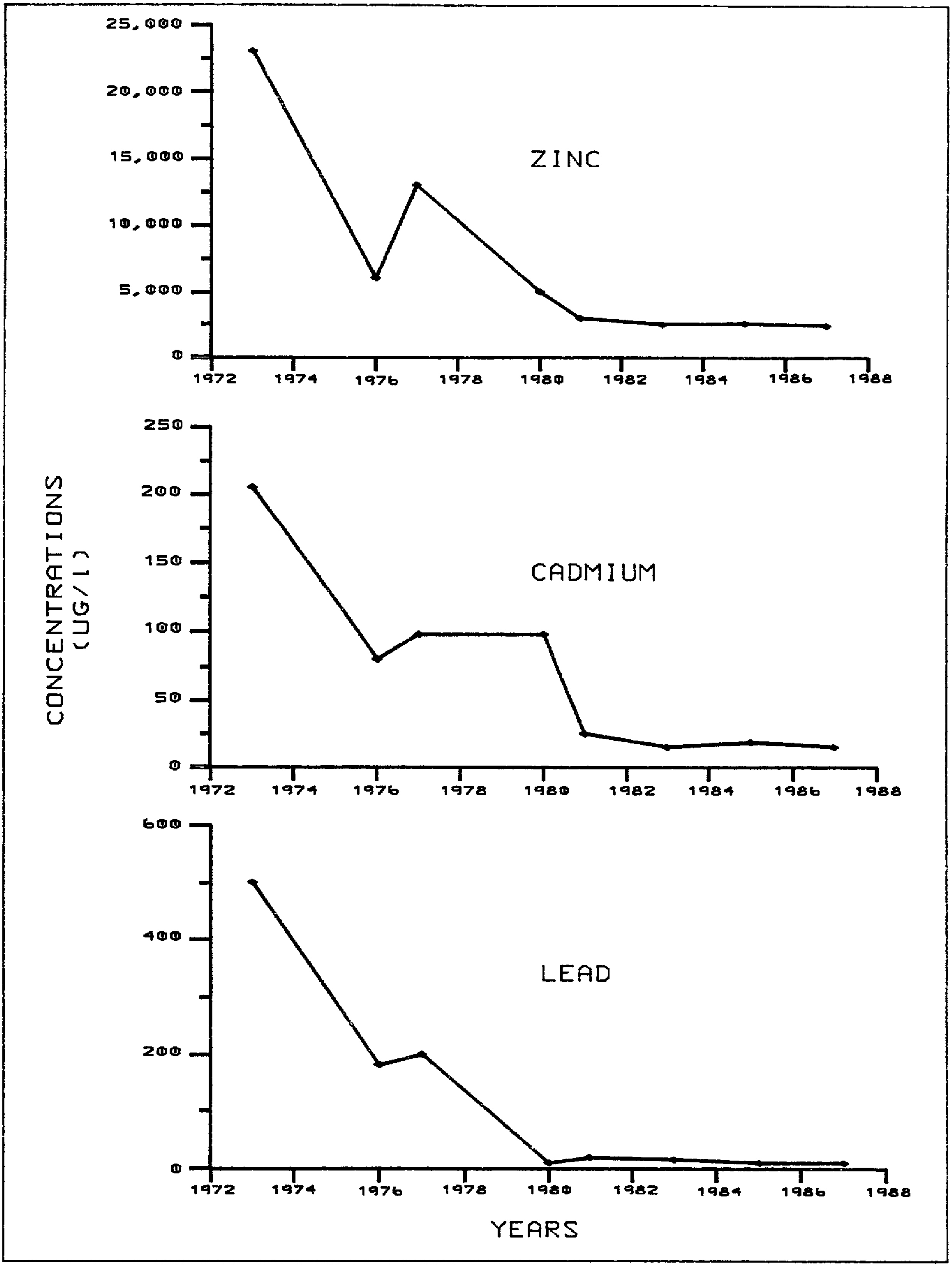


Figure 3-4. Trends in Metal Concentrations for the South Fork Coeur D'Alene River.

Source: US EPA, 1987.

the national categorical standards (BPT/BAT), however, many of the mills are discharging at lower levels. The Wisconsin Department of Natural Resources (WDNR) is currently revising its effluent permits to reflect water quality-based limits for toxic pollutants; nonetheless, the national effluent standards have had a beneficial impact on the Lower Fox River. According to historical trends related to macroinvertebrates, there has been a recent increase in pollution intolerant aquatic life (WDNR, 1985).

Other Case Studies

There are several other case studies in which the water quality improvements can be at least partially attributed to the implementation of national categorical effluent standards. The first involves the Scioto River in Ohio. Using a macroinvertebrate index as a measure of overall water quality, the Ohio Environmental Protection Agency (OEPA) determined that prior to 1976, the Scioto River had marginal attainment of a warm water habitat. A great change in the index was noted between 1977 and 1978, reflecting an index indicative of exceptional macroinvertebrate fauna. These exceptional conditions continued to exist through 1985. The changes in water quality "are most attributable to improvements in wastewater treatment" at a major pulp and paper facility on the river (OEPA, 1988).

Using the same macroinvertebrate index, OEPA has shown an improving trend in biological conditions on the Mohican River. "These improvements may be attributable to industrial waste pretreatment (electroplaters) requirements in the cities of Mansfield and Ashland, as well as wastewater treatment improvements by various industries and WWTPs" (OEPA, 1988).

Delaware River Estuary

To determine the effects of the BAT regulations on estuaries a case study of the Delaware Estuary was performed. The general methodology for this case study follows that used in the nationwide analyses of BAT facilities and reaches. A modified water quality model, developed for EPA [from information obtained from the National Oceanic and Atmospheric Administration (NOAA)], for use in determining 304(l) lists of waters impaired by toxics, was used to project in-stream pollutant concentrations from pre- and post-BAT effluent discharges from BAT industries. This model used the same industry-wide concentrations of the ten selected pollutants as the nationwide water quality model analysis. Ambient water quality monitoring data were also retrieved from EPA's STORET Water Quality File to show trends in selected pollutant levels between the pre-BAT (1970-1980) and post-BAT (1985-1988) time periods and to verify projected compliance with WQC (no State standards available).

This analysis was based on estuary zones rather than reaches. There are three zones in any estuary: a freshwater tidal zone, a saltwater tidal zone, and a mixing zone located between the two. For this analysis, the in-stream (or in-estuary) pollutant concentration was calculated using "pollutant concentration potentials," a procedure developed by NOAA, that takes into consideration both the flow available for dilution and the zone characteristics (salinity). The concentration potentials do not consider pollutant fate. A more detailed explanation of this approach can be found in U.S. EPA (1988).

The Delaware estuary water quality model evaluated 64 BAT facilities discharging at pre- and post-BAT levels. Twenty-two discharged to the freshwater zone (Zone 1), 39 discharged to the mixing zone (Zone 2), and 3 discharged into the saltwater zone (Zone 3). The model evaluated each zone independently and did not account for inputs from upstream zones or other sources. Table 3-4 presents the results of the water quality model for the Delaware estuary. Prior to the implementation of BAT, Zone 1 was projected to not comply with freshwater criteria for mercury, copper, lead, zinc, and cyanide. After the facilities met the discharge requirements of BAT, all pollutants were projected to comply with of WQC. Likewise, in Zone 2, four pollutants (mercury, copper, lead, and cyanide) did not comply with WQC prior to BAT and full compliance was projected after BAT. The WQC used for this zone was the more stringent of the two freshwater and saltwater criteria. All

Table 3-4

Water Quality Model Results for the Delaware Estuary

		Pollution Concentration (ug/l)																			
	Number of	Cadmium		Mercury		Copper		Lead		Nickel		Zinc		Cyanide		Phenol		Toluene		Benzene	
Zone	Facilities	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT	RAW	BAT
1	22	0.15	0.016	0.41 *	0.001	20.3 *	0.35	24.9 *	0.13	1.07	0.05	118.3 *	0.90	36.7 *	0.14	165.5	0.05	26.1	0.04	21.95	0.03
2	39	0.31	0.037	0.90 *	0.008	6.5 *	0.18	7.1 *	0.18	2.22	0.13	30.4	1.02	11.0 *	0.32	43.9	0.09	8.0	0.01	5.6	0.02
3	3	0.0	0.000	0.00	0.000	0.04	0.00	0.01	0.00	0.04	0.00	0.1	0.00	0.04	0.00	0.07	0.00	0.01	0.00	0.01	0.00
Fresh WQC			1.1		0.012		11.4		3.0		100		102		5.2		750		650		40
Salt WQC			9.3		0.025		2.9		5.6		8.3		86		1.0		290		3200		40

* Predicted in-stream concentration exceeds WQC.

NOTE: Fresh WQC compared to in-stream concentrations in Zone 1.
Salt WQC compared to in-stream concentrations in Zone 3.
The more stringent of the two WQC was compared to in-stream concentrations in Zone 2.

pollutants in Zone 3 were projected to comply with WQC (saltwater) both before and after the implementation of BAT.

The ambient monitoring data analysis used information obtained from monitoring stations designated as "estuarine," as opposed to ambient "stream" stations used in the nationwide evaluation. Values that were reported as "less than detection limit" were handled in the same manner as the nationwide evaluation. Data from two stations were used to represent average pollutant concentrations in Zone 1 and seven stations were averaged for Zone 2 (see Table 3-5). No ambient estuarine data were available for Zone 3 and limited data (in terms of the number of pollutants) were available for Zones 1 and 2. The results of the monitoring data analysis compare favorably to the water quality model. In Zone 1, the average pre-BAT concentrations for copper and lead did not comply with WQC. After BAT, only lead still did not comply with criteria, but only by a slight margin. All monitored levels decreased by at least 83 percent. In Zone 2, all pollutants showed a marked decrease in average pollutant concentration. Cadmium decreased by 91 percent, mercury by 55 percent, copper and lead by over 90 percent each, and zinc by 81 percent. The pre-BAT average concentrations for cadmium, mercury, copper, and lead were above WQC levels. These pollutants were also above WQC after BAT, but by a much smaller margin. One possible reason to account for the non-compliance is that 12 of the 39 BAT facilities were in the organic chemicals category and may not have fully implemented the requirements of the BAT regulations (the phase II regulations were promulgated in November 1987).

Table 3-5

Ambient Water Quality Monitoring Data Summary for Delaware Estuary

		Average Pollutant Concentration (ug/l)									
	Number of	Cadmium		Mercury		Copper		Lead		Zinc	
Zone	Facilities	70-80	85-	70-80	85-	70-80	85-	70-80	85-	70-80	85-
1	22					49.7 *	2.70	53.2 *	5.1 *	61.0	10.4
2	39	29.2 *	2.52 *	1.6 *	0.722 *	51.5 *	2.92 *	53.8 *	5.1 *	64.0	11.9
3	3										
Fresh WQC			1.1		0.012		11.4		3.0		102
Salt WQC			9.3		0.025		2.9		5.6		86

* Average concentration exceeds WQC.

NOTE: Fresh WQC compared to in-stream concentrations in Zone 1.
Salt WQC compared to in-stream concentrations in Zone 3.
The more stringent of the two WQC was compared to in-stream concentrations in Zone 2.
70-80 represents the pre-BAT time period (1970-1980).
85- represents the post-BAT time period (1985-present).

Chapter Four

CONCLUSIONS

The three components of this study indicate that water quality has improved as a result of the implementation of the BAT effluent limitation regulations:

Water Quality Model.

The results of the water quality modeling effort, which evaluated 2,490 BAT facilities impacting 24,289 total river miles (1,546 unique reaches), show that under low stream flow conditions 14,169 river miles (58 percent) comply with all the water quality criteria for the ten selected pollutants after the implementation of BAT (an additional 29 percent improvement over pre-BAT conditions).

Under average receiving stream flow conditions, the model predicts that 59 percent of the river miles modeled will comply with all criteria prior to the implementation of BAT. After BAT, 88 percent of the river miles assessed (an additional 29 percent) were projected to meet all ten criteria. The major causes of noncompliance with criteria are discharges of mercury, lead, and copper. All other pollutants comply with criteria in at least 81 percent of the assessed river miles at low flow (98 percent at average flow).

The use of the water quality model does have certain limitations. The model does not consider upstream sources of pollutants, nor does it consider the discharge of other "nonselected" pollutants by the BAT facilities. These sources could impact the extent of compliance with criteria. This limitation is offset to a certain extent by the fact that pollutant fate is also not considered. The model also assumed all facilities, within a particular category, discharged the same pollutants at the same concentrations. While this is not a particularly valid assumption when dealing with an individual facility, on a nationwide basis, the tendency to overrepresent or underrepresent actual discharge levels is, at least partially, eliminated. Finally, this modeling effort does not take into consideration the treatment technologies in place prior to the Clean Water Act, and thus the actual improvements should be somewhat less than projected.

Based on the results of the water quality model, the national categorical effluent standards program (BAT) has been found to be an effective tool for improving water quality up to a point. However, there may be a need for additional water quality-based controls beyond BAT in some cases in order to meet State water quality standards. The model predicts that 42 percent of the assessed river miles may exceed EPA national water quality criteria under low stream flow conditions after BAT is in place (12 percent of the river miles do not comply at average flow conditions). This projection, however, is not a precise measure, since it is dependent on the number of pollutants evaluated. In many cases, water quality-based NPDES permit limits may have been already developed in order to meet locally applicable State water quality standards, and in other cases new water quality-based permit limits may be needed.

Ambient Water Quality Monitoring Data

Improvements in water quality, based on the ambient water quality monitoring data analysis, are not as evident. Appropriate ambient monitoring data were available for only 35 percent of the river miles assessed by the model, and no comparable data (same reach for both the periods) were available for the organic chemicals selected. This lack of ambient monitoring data is expected, especially for the organic chemicals, since the Agency's major focus during the early and mid-1970's was on conventional pollutants. Only after the Clean Water Act of 1977 were toxic pollutants emphasized. It is also important to note that ambient monitoring data is collected for many other purposes that just to determine the effectiveness of controls placed on industrial discharges. Nevertheless, it is apparent that a more goal-oriented and focused effort needs to be made to truly evaluate controls on industrial discharges.

The monitoring data analysis, however, did show a great improvement, in terms of pollutant reductions, between the pre- and post-BAT time periods. About 76 percent of the river miles (assessed in this evaluation) indicated an overall decreasing trend in in-stream concentrations of toxic pollutants. However, about 14 percent showed an increase. Concentrations of individual pollutants (cadmium, mercury, lead, and cyanide) improved in 80 percent or more of the assessed river miles, while zinc, nickel, and copper showed increases (deterioration) in 20 to 25 percent of the assessed miles.

The full benefit of the implementation of BAT is not reflected in the ambient monitoring analysis. National categorical standards have recently been promulgated for one major industry, organic chemicals manufacturing, which will reduce the industry's toxic pollutant direct discharge loadings by 1.1 million pounds per year. Standards for another category (pesticides manufacturing) are currently being prepared. While the ambient data do reflect some of the benefits attributable to BAT, the full effect will not be evident until the early 1990s. The second component of this study has several other limitations. The sources of pollutants represented in the monitoring data are not known, although these sources should include the BAT facilities evaluated in the model. Other sources could include upstream BAT facilities, municipal facilities, hazardous waste sites, nonpoint, and natural (background) sources. Reductions in the monitored pollutants could possibly be attributed to controls on these sources. Another factor that could account for some of the decreasing pollutant concentration trends is the increase in accuracy of the analytical techniques used to determine the pollutant concentrations. In the past decade, increased sophistication of the laboratory equipment has enabled the detection limits for all pollutants to be lowered.

The statistical significance of comparing monitoring data from time periods of different spans was not evaluated. Also, the naturally occurring variability in monitored pollutant levels was not assessed; however, the effect of such variability should be reduced by using average values over the periods evaluated.

Case Studies

Actual cases where the implementation of BAT has resulted in water quality improvements present the best illustration of the effectiveness of the categorical standards. The few case studies that are available show that the BAT regulations have had a positive impact on the receiving stream quality, in terms of both chemical and biological improvements. In most instances, the streams/rivers assessed in these case studies were highly polluted prior to BAT. Even after the discharge levels were reduced to levels proscribed by BAT, additional water quality-based controls may be needed in order to meet State water quality standards. In all cases, the implementation of BAT has resulted in considerable improvements in the biological quality (as measured by an increase in less pollution-tolerant aquatic life) of the receiving waters.

The special case study predicted and verified that improvements have occurred in the chemical water quality of the Delaware estuary. All pollutants, as projected by the water quality model, that exceeded criteria prior to BAT complied with criteria after the implementation of these regulations. The ambient monitoring data analysis verified these improvements. However, in Zone 2, the area most influenced by organic chemical manufacturing discharges, the predicted improvements are not yet fully realized (e.g., the BAT regulations for the organic chemicals category are not yet fully implemented by industry).

Summary of Water Quality Improvements

Considering the results of each component of this analysis, together with their respective assumptions and limitations, the BAT regulations have been an effective step toward improving the quality of our nation's waters. The extent of this effectiveness is difficult to assess using the existing EPA data sources and considering the fact that the full benefit of BAT has not yet been realized. Also, by not considering improvements resulting from the categorical pretreatment requirements, the extent of the improvements resulting from the overall national water quality program are underestimated. There may be a need for additional water quality-based controls beyond BAT in some cases to meet State water quality standards. In addition, as required by Section 304(m) of the Water Quality Act of 1987, the Agency will establish a schedule for: (1) the annual review and revision of promulgated effluent guidelines, and (2) the promulgation of regulations for industrial categories identified as sources of toxic and nonconventional pollutants for which guidelines have not previously been established.

Chapter Five

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