environmental rehabilitation in the AOC (Indiana Department of Environmental Management, [1988b]). The EAP however, was never fully implemented and was not consistent with the IJC's goals of systematic and comprehensive remediation in the AOC (Holowaty and others, 1991)

Current water-quality management efforts

The Northwest Indiana Action Plan

Current strategies for environmental remediation in the Calumet Area are outlined in the Northwest Indiana Action Plan (NWIAP), which is currently being developed by the IDEM and USEPA. The plan requires that comprehensive and innovative approaches be used to solve environmental problems, and that success be measured from tangible environmental improvement. The NWIAP is being developed to outline common goals of the USEPA and state agencies in the Calumet Area.

The action plan identifies six restoration objectives for the Calumet Area (U.S. Environmental Protection Agency and Indiana Department of Environmental Management, 1992):

1. Ensure the remediation of sediments of the Indiana Harbor Canal and Grand Calumet River.
2. Achieve a high level of compliance with all federal and state environmental statutes.
3. Investigate and remediate petroleum distillate floating on ground water in the Area.
4. Initiate pollution-prevention activities with local industries and municipalities.
5. Develop the Remedial Action Plan (RAP) and Lakewide Management Plan (LaMP) to improve water quality in the Area of Concern and Lake Michigan, respectively.
6. Involve the public in the decision-making process by public participation and education efforts.

The enforcement activities outlined in objective number two of the Action Plan are facilitated through a Geographic Enforcement Initiative (GEI) Task Force maintained by the USEPA. Initiated in February of 1990, the GEI Task Force concentrates on developing and coordinating multimedia enforcement cases throughout northwest Indiana, and functions as a clearinghouse for enforcement activities. Some activities of the GEI Task Force have resulted in agreements and consent decrees with companies and agencies for environmental remediation (U. S. Environmental Protection Agency and Indiana Department of Environmental Management, 1992: U.S. Environmental Protection Agency, [1993?]).

The RAP and the Lake Michigan LaMP mentioned in the fifth objective are environmental management plans specified in the Great Lakes Water-Quality Agreement.

The Remedial Action Plan for the Grand Calumet River/Indiana Harbor Canal-Nearshore Lake Michigan Area of Concern

Before environmental remediation begins in an AOC, the IJC recommends that appropriate agencies and organizations identify and classify causes of environmental impairment in the AOC. The responsible agencies and organizations should then, develop and implement remedial actions based on the identified causes of impairment. The strategies are to be enunciated in a distinct Remedial Action Plan (RAP) developed for each AOC. The RAP identifies the specific actions needed to control existing pollution sources, abate contamination already present, and restore beneficial uses to an AOC. The RAP also provides a historical record of past remedial actions and changes in the environmental quality of the AOC, and a timetable for implementing remedial actions (Great Lakes Water-Quality Board, 1987; Indiana Department of Environmental Management, [1988b]). A RAP therefore, can be viewed as a technical management document to be used to coordinate and direct all concerned communities, agencies and programs toward common restoration goals, and to provide a framework for future analysis and decision making (Great Lakes Water-Quality Board, 1987; Indiana Department of Environmental Management, [1988b]).

Because the environmental problems in the AOC are complex, development and implementation of the RAP will be conducted in stages: 1) defining ecosystem problems, 2) reviewing and choosing solutions, and 3) implementing the solutions. By developing the RAP in stages, the remediation process will be organized in a way that should assure that problems will be defined and comprehensive solutions will be developed.

The stage 1 RAP defines the ecological problems in the AOC. This part of the RAP contains a description of current biological, hydrologic, and environmental conditions; in addition, it contains a description of human activities which have affected these parts of the ecosystem. It also identifies human conduct and institutional arrangements which obstruct environmental remediation in the AOC (Indiana Department of Environmental Management, 1993). The stage one RAP essentially describes environmental conditions and concerns in the AOC and sets priorities for the remediation process.

The first draft of the stage 1 RAP for the Grand Calumet River/Indiana Harbor Canal AOC was completed in 1988. The IDEM, USEPA and CAC met regularly, from March to November of 1988, to revise the RAP draft. Work resumed on revisions to the plan in 1990 with a special Citizen's Advisory for the Remediation of the Environment (CARE) Committee representing community interests in place of the defunct CAC (Holowaty and others, 1991). The stage 1 RAP was submitted to the IJC for review in early 1991.

When the stage 1 RAP was completed, some relevant studies on the extent of environmental degradation in the AOC had not been completed. Nevertheless, the stage 1 RAP was submitted for IJC review so that work could begin on stage 2 of the RAP (Indiana Department of Environmental Management, 1991). The IJC comments on the draft suggested that the stage 1 RAP would need considerable improvement, but the IJC recognized the need for additional studies to fully quantify ecological problems in the area. Therefore, as work progresses on the stage 2 RAP, periodic revisions will be made to stage 1 so that more efficient programs for implementing RAP goals can be developed (Indiana Department of Environmental Management, 1993).

The stage 2 RAP is currently being developed by the IDEM with the assistance of the USEPA. In May of 1993, the IDEM released a draft of the Water-Quality Component of the stage 2 RAP for public comment. The Water-Quality Component is only a part of the overall stage 2 process. Eventually, the stage 2 RAP will include components for habitat restoration, sediments, and land remediation (Indiana Department of Environmental Management, 1993).

The draft Water-Quality Component of the stage 2 RAP outlines strategies for restoration and protection of the water resources in the AOC. This component of the RAP defines the overall restoration goals for surface waters in the AOC, and describes general remedial activities which could assist in achieving these goals. The draft Water-Quality Component also summarizes alternate plans for remediation. The water resources considered in this component of the stage 2 RAP include nearshore Lake Michigan, the Grand Calumet River, the Indiana Harbor Canal, Wolf Lake, George Lake, interdunal wetlands and area ground waters (Indiana Department of Environmental Management, 1993).

The Water-Quality Component of the stage 2 RAP will be reviewed on a regular basis to evaluate the allocation of resources and progress being made toward restoring ecological integrity and beneficial uses in the AOC. During the review process, the stage 2 RAP will be modified if changes in environmental conditions or in regulatory practices necessitate such action. Progress reports generated from these reviews will be used to guide revisions to the programs and objectives outlined in the RAP.

The third and final stage of the RAP requires implementation of the remedial activities and programs needed for environmental restoration in the AOC. The programs outlined in the second stage will be implemented by different agencies, individuals, work groups and other RAP participants. Coordination of involved parties will be managed through the stage 3 RAP process (Indiana Department of Environmental Management, 1993). The stage 3 RAP, when developed, will seek to guarantee that the remedial measures are instituted by the appropriate authorities.

The Lakewide Management Plan

In 1987, amendments to the Great Lakes Water Quality Agreement (discussed on pages 99 and 100) required the governments of the U.S. and Canada to develop a Lakewide Management Plan (LaMP) for each of the Great Lakes. The purpose of a LaMP is to outline efforts and management practices required to reduce loadings and ambient levels of certain toxic and bioaccumulative pollutants in the Great Lakes. The LaMPs also provide a mechanism to coordinate federal, state, local and international programs relating to pollutant load reduction and water quality protection. Amendments to the Clean Water Act directing federal, state and local agencies to achieve the goals and objectives of the Great Lakes Water Quality Agreement establish legal mandate for LaMP development in the U.S. (U.S. Environmental Protection Agency, 1993b).

Because Lake Michigan is entirely within the U.S., development of the LaMP is ultimately the responsibility of the U.S. Environmental Protection Agency. Participation in the LaMP process by other federal government agencies, state governments, and private interests is facilitated through various groups and committees. The LaMP for Lake Michigan will outline technical efforts required for reducing the ambient concentrations and inputs of toxic pollutants in Lake Michigan. The ultimate goal of the LaMP is the virtual elimination of the input of persistent, bioaccumulative and toxic chemicals into the Lake environment. The LaMP also provides a summary of current knowledge regarding specific pollutants influencing the water quality of Lake Michigan (U.S. Environmental Protection Agency, 1993b; Illinois-Indiana Sea Grant, 1994).

The Indiana Department of Environmental Management participates in the LaMP development process for the state of Indiana. The IDEM plans to coordinate the Water-Quality component of the stage 2 RAP with development of the LaMP. Coordinating the development and implementation of the LaMP and RAP should facilitate meeting remediation goals and minimize any duplication of efforts (Indiana Department of Environmental Management, 1993).

In Indiana, some key activities in the development and implementation of the LaMP include: 1) identifying persistent toxic substances released from the Grand Calumet River Basin into Lake Michigan; 2) identifying specific sources of critical pollutants to the Grand Calumet and Lake Michigan ecosystems; 3) estimating the total pollutant load from the Grand Calumet River into Lake Michigan; 4) developing of pollutant load estimates and monitoring plans for individual sources; 5) identifying activities to reduce pollutant loads; 6) developing data management processes to routinely track and report pollutant load reductions (U.S. Environmental Protection Agency and Indiana Department of Environmental Management, 1992).

The Great Lakes Initiative

Federal and state agencies are presently developing a basin-wide strategy, called the Great Lakes Initiative (GLI), for protecting water quality in all of the Great Lakes. The GLI is a cooperative effort between the USEPA and the Great Lakes states to develop uniform environmental standards and practices for the entire Great Lakes Basin within the U.S. The initiative is intended to assure adequate protection of the Great Lakes ecosystem and to promote development of consistent water-quality standards for all the states in the Great Lakes Basin.

The GLI will set uniform discharge standards for the region. Prior to development of the Initiative, each Great Lakes state determined local discharge limits within its boundaries. Some states, therefore, were permitting higher discharges of certain constituents than other Great Lakes states. The Great Lakes Initiative however, will recommend revised surface-water quality standards and discharge practices for all Great Lake states (Indiana Environmental Institute, 1992; Rubin and others, 1993).

The ultimate goal of the GLI is to virtually eliminate the discharge of all toxics into the Great Lakes. The initiative proposes strict regulations on the levels of 28 toxic and *bioaccumulative* chemicals. Regulations are also proposed for "Tier II" criteria pollutants. Tier II substances are thought to be toxic, but hazards associated with them have not been fully determined or quantified (Rubin and others, 1993; Mehan and Grant, 1994).

The GLI will focus primarily on regulating and reducing point-source discharges in the Great Lakes Region. Non-point sources will partially be addressed by the 1990 Clean Air Act and new stormwater regulations. Furthermore, the USEPA is beginning work on another basin-scale strategy, the Great Lakes Toxics Reduction Initiative, which will address multi-media pollution issues in the region (Rubin and others, 1993).

The USEPA is also developing new criteria and guidelines for water quality and the discharge of pollutants into the Great Lakes. The new guidelines would require that significant increases in pollution discharges must be necessary and must support important social and economic benefits. These rules would also restrict, and possibly eliminate, the practice of establishing mixing or dilution zones in waters receiving state-permitted industrial or municipal discharges (Rubin and others, 1993).

The proposed criteria and guidelines have been published in the Federal Register (58 Federal Register 20802, 1993) under the title of Water Quality Guidance for the Great Lakes System. Committees involved with the Great Lakes Initiative developed the basis for procedures outlines in the Great Lakes Water Quality Guidance. Actual rules for the proposed Great Lakes Guidance were developed by the USEPA and the eight Great Lakes states with participation from municipalities on the Great Lakes, industry, academia, Native American tribes, and environmental groups. The proposed Guidance establishes minimum water-quality standards, antidegradation policies, and implementation procedures for waters within the Great Lakes Basin. The USEPA published the proposed Water Quality Guidance for the Great Lakes on April 16, 1993, and is currently under court order to finalize the Guidance by March 1995 (Mehan and Grant, 1994).

Trail Creek Watershed Management Plan

Trail Creek in northern LaPorte County is one of the more important *salmonid* streams in Indiana. An IDNR fish-stocking program has helped maintain this designated cold-water fishery since the early 1970's. Trail Creek is also classified by the IDEM as a recreational-use stream. Water-quality problems, however, have historically prevented Trail Creek from supporting these designated uses (Indiana Department of Environmental Management, [1988a] and [1994?]).

Efforts to improve water quality in Trail Creek began with upgrades at the Michigan City wastewater treatment plant. In 1984, the Michigan City Sanitary District received funding for design changes to reduce the amount of raw and undertreated sewage entering Trail Creek. The sanitary district plugged many CSO outlets, constructed a stormwater storage basin to eliminate combined sewer overflows, and increased the capacity of the treatment plant to reduce the frequency of bypassing (Indiana Department of Environmental Management, [1990]). However, this stream still does not support designated recreational and aquatic life uses.

In 1991, the municipality of Michigan City and the IDEM signed a Memorandum of Understanding (MOU) outlining the allocation of funds for water-pollution control in Trail Creek. Michigan City, in cooperation with the Trail Creek Improvement Program (TIP) committee, had developed a water-quality improvement plan for Trail Creek (see page 63 for a discussion of the TIP committee). This improvement plan consisted of various strategies to improve water quality, decrease sedimentation, and reduce non-point source pollution in the Trail Creek waterway. The IDEM agreed to reimburse Michigan City with funds from the USEPA for these water-quality activities.

The funds however, could not be accessed until a comprehensive watershed management plan was developed for Trail Creek. The IDEM subsequently contracted the Northwestern Indiana Regional Planning Commission to develop a watershed management plan for this stream. Community input to the plan was facilitated through the Trail Creek Watershed Management Resources Committee, a subcommittee of the TIP Committee composed of community, government, and private interests. The plan, completed in 1993, establishes four goals for the restoration of the Trail Creek watershed: 1) reduce potential health hazards due to poor water quality in the stream of Trail Creek; 2) improve conditions for aquatic life in Trail Creek; 3) increase the quantity and quality of recreational opportunities in the Trail Creek watershed in order to stimulate economic growth; 4) develop a public awareness of the unique and diverse opportunities that the stream of Trail Creek provides (Steve Davis, Indiana Department of Natural Resources, personal communication, 1993; Janellen McCoy, Northwestern Indiana Regional Planning Commission, personal communication, 1993).

One part of the Trail Creek Watershed Management Plan consists of a natural resource plan for controlling soil erosion in the Trail Creek drainage basin. The natural resource plan was developed by the Soil Conservation Service of the U.S. Department of Agriculture in cooperation with the LaPorte County Soil and Water Conservation District (SWCD). Development of this plan was sponsored by the IDEM, the NIRPC, the TIP committee, and the LaPorte County SWCD. The natural resource plan describes soil erosion on cropland, pastureland and woodland, and it develops alternative conservation plans for reducing erosion. The LaPorte County SWCD and local land owners will use the natural resource plan as a guide for future erosion-control activities (Bruce Milligan, U.S. Soil Conservation Service, personal communication, 1993).

Designated surface-water uses in Indiana

The Indiana Department of Environmental Management (IDEM) [1990] estimates that there are approximately 90,000 miles (144,000 km) of open-channel waterways in the state of Indiana. These waterways include navigable rivers, perennial streams, intermittent streams and drainage ditches. All of these waterways are considered "waters of the state" and are protected by Indiana stream pollution control laws.

The IDEM assigns one or more specific use classifi-

Table 15. Designated uses and use-support status of selected streams

{Adapted from Indiana Department of Environmental Management 1992-1993 305(b) [1994?]}

Designated surface-water uses in Indiana: Aquatic life; Recreation; Agriculture; Industrial; Public-water supply

Use support status: FS, stream is currently supporting designated use; PS, stream is partially supporting designated use; NS, stream is not supporting designated use at present.

Watercourse	Nearest town(s)	Designated use support status	Miles affected	Probable cause of impairment
Coffee Creek	Chesterton	NS (aquatic life)	2	Urban Runoff
Upper Salt Creek	Valparaiso	NS (aquatic life) NS (recreation)	4	Low D.O. Bacteria
Lower Salt Creek	Portage	NS (aquatic life) NS (recreation)	4	Low D.O. Bacteria
Upper Trail Creek and tributaries	Michigan City	NS (aquatic life) NS (recreational)	42	Bacteria, Pesticides Agricultural Runoff, PCBs
Lower Trail Creek	Michigan City	NS (aquatic life) NS (recreational)	3	Pesticides Bacteria, PCBs
Galena River and tibutaries	Heston, Lalimere	FS (aquatic life)	13	
Burns Ditch	Lake Station, Portage	NS (aquatic life) NS (recreational)	8	PCBs, Pesticides Bacteria
Little Calumet River	Porter, Chesterton	NS (aquatic life) NS (recreational)	6	Bacteria, PCBs Cyanide, Pesticides
Little Calumet River	Hammond	NS (aquatic life) NS (recreational)	10	Bacteria, PCBs Cyanide, Pesticides
Indiana Harbor Canal	Whiting, E. Chicago	NS (aquatic life) NS (recreational)	4	Bacteria PCBs, Pesticides Mercury Low D.O.
E. Branch, Grand Calumet River	Gary, E. Chicago	NS (aquatic life) NS (recreational)	10	Bacteria Oil and grease PCBs, Pesticides Cyanide Lead
W. Branch, Grand Calumet River	Hammond, E. Chicago	NS (aquatic life) NS (recreation)	3	Bacteria Low D.O. PCBs, Pesticides Lead Ammonia CSO, cyanide
Plum Creek	Dyer	FS (aquatic life)	4	
Hart Ditch	Munster, Highland	FS (aquatic life)	2	
Beaver Dam Ditch	Crown Point	NS (aquatic life)	7	Poor Habitat Low D.O.
Deep River	Hobart	NS (aquatic life)	4	Runoff, POTW Poor Habitat
Deep River	Lake Station	NS (aquatic life)	4	Sewage

cations to the streams of the state. The use classifications reflect the benefits that can be derived from the stream by people and wildlife. The types of designated stream uses in Indiana include: aquatic life, recreation, agriculture, industrial, and public-water supply. Of the total estimated 90,000 miles (144,000 km) of waterways in the state, the Indiana Department of Environmental Management [1994?] estimates that approximately 21,000 miles (33,800 km) can reasonably be expected to support designated uses. The watercourses that support designated uses consist of permanently flowing rivers and some intermittent streams that have adequate depth and duration of flow.

In a recent evaluation of the Lake Michigan Region, the IDEM assessed approximately 210 stream miles for aquatic life use and 102 stream miles for recreational use (Indiana Department of Environmental Management, [1994?]). Some of the streams in the Region are listed in table 15, along with designated uses, support status, probable causes of impairment, and miles affected. Many streams in the Region, particularly those in urban areas, cannot fulfill designated uses because of the adverse effects of pollution.

Water quality standards

Water-quality standards are legally established limits for various physical, chemical, or biological parameters that may affect use, safety, or aesthetics of water resources. Federal and state agencies establish numerical and/or narrative standards that may be used as one criterion for assessing water quality. This report compares levels of selected constituents measured in streams and lakes in the Region with state and federal water-quality standards.

In Indiana, water quality standards are promulgated under Rule 1, Article 2, Title 327 of the Administrative

Table 16. Surface water standards in Indiana

All surface water resources in the state of Indiana are protected by water-quality standards established in subsection (a) of 327 IAC 2-1-6 (1992). These standards essentially state that acutely or chronically toxic chemicals and noxious substances must not be present in surface-waters at levels that will have detrimental effects on water quality.

Additional aspects of this law define standards that are preferentially applied to surface-water bodies on the basis of use. These additional standards are enforced to help assure that Indiana's surface-water resources can fulfill designated uses for humans and wildlife. Standards for protecting surface-water uses are generally specified for particular parameters which can limit or prevent the potential use of surface-water resources. For example, limits on Escherichia coli (E. coli) bacteria are enforced to protect people from disease caused by possible sewage contamination. Streams or lakes which violate E. coli standards would probably not be considered safe for body-contact recreation or water supply. A listing of fundamental surface-water uses and their corresponding water quality standards are outlined in the table below.

Designated stream-use	Specific standards defined under 327 IAC 2-1-6 (1992)
Recreational (full body contact)	E. coli may not exceed 125/100 ml as a geometric mean of 5 or more samples equally spaced over 30 days, nor exceed 235/100 ml in any single sample over a thirty day period.
Public Supply[1]	Coliform bacteria cannot exceed 5000/100 ml as a monthly average nor exceed 5000/100 ml and 20,000/100 ml in more than 20 and 5 percent, respectively, of all monthly samples. E. coli limits are the same as those established for recreational use streams. Concentrations of either sulfates or chlorides must not exceed 250 mg/L. Radiation levels due to radium-226 and strontium-90 must not exceed 3.0 pCi/L and 10.0 pCi/L, respectively (in the known absence of strontium-90 and other alpha emitters, beta particle activity of up to 1000 pCi/L is acceptable)
Industrial Supply[2]	Total dissolved solids cannot exceed 750 mg/L (subsection (f) specifies that a specific conductance of 1,200 µmhos/cm at 25°C can be considered equivalent to a TDS of 750 mg/L).
Agricultural use	Waters must meet all requirements specified in 327 IAC 2-1-6(a) (the minimum water-quality standards).
Aquatic life[3]	Allowable pH range of 6.0 - 9.0. Dissolved oxygen level must average at least 5.0 mg/L daily, without being lower than 4.0 mg/L at any time. Maximum temperature increase due to anthropogenic activity may not exceed 5.0°F (2.8°C) in streams or 3.0°F (1.7°C) in lakes and reservoirs. No substances which impart unpalatable flavor to fish or offensive odor may be discharged into designated aquatic life streams.

Table 16. Surface water standards in Indiana – Continued

Designated stream-use	Specific standards defined under 327 IAC 2-1-6 (1992)
Salmonid streams[3]	6.0 mg/L minimum dissolved oxygen level (7.0 mg/L in spawning areas during spawning season). Any temperature increases due to anthropogenic activity can not exceed 2°F (1.1°C). Maximum water temperature must not exceed 65°F (18.3°C) during spawning season, 70°F (21.1°C) during the rest of the year. The same limits on pH and the discharge of noxious substances specified for aquatic-life designated streams also apply to cold water fish streams. Designated salmonid streams in the Lake Michigan Region include Trail Creek and its tributaries, the Galena River and its tributaries, the East Fork of the Little Calumet River and its tributaries, and Kintzele Ditch downstream from Beverly Drive in Porter County.
Limited use streams	In addition to standards established in subsection (a), limited use streams must meet the standards established for recreational and industrial uses. Aerobic conditions must prevail at all times.
Exceptional use streams	Unless standards are specified on a case-by-case basis, the quality of waters designated for exceptional use shall be maintained without degradation.
Lake Michigan	The following criteria outlined in subsections (j) and (k) of 327 IAC 2-1-6 apply to all waters in the Indiana portion of Lake Michigan: minimum dissolved oxygen = 7.0 mg/L pH between 7.5 and 8.5 No human-induced temperature changes that will have adverse affects on aquatic organisms or the propagation of the aquatic community. Maximum permissible values on the following chemical constituents chlorides: 15 mg/L monthly average, 20 mg/L daily maximum phenols: 0.001 mg/L monthly average, 0.003 mg/L daily maximum sulfates: 26 mg/L monthly average, 50 mg/L daily maximum total phosphorus: 0.03 mg/L monthly average, 0.04 mg/L daily maximum TDS: 172 mg/L monthly average, 200 mg/L daily maximum fluorides: 1.0 mg/L daily maximum iron: 0.3 mg/L daily maximum

1 Standards apply at the point where water is withdrawn for treatment. Water distributed for public supply must also meet drinking water standards defined in 327 IAC 8-2.
2 Standards apply at the point where water is withdrawn for use.
3 Standards on excessive (above 9) pH do not apply when daily high pH values are correlated with photosynthetic activity by plants.

Code (327 IAC 2-1). Applicability of the standards depends on the presence of an in-stream mixing zone for effluent dilution, which may or may not be allocated to a discharger. The rule defines the minimum water-quality standards which apply to all waters of the state at all times, including waters in the mixing zones. Minimum standards essentially require that waters of the state be free of substances from anthropogenic sources that can have detrimental effects on water quality. Specifically, the rule extends this restriction to substances 1) that can have adverse effects on the aesthetic aspects of a water body; 2) that are in amounts sufficient to be acutely toxic to humans, aquatic life, plants or animals. The numeric criterion used to define acute toxicity for minimum water-quality protection is the *acute aquatic criterion* (AAC). The statutes also specify that all waters in the state outside the mixing zones must not contain substances at levels that can be chronically toxic, *carcinogenic*, *mutagenic* or *teratogenic* to humans, animals, plants or aquatic life. Indiana water-quality statutes define standards, such as the chronic aquatic criterion (CAC) to protect organisms from chronic toxicity. Other standards outlined in the rule are established for specific water-quality parameters and stream-use situations (table 16). The regulations also specify that when a stream is designated for more than one use, the most protective standards apply.

Water-quality standards are reviewed and revised in order to accommodate new environmental and public-health concerns, or when new data indicates the allowable level of a specific contaminant should be changed. It is thus, possible for the use-support status of a stream or lake to change even though water quality remains constant, because revisions are made in the water-quality standards. In the following section, the quality of major streams in the Region is evaluated relative to 1992 state water-quality standards. This evaluation will help illustrate progress toward contemporary wa-

Table 17. IDEM water-quality monitoring stations in the Lake Michigan Region

{Compiled from Indiana Water Quality Monitoring Station Records- Rivers and Streams, Indiana State Board of Health/Indiana Department of Environmental Management, and personal communication IDEM staff (1957-present).}

Location: Site locations are shown in figure 41.

Water Quality: Measurements of specific parameters vary with location and time during periods of record; samples collected monthly.

Plankton/algae: Samples collected monthly.

Toxics: Samples taken quarterly; measurements of specific parameters vary with location and time.

Location	IDEM code	Water Quality	Plankton/algae	Toxic compounds
Grand Calumet River				
Hohman Av bridge, Hammond	GCR 34	1958-	1959-63, 1966-72	1988-
Indianapolis Blvd, E. Chicago	GCR 36	1964-67		
Kennedy Av bridge, E Chicago	GCR 37	1964-67, 1981-		1989-
U.S. 12, Gary	GCR 41	1964-85		
Bridge St bridge, Gary	GCR 42	1986-		1989-
Indiana Harbor Canal				
Mouth of Ind. Harbor Canal	IHC 0	1973-76, 1978-	1976, 1978-79	
Dicky Road bridge, E Chicago[1]	IHC 2	1964-90	1977	1989-90
Columbus Dr, E Chicago	IHC 3S	1964-		
Indianapolis Blvd, E Chicago	IHC 3W	1964-		
Little Calumet River				
Hohman Av, Hammond	LCR 13	1958-	1959-63, 1966-72	
Bridge on State Route 149	LCR 39	1971-	1973-75	
Burns Ditch				
Near mouth of Burns Ditch	BD 0	1964-84	1974-79	
Midwest Steel truck bridge	BD 1	1966-	1971-73	1989-
Bridge on State Highway 249	BD 2E	1966-		
Portage Boat Yard dock	BD 3W	1966-		
Trail Creek				
Franklin St, Michigan City[2]	TC 0.5	1973-		
U.S. 12, Michigan City	TC 1	1969-72, 1977-	1969-72	1989-
Walker St, Michigan City	TC 1.3	1973-76		
Krueger Park, Michigan City	TC 2	1986-		
Salt Creek				
U.S. 20, Portage	SLC 1	1986-		
U.S. 6 near Valparaiso	SLC 7	1971-72		
S.R. 130 bridge, Valparaiso[3]	SLC 17	1973-		1989-

Table 17. IDEM water-quality monitoring stations in the Lake Michigan Region – Continued

Location	IDEM code	Water Quality	Plankton/algae	Toxic compounds
Lake Michigan				
East Chicago intake crib	LM EC	1969-	1971-90	
Gary intake crib	LM G	1969-	1971-90	
Hammond intake crib	LM H	1969-	1971-90	
Michigan City intake crib	LM M	1957-	1979-90	
Whiting intake crib	LM W	1957-	1979-90	1989-
Wolf Lake				
129th St culvert, Hammond	WL SL	1966-	1971-75	1988-

[1] Previously designated IHC 1 (1964-1985)
[2] Previously designated TC 0.3 (1973-1985)
[3] Previously designated SLC 12 (1973-1985)

ter-quality goals, but may not necessarily reflect a stream's past use-support status.

In addition to a comparison to state water-quality standards, levels of specific parameters in Lake Michigan Region streams are also compared to certain drinking water standards and guidelines. The federal criteria used for comparison in this section include the maximum contaminant level (MCL) and the secondary maximum contaminant level (SMCL). The MCLs are legally established limits for the concentrations of specific constituents to protect human health. The maximum contaminant levels are enforced for finished water that is treated and distributed specifically for public supply. The SMCLs are recommended, non-enforceable standards established to protect aesthetic properties of drinking water, such as taste and odor. Although the streams in the Region are not sources for public water supply, water quality in these streams may be compared to federal drinking-water guidelines for descriptive purposes. The established MCLs and SMCLs for certain inorganic ions are listed in appendix 6.

Water-quality monitoring and data collection

Long-term monitoring of water quality in Indiana was initially the responsibility of the Indiana State Board of Health (ISBH - now Indiana State Department of Health). In 1957, the ISBH began collecting and analyzing surface-water samples from a network of 49 stations located along streams throughout the state. The ISBH maintained and expanded the system until 1986, when the Office of Water Management of the Indiana Department of Environmental Management (IDEM) assumed responsibility for the stream monitoring network. The IDEM-managed system presently consists of over 100 water-quality monitoring stations located throughout the state.

Near-surface *grab samples* are collected on a monthly or quarterly basis at most IDEM monitoring stations. The grab samples are analyzed in the field and laboratory to quantify the values of numerous water-quality parameters. The data obtained in the process are used to detect changes in surface-water quality, evaluate pollution-abatement strategies, estimate background levels of various chemical constituents, determine if a stream can meet designated uses, and help document compliance with state and federal pollution-control mandates.

At present, the IDEM collects samples at 22 active monitoring stations in the Lake Michigan Region (figure 41 and table 17). Five of the active stations sample water from Lake Michigan through municipal-supply intakes. One station monitors water quality in the Indiana portion of Wolf Lake. The remaining 16 active monitoring stations are located along various rivers, creeks and drainage ditches in the Region. Water-quality information from six discontinued Region stations is also on record with the State.

Stream-water samples are analyzed for a variety of physical parameters, chemical constituents, and biological-quality indicators. Levels of total suspended solids (TSS), *biochemical oxygen demand* (BOD),

Table 18. Stream-quality monitoring stations with radiation measurements

{Compiled from Indiana Water Quality Monitoring Station Records-Rivers and Streams, Indiana State Board of Health/Indiana Department of Environmental Management (1957-1985).}

Location: Site locations are shown in figure 41.

Period of Record: Samples analyzed monthly until 1978. After 1978, three consecutive monthly samples were combined and analyzed as a quarterly sample.

Location	IDEM code	Period of Record
Lake Michigan		
East Chicago intake crib	LM EC	1973-85
Gary intake crib	LM G	1973-85
Hammond intake crib	LM H	1972-85
Michigan City intake crib	LM M	1957-85
Whiting intake crib	LM W	1957-85
Tributaries to Lake Michigan		
Near mouth of Burns Ditch	BD 0	1973-84
Mouth of Ind. Harbor Canal	IHC 0	1973-76, 1978-85
Dickey Road bridge, E. Chicago[1]	IHC 2	1972-73, 1976-77
Trail Creek[2]	TC 0.5	1981

[1] Previously designated IHC 1 (1964-1985)
[2] Previously designated TC 0.3 (1973-1985)

dissolved oxygen (DO), ammonia, bacteria and certain inorganic ions are determined for samples from most of the active monitoring stations in the Region. Many samples are also analyzed for certain toxic substances such as arsenic, cyanide, phenols and heavy metals.

The IDEM also tests stream waters for the presence of certain toxic organic compounds. Quarterly, water samples from some stations are analyzed for detectable concentrations of organic compounds including *polychlorinated biphenyls* (PCBs), pesticides, herbicides, *volatile organic compounds* (VOCs) and benzene-based compounds. At present, quarterly water samples from eight of the monitoring stations in the Lake Michigan Region are analyzed for toxic organic compounds (table 17).

Samples of fish tissue and streambed sediment are also analyzed by the IDEM for potential contamination by PCBs, heavy metals and pesticides. In the Lake Michigan Region, fish and sediment samples from the Grand Calumet River, Trail Creek, Burns Ditch, the Indiana Harbor Canal, the Lake George Canal, and the Marquette Park Lagoons have been tested for potential contamination. The results of these analyses were utilized in the development of IDEM fish advisories for the Region (see page 127).

Plankton data of Lake Michigan Region waters were collected monthly at certain monitoring stations from 1959 until 1990 (see figure 41 and table 17). Algae can clog filters and cause taste and odor problems. The reported data consists of the relative proportions of blue-green algae, green algae and *diatoms* detected in a 125 ml sample.

Regular measurements of radiation levels in water samples were made by the ISBH at select monitoring stations in the Lake Michigan Region (table 18 and figure 41). Radiation quality is expressed as measured alpha particle and beta particle activities in both the suspended sediment load and dissolved solids load of a sample. Monthly data collection began in 1957 and continued until quarterly sampling was initiated in 1978. Regular measurement of radiation levels in samples from the monitoring network ended after 1985.

The U.S. Geological Survey (USGS) has collected water-quality data from numerous streams during its research and resource-evaluation efforts in the Region. Water samples were collected by the USGS at three gaging stations on the Little Calumet River, Trail Creek and the Galena River. Additional data for the Little Calumet River were collected at a USGS-oper-

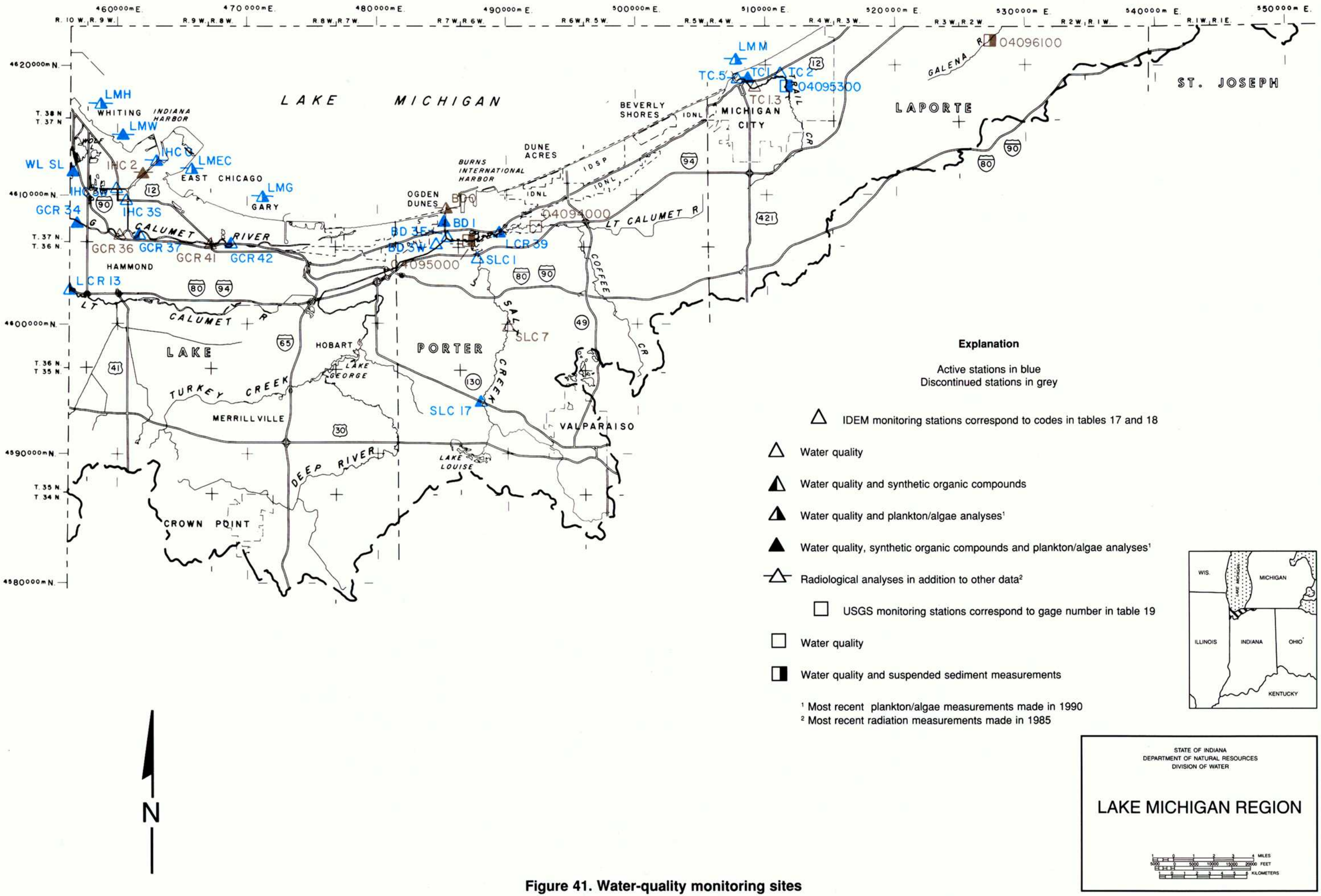


Figure 41. Water-quality monitoring sites

ated national stream quality accounting network (NASQAN) station (figure 41 and table 19). Water samples from these stations were used to determine the concentrations of various chemical constituents and total suspended sediment loads.

In October of 1984, the USGS conducted a diel (24-hour) survey of stream flow and water quality in the Grand Calumet River. Water samples were collected and flow measurements were taken at 11 stations along the Grand Calumet River and at 23 wastewater outfalls discharging into the river. Samples were analyzed for a variety of water-quality parameters, including dissolved oxygen. The water-quality and flow data obtained in the study were used to calculate chemical loads from known sources and to estimate the contribution of non-point sources to the total pollutant load in the Grand Calumet River. The results of the study are published as a USGS water-resource investigation report (86-4208) listed under Crawford and Wangsness (1987) in the **Selected References** section of this report.

The USGS has also collected data at partial-record and temporary monitoring stations along streams in and around the Indiana Dunes State Park and National Lakeshore. Data collected from these stations include ion concentrations and nutrient levels in stream samples and trace-element and synthetic hydrocarbon levels in sediments. Streams in the Indiana Dunes State Park/ National Lakeshore sampled by the USGS include the Little Calumet River, Kintzele Ditch, Dunes Creek, Derby Ditch, Markowitz Ditch, and Striebel Arm. The data have been used in USGS water-resource investigation reports prepared by Arihood(1975) and Hardy (1984).

Additional sampling efforts have been recently undertaken by the National Biological Survey on three small streams in the Region. During part of 1993 and 1994, a total of 21 sites have been sampled monthly on Dunes Creek, Derby Ditch, and Kintzele Ditch. Water quality, diatoms, and macroinvertebrates have been sampled. Mapping of land use and wetland plant distribution and abundance has also occurred. In addition to the monthly sampling on the small streams, sampling for E. coli has also been undertaken during storm events for Deep River, Salt Creek, East and West Branches of the Little Calumet River, and Burns Ditch.

In February and May of 1977, the Michiana Area Council of Governments (MACOG) conducted sampling on Trail Creek and the Galena River to quantify levels of dissolved oxygen, suspended solids, BOD, ammonia and phosphate. Their results were used to describe quality conditions in these streams, and were included in a water-quality assessment report for LaPorte, Saint Joseph, Elkhart and Marshall Counties

Table 19. Stream-quality data from USGS gaging stations

{Compiled from Water Resources Data, Indiana (1978-80), U.S. Geological Survey, and personal communication, David Cohen, U.S. Geological Survey, Water Resources Division, Indianapolis.}

Location: Site locations are shown in figure 41.

Water quality: Measurements of specific parameters vary with location and time.

USGS river gage location	Gage number	Water Quality	Suspended sediments
Little Calumet River 200 ft. upstream from bridge on U.S. Hwy 20, Porter Ind.[1]	04094000	1973-80	NA
Little Calumet River at Samuelson Rd near McCool, Porter County[2]	04095000	1978-80	1979-80
Trail Creek downstream from bridge on Springland Av, Michigan City[1]	04095300	1977-81, 1990-93	1979-93
Galena River downstream from bridge on County Rd 125 E. LaPorte County[1]	04096100	1977-80	1979-80

[1] Site of USGS river-gaging station. See table 11 for period of flow records.
[2] Site of USGS national stream-quality accounting network (NASQAN) station.
NA = Not applicable - data not collected at this site.

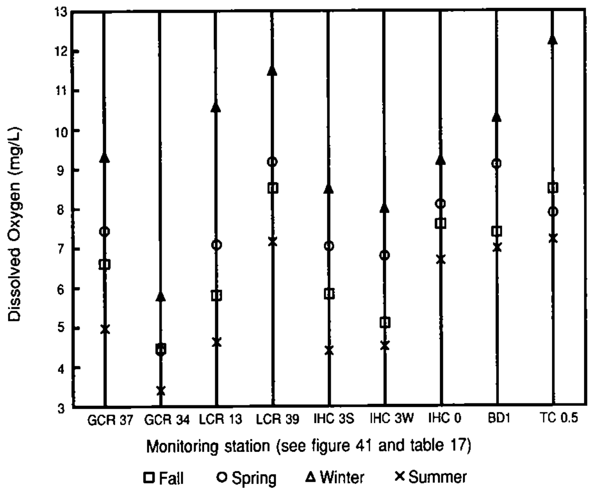


Figure 42. Seasonal median dissolved oxygen at selected stations

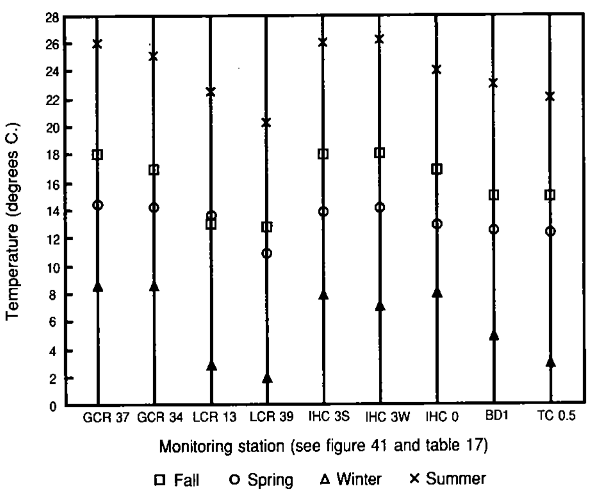


Figure 43. Seasonal median temperature at selected stations

(Michiana Area Council of Governments, 1978a).

Water quality in the Trail Creek watershed is also monitored through a cooperative effort between the LaPorte County Health Department and the Michigan City Sanitary District. The primary goal of the monitoring effort is to assess the effects of improved land-management practices on water quality in the stream of Trail Creek (Northwestern Indiana Regional Planning Commission, 1993).

Stream quality

Sources of data for analysis

Data from selected IDEM monitoring stations were used to analyze the water quality of streams in the Lake Michigan Region. Data were analyzed from monitoring stations along the Grand Calumet River (GCR 34 and GCR 37), the Little Calumet River (LCR 13 and LCR 39), the Indiana Harbor Canal (IHC 0, IHC 3S, and IHC 3W), Trail Creek (TC 0.5) and Burns Ditch (BD1).

The water-quality analyses in this section focuses on the major drainage systems in the Region, such as the Grand Calumet River, Little Calumet River, Indiana Harbor Canal, and Trail Creek. A general lack of adequate data for headwater streams in the Lake Michigan Region (figure 41) precluded a meaningful analysis of the smaller streams. Ground water is, however, the primary source of water for most head-water areas in the Region; and a comprehensive discussion of ground-water quality is presented in the **Ground-Water Quality** section of this report.

The data used for this report were collected at the above monitoring stations over a ten-year period (1982-1992 at stations LCR 39 and TC 0.5; 1983-1993 at all other selected stations). The water quality parameters examined consist of dissolved oxygen (DO), pH, *specific conductance* at 25°C, hardness, chloride, and total iron. Analysis of some water-quality parameters was not possible at certain stations because of insufficient or unavailable data.

Seasonal variations in water quality

The median values of the dissolved oxygen and specific conductance data collected during each climatic season (winter, spring, summer and fall) were compared to discern possible seasonal trends in water quality. Dissolved oxygen and specific conductance were examined for temporal trends because seasonal variations are often observed in these parameters, and specific limits for their levels have been established for certain stream-uses (table 16). Possible seasonal variations in DO concentrations and specific conductance levels could, therefore, be a factor in stream-quality assessment.

At all of the monitoring stations examined, the highest seasonal median dissolved oxygen levels are

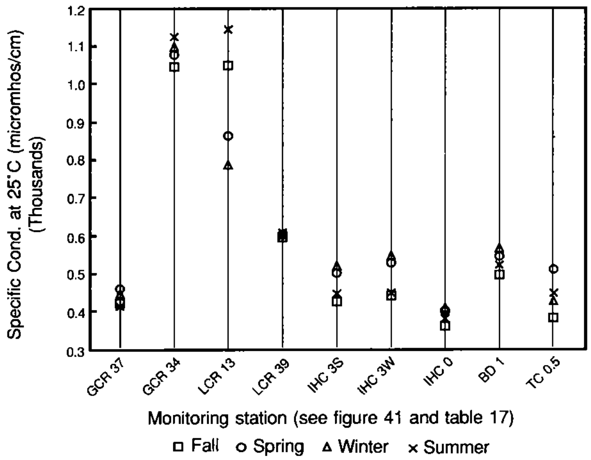


Figure 44. Seasonal median specific conductance at selected stations

observed during winter and the lowest levels occur during summer (figure 42). Because the largest contrasts in median water temperature (figure 43) are also observed between winter and summer, this trend in DO levels probably reflects changes in oxygen solubility due to seasonal variations in average water temperature. At most of the monitoring stations examined, higher median DO concentration and lower median temperatures occur during spring than during fall. This pattern, however, is not observed at certain monitoring stations (TC 0.5, GCR 34 and LCR 13). Discrepancies in the expected seasonal trends in DO concentrations may reflect other factors (see box on page 116) which influence the dissolved oxygen content of streams.

Graphs of median specific conductance in water samples from the selected monitoring stations are displayed in figure 44. The largest differences in seasonal specific conductance levels are detected in water samples from the West Branch of the Little Calumet River (monitoring station LCR 13). The median specific conductance value for samples collected during summer exceeds the median value in winter samples by approximately 350 µmhos/cm (at 25°C) at this station. In contrast, median specific conductance levels in water samples from the East Branch of the Grand Calumet River (monitoring station LCR 39) appear to be very consistent throughout the year.

Seasonal differences in specific conductance in the water samples from the other stations (GCR 34, GCR 37, IHC 0, BD 1, TC 0.5) may not be very significant (figure 44). It is possible however, that some of the annual variability in the specific conductance levels of these streams relates to seasonal influences.

Spatial variations in water quality

Box plots are a graphical device used to display the median and percentile ranges of a data set. These graphs are generally used to provide a concise visual summary of a single set of data and for comparison among different data sets. Box plots for water-quality data from the selected monitoring stations are displayed in figure 45.

Variability in the levels of dissolved oxygen are observed among different streams in the Lake Michigan Region (figure 45 and appendix 7). The highest median dissolved oxygen concentration (8.9 mg/L) is observed in water samples from the East Branch of the Little Calumet River (monitoring station LCR 39). Median dissolved oxygen levels are also relatively high (above 8.0 mg/L) in samples collected from Burns Ditch (monitoring station BD 1) and near the mouth of Trail Creek (TC 0.5). The lowest median DO level is observed in samples from the West Branch of the Grand Calumet River (monitoring station GCR 34).

In addition to variability among streams, differences in median DO levels are observed at different locations along a single stream. Lower median DO levels are observed in samples from the West Branch of the Grand Calumet River relative to samples from the East Branch (monitoring station GCR 37). A similar pattern is observed between the East and West Branches of the Little Calumet River, where median DO levels are lower in samples from the West Branch of the Little Calumet River compared to samples from the East Branch of this river. Apparent differences in median DO levels are also detected among water samples from the different monitoring stations along the Indiana Harbor Canal (figure 45 and appendix 7).

Box plots of specific conductance levels in water samples from the selected monitoring stations are displayed in figure 45. The highest median specific conductance levels are observed in samples from the West Branches of the Grand Calumet River and the Little Calumet River. Differences in median specific conductance levels among and within streams may relate to factors which affect the dissolved solute concentrations in surface waters. Some such factors include local variations in the abundance of soluble

Factors affecting surface-water quality

The efficient management of water resources requires knowledge of the naturally-occurring and human-induced processes that can influence the chemistry and quality of surface waters. Surface-water quality is influenced by numerous physical, chemical and biological factors which generally vary in time and with location. Describing the effects of these factors and variations in their influence is critical for developing strategies to protect water quality while permitting reasonable levels of water use (Hem, 1993).

Many of the current efforts to protect surface-water resources emphasize controlling degradation associated with industry, agriculture, municipal waste disposal, flow diversions and other *anthropogenic* activities. Pollutants and waste products from these and other sources can enter surface-water systems through inadequately treated wastewater discharges, runoff, soil erosion, atmospheric deposition, chemical spills, and combined sewer overflows. Human activities that alter the flow characteristics or physical state of a stream, such as dam building, dredging or channelization may affect both water chemistry and sediment transport. Surface-water quality can also be influenced by irrigation and ground-water pumping (Hem, 1993).

Any possible effects human activities have on water quality depends on the types and volumes of pollutants released, and the extent of dilution that occurs in the receiving surface-water body. Adverse affects from human activities can also be minimized by proper wastewater treatment, adequate solid-waste disposal, erosion control, and other pollution control practices. Municipalities, industry, and other water users are required to protect the quality of surface-water resources they utilize. In many cases, their specific obligations are defined in federal, state and local regulations. The effects of anthropogenic activities on water quality will also be modified by the hydrologic and chemical conditions of the receiving surface-water system.

Surface-water quality is also influenced by various natural factors in the environment. The natural factors that affect water quality can be considered, in general, the various physical, chemical and biological aspects of a watershed. Examples of these factors include climate, geology, soil type, vegetation and stream ecology. Natural influences on water-quality must be quantified to accurately describe variations in water quality, and to discern possible human-induced effects on water resources.

In many temperate areas, variations in water quality over time can be correlated with seasonal changes in the prevailing meteorological conditions. Both the temperature and the volume of precipitation influence weathering of rocks. Alternating wet and dry seasons may thus promote seasonal variability in weathering reactions which produce soluble minerals. This variability in weathering may result in seasonal differences in the volume and types of ions transported into surface waters by *direct runoff*, creating seasonal variations in solute chemistry.

Seasonal trends in the concentrations of certain anthropogenic chemicals are sometimes observed in the surface waters. Such trends are most commonly associated with chemicals used over wide areas of agricultural or urbanized watersheds and during certain months of the year. Such chemicals can be transported to streams by runoff after precipitation or snow-melting events. Examples of anthropogenic chemicals which could reach seasonal high levels in surface water include deicing salts for roads, nitrogen-based fertilizers, and pesticides.

Water temperature can be a particularly important parameter in water-quality studies. Many aquatic organisms can survive and function only within a particular range of water temperatures. These organisms may die, fail to reproduce, or suffer other adverse effects if the appropriate temperature range is exceeded.

minerals, differences in stream discharge, differences in the volume of base flow, and anthropogenic sources of dissolved constituents.

Box plots of hardness levels in samples from the selected monitoring stations are displayed in figure 45. Median hardness levels range from approximately 160 mg/L ($CaCO_3$ equivalent) in samples from the mouth of the Indiana Harbor Canal to 380 mg/L ($CaCO_3$ equivalent) in water samples from the West Branch of the Little Calumet River. This range of hardness values would classify the waters from the select monitoring stations as "hard" to "very hard" in the hardness classification scale (see page 166 of this report) of Durfor and Becker (1964).

Hardness can be an important factor in surface-water quality because the minimum water-quality criterion for certain metals are functions of hardness. Applicable criteria outlined in the Indiana minimum water-quality requirements (327 IAC 2-1-6) include the *acute aquatic criterion* (AAC) and the *chronic aquatic criterion* (CAC). The present AACs and CACs for cadmium, chromium(+3), copper, lead, nickel, silver and zinc are not defined as whole-number limits, but rather as exponential functions of hardness. It is thus, possible that different CACs and AACs may apply to different streams, or along different segments of the same stream, because of variations in hardness.

Chloride levels appear to be higher in the West Branch of the Grand Calumet River than in the other streams analyzed (figure 45 and appendix 7). The median chloride concentration in samples from the Grand Calumet River equals 165 mg/L. In contrast, median chloride levels do not exceed 50 mg/L in samples from the other selected monitoring stations. Chloride statistics were not calculated for the data sets from the East and West Branches of the Little Calumet River because relatively few chloride measurements were available from these stations for the period of study.

Violations of applicable standards for chloride were only observed in the samples from the West Branch of the Grand Calumet River. A total of eight samples collected over the 1983-1993 period had chloride levels above the current critical aquatic-life criterion of

The effect of most concern however, is probably the inverse relation between water temperature and dissolved oxygen (DO) levels. Most gases, including oxygen, become less soluble in water as temperature increases. It is therefore, possible to detect the lowest average DO levels of the year during summer and early fall when ambient water temperatures reach yearly high levels. Localized increases in water temperature and decreases in DO levels can also occur if effluents are discharged at much higher temperatures than water in the receiving stream.

Geologic conditions in a drainage basin can be a significant control on the solute chemistry of surface waters. The types and concentrations of dissolved ions in most waters is influenced by the chemical composition of minerals in contact with the water body. Soluble minerals in bedrock, soil or weathered geologic material may be the principal source of dissolved inorganic ions in unpolluted streams and lakes. Water quality will also be influenced by a variety of other geologic factors including the purity, solubility and crystal size of the minerals; rock texture and porosity; regional structure; and the presence or absence of fissures (Hem, 1985).

The aquatic biota, which consists of all plants, animals and microorganisms inhabiting a stream or lake, can be a significant influence on the chemistry of surface waters. Biological influences on water quality can result from the metabolic processes performed by organisms to maintain life functions and reproduction. These metabolic processes often influence the rates of chemical reactions, An example of reaction influenced by organisms in the aquatic environment is the oxidation of organic matter. Certain microorganisms obtain metabolic energy from organic matter through cellular reactions involving oxygen. This organism-mediated process can promote rapid decomposition of organic matter in the aquatic environment, and may have significant effects on the dissolved oxygen levels of surface waters.

Aquatic organisms also remove and redistribute certain constituents from the aquatic environment. Some constituents removed by organisms are essential nutrients required to maintain metabolic functions and physical growth. Examples of such nutrients include iron, phosphorous and nitrogen. Other constituents, such as calcium and silica, are extracted from the aquatic environment by certain organism for the development of shells and skeletons. Absorption by aquatic organisms may be a significant influence, and possibly the controlling factor, on the concentration of certain ions in unpolluted waters (Hem, 1985).

Photosynthesis by algae and aquatic plants often has discernible influence on the chemistry of surface waters. During photosynthesis by aquatic plants, dissolved carbon dioxide is removed from the water column. The removal of this gas can result in a noticeable increase in the pH of water in a lake or stream. Oxygen is a by-product of the photosynthesis process, and increases in dissolved oxygen levels may result from photosynthetic activity. Because photosynthesis requires sunlight, plants can only conduct this process during daylight hours. In some streams, this daily variation in photosynthetic activity results in discernible twenty-four hour cycles in pH and dissolved oxygen concentrations (Hem, 1985).

The types and numbers of aquatic plants and animals must also be considered in water-quality assessments because the mere presence of certain organisms can seriously limit the utility of a lake or stream. The presence of disease-causing bacteria, parasites or viruses can make a surface-water body unsafe for swimming, fishing, or use as a water supply. Algae and aquatic plants are normally vital parts of the aquatic ecosystem; however, excessive growth of these organisms due to *eutrophication* can cause serious water-quality problems. Severe problems can also result when non-indigenous species of plants and animals are introduced into a surface-water system. A discussion of some non-indigenous species in Lake Michigan is presented in the box entitled **Recently introduced aquatic species in the Great Lakes**.

230 mg/L. Furthermore, the chloride levels in three of the samples in violation of the CAC were high enough to also exceed the SMCL for chloride (250 mg/L).

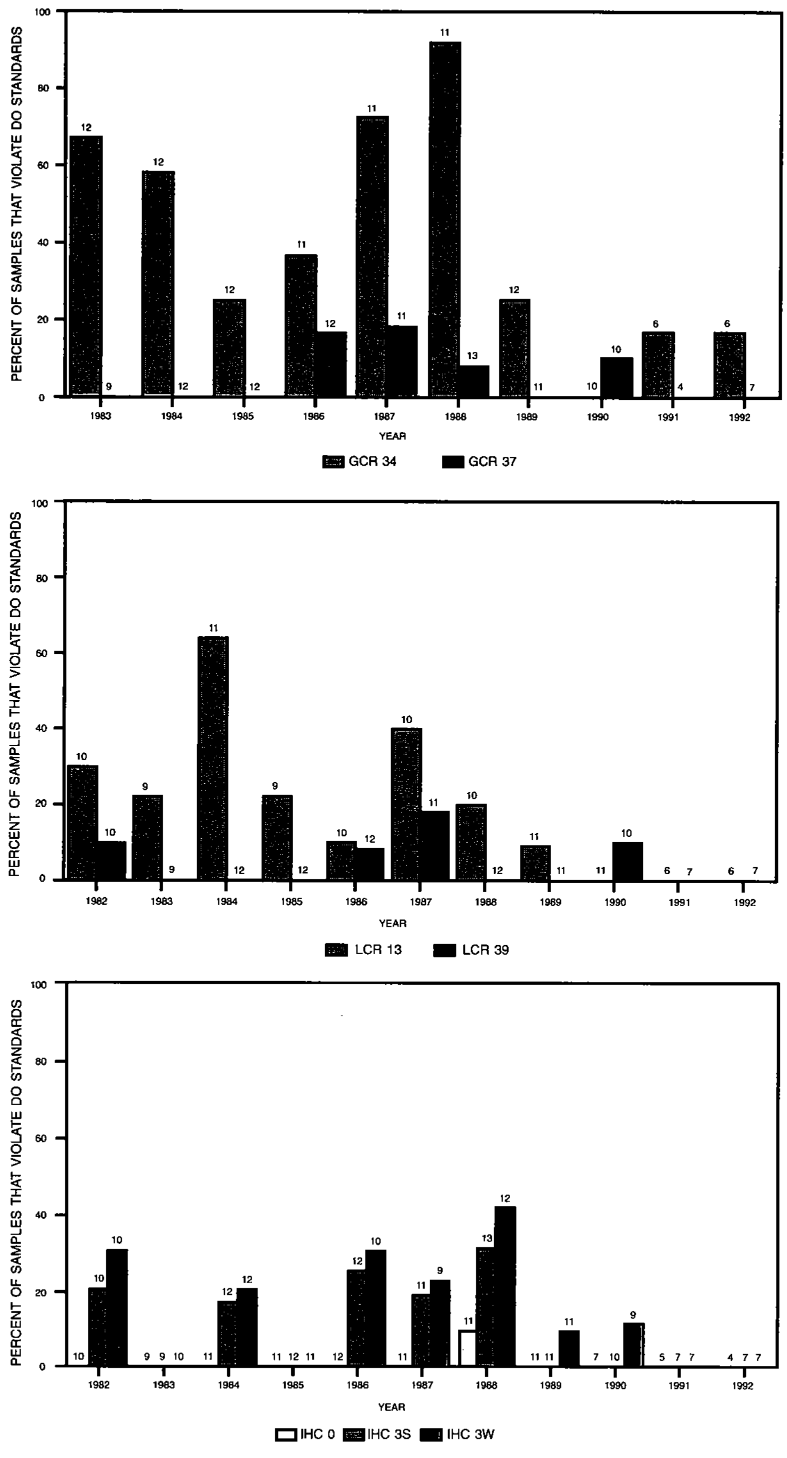
The box plots for total iron in samples from the selected monitoring are displayed in figure 45. Median total iron levels are the highest in samples from the East Branch of the Grand Calumet River and the South Branch of the Indiana Harbor Canal. Most samples from the selected streams contain iron levels that exceed the 0.3 mg/L secondary maximum contaminant level (SMCL). Specifically, iron concentrations above the SMCL are observed in 75 to almost 100 percent of samples, depending on the monitoring station under consideration.

Additional aspects of stream quality

Dissolved oxygen

Dissolved oxygen (DO) is the term used to express the quantity of oxygen gas dissolved in a unit volume of water. In most surface-water systems, the principal source of dissolved oxygen is the diffusion of atmospheric oxygen across the water surface. However, the equilibrium concentration of dissolved oxygen is also influenced by temperature, atmospheric pressure, photosynthesis by aquatic plants, and the concentration of dissolved solutes (Hem, 1985). Fish and other gill-breathing animals can only utilize oxygen dissolved in water for their respiration, thus dissolved oxygen is generally considered a fundamental surface-water quality indicator.

Dissolved oxygen concentrations can be affected by the levels of oxidizable organic matter in a lake or stream. In the aquatic environment the decay of organic matter is often facilitated by oxygen-consuming bacteria. These bacteria degrade the organic matter through oxidizing reactions in order to obtain energy for metabolic functions. In most surface-water systems, the principal source of oxygen for this process will be the dissolved oxygen in the water column. Thus, if the rate of oxygen consumption by bacteria exceeds the rate of oxygen replenishment, the DO level of the



* see figure 41 and table 17 for locations.
Minimum DO limited to 6.0 mg/L for LCR 39, 4.0 mg/L for other monitoring stations.
(number of samples for each year displayed above bars)

Figure 46. Percent of monthly samples at selected stations which violate dissolved oxygen requirements

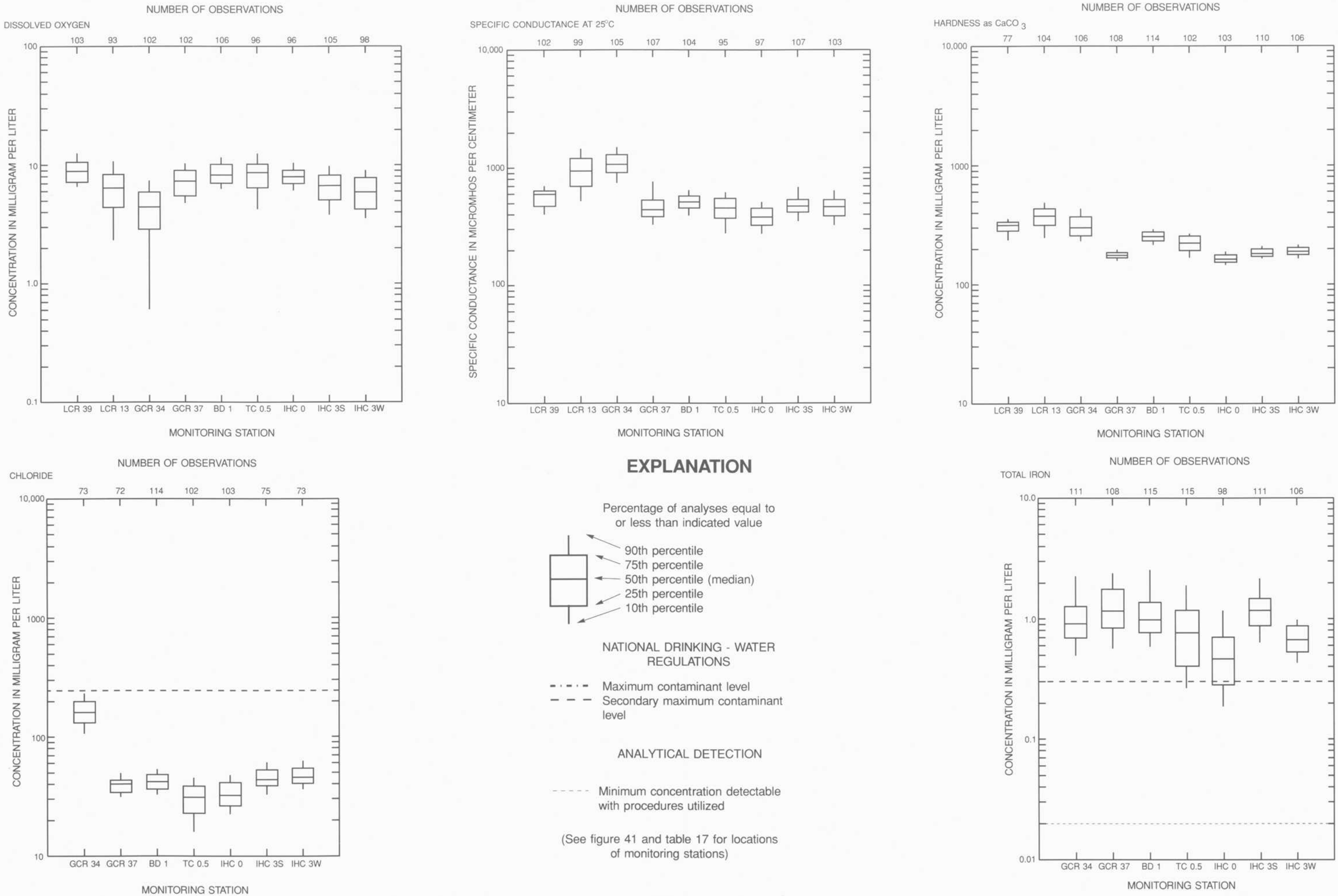


Figure 45. Statistical summary of selected water-quality constituents for selected stream monitoring stations.

water body will begin to decrease.

Large volumes of dissolved and suspended organics are often required to cause significant decreases in surface water DO levels. When high levels of oxidizable organic matter are present in a lake or stream, enough dissolved oxygen may be consumed during the decay process that a stream or lake may become uninhabitable for many aquatic species. In extreme cases, it is possible for the total biochemical oxygen demand to exceed the total volume of dissolved oxygen in a stream or lake. In such a situation, anaerobic (no available oxygen) conditions may develop. Very high levels of organic matter may develop in surface waters as a result of eutrophication, non-point source discharges, combined sewer overflows, and discharge of undertreated wastewater.

Violations of DO criteria for aquatic-life uses (table 16) has been a chronic water-quality problem in the West Branch of the Grand Calumet River. It is reported in the 1990 IDEM 305(b) report that the minimum dissolved oxygen standard was violated in 71 percent of all samples collected from the West Branch (monitoring station GCR 34) during the 1988-1989 period. During the period of time from 1991 through 1993, dissolved oxygen levels below 4 mg/L are observed in approximately nine percent of all samples from the West Branch of the Grand Calumet River and nearly five percent of all samples from the East Branch.

Over the ten-year period from 1982 to 1992, violations of the dissolved-oxygen criteria were observed in a greater percentage of samples from the West Branch of the Grand Calumet River, than in samples from the East Branch (figure 46).

Oxygen-consuming organic matter in the Grand Calumet River probably originates from numerous sources. Point-source discharges from industrial facilities and municipal water-treatment plants have long been implicated as sources of oxidizable organic materials in the Grand Calumet River (U.S. Department of Health, Education, and Welfare, 1965; Indiana Department of Environmental Management, [1988b]). Non-point sources may also contribute significant amounts of organic matter and other pollutants to the Grand Calumet River. Possible non-point sources along the Grand Calumet River include urban areas, industrial lands contiguous with the River, and contaminated ground-water (Indiana Department of Environmental Management, [1988b]).

Daily fluctuations in DO levels in the Grand Calumet River were estimated by Crawford and Wangsness (1987). Daily variations in the DO levels of water samples from the East Branch of the Grand Calumet River ranged from 1 to 2 mg/L. Variations in DO levels in the East Branch appeared to be random and unrelated to photosynthetic activity. Fluctuations of DO levels in samples from the West Branch ranged from 0.5 mg/L in samples collected in Cook County (Illinois) to 3 mg/L in samples collected near its confluence with the Indiana Harbor Canal. Large fluctuations in DO levels in samples collected near the Indiana Harbor Canal were attributed to flow reversals and mixing of waters between the West Branch and the Canal (Crawford and Wangsness, 1987).

Low dissolved oxygen levels have been a significant water-quality problem in sections of the Indiana Harbor Canal (figure 46). Over the ten-year period from 1982 to 1992, the highest percentage of DO criteria violations are observed in the Lake George Branch of the Canal (monitoring station IHC 3W). No violations of DO criteria have been observed in IDEM monthly samples collected during 1991 to 1993 at any of the monitoring stations on the Canal. However, an assessment of the fish community in the Indiana Harbor Canal/Grand Calumet River system indicates that low dissolved oxygen levels may still occur (Indiana Department of Environmental Management [1994?]).

During the 1982 to 1992 period, DO criteria violations were recorded in fewer IDEM monthly samples from the East Branch of the Little Calumet River (monitoring station LCR 39) than in samples from the West Branch (figure 46). Historically, possible sources of oxygen-consuming materials in the Little Calumet River include combined sewer overflows, stormwater discharges, and the discharge of inadequately treated wastewaters into the river or its tributaries (U. S. Department of Health, Education and Welfare, 1965). Although some sewage-related problems still exist in the Little Calumet River (Indiana Department of Environmental Management, [1994?]), no violations of minimum DO criteria were recorded in water samples from the Little Calumet River during 1991 and 1992.

Trail Creek in northern LaPorte County is a designated salmonid stream and is therefore, regulated by the aquatic-life standards specifically established for cold-water fisheries. Violations of DO standards for salmonid streams however, have been recorded in this stream. Low dissolved-oxygen levels are one factor implicated in four fish kills that occurred in Trail Creek during 1986 and 1987 (Indiana Department of Environmental Management, [1988a]). Dissolved-oxygen levels below the minimum criteria (6.0 mg/L for salmonid streams) were measured in 40 percent of all samples collected from Trail Creek during the period from 1986 to 1987. Violations of the DO criteria for cold-water fisheries are also observed in 11 percent of all IDEM monthly samples collected during the 1988-1989 period and 18 percent of samples collected during 1990 and 1991. No violations of DO criteria were observed for the 1992-1993 period (Indiana Department of Environmental Management, [1990]; [1994?]).

In order to decrease the volume of oxidizable organic matter entering Trail Creek, the Michigan City Sanitary District (MCSD) has recently plugged many CSO outfalls and constructed a stormwater detention basin. The total capacity of the Michigan City wastewater treatment plant has been increased to handle larger volumes of wastewater. The treatment plant also supersaturates its discharge effluent to 13 mg/L DO during the summer months (Indiana Department of Environmental Management, [1994?]; Northwestern Indiana Regional Planning Commission, 1993).

Several communities in the Lake Michigan Region began or completed upgrades at local treatment plants during the 1980s. Specific changes were made to individual treatment plants depending on their requirements for improving operations and effluent quality. Although some improvements in stream quality have been associated with these upgrades, many of the Region streams do not support designated uses due to DO levels (table 15).

Toxic compounds

In the past, a variety of potentially-toxic substances have been detected in the waters of the Grand Calumet River and the Indiana Harbor Canal. Chemicals such as mercury, lead, copper, cyanide and PCBs have been detected at levels considered to be toxic to aquatic organisms. Violations of applicable standards for some of these substances are still intermittently detected in the Grand Calumet River and the Indiana Harbor Canal. However, the overall levels of many toxic substances in the River and the Canal are generally lower today than during the past (Indiana Department of Environmental Management, 1991).

In July of 1988, the Indiana Department of Environmental Management conducted a water-quality survey to quantify the presence and distribution of toxic substances in the Grand Calumet River and Indiana Harbor Canal. Water samples for the study were collected at 11 different locations in the water-column and from 36 wastewater outfalls along the River and the Canal. The locations of the sampling points is presented in the IDEM 305(b) report for 1988-1989. Collected samples were analyzed for a variety of potentially-toxic constituents, including trace metals, cyanide, and a variety of synthetic organic compounds.

Various trace metals were detected in both effluent and ambient water samples collected during the 1988 IDEM study. Detectable levels of antimony, nickel and zinc were found in some samples, but no violations of minimum water-quality criteria for these metals were observed. Verifying the compliance status of other trace metals, however, was complicated by limited laboratory accuracy. The detection limits for both copper and arsenic exceeded the minimum criteria for these substances throughout the Grand Calumet River and Indiana Harbor Canal. The detection limit for lead also exceeded minimum criteria for this metal except in the harder waters of the West Branch of the Grand Calumet River (see page 116 of this report). It is therefore, possible that undetected violations of the standards for these metals occurred in some samples.

Some definite violations of minimum water-quality standards for copper, lead and arsenic were observed in the 1988 IDEM survey. The violations occurred in samples where the concentrations of these trace metals exceeded the laboratory detection limit, and were all observed in samples from the West Branch of the Grand Calumet River (Indiana Department of Environmental Management, [1990]).

The samples from the 1988 IDEM study of the Grand Calumet and Indiana Harbor Canal were screened for a variety of synthetic organic compounds. Analyses were conducted for 145 different synthetic organic compounds, but only 35 of the compounds were present at detectable concentrations in effluent or stream-water samples. The only organic compound in violation of the minimum water-quality standards was 1,2-dichloroethane. This violation was observed in a water-column sample from the West Branch of the Grand Calumet River.

The IDEM noted that only 11 of the 35 organic compounds detected in the 1988 stream-water samples were also detected in effluent samples. This may indicate that non-point sources are contributing synthetic organic compounds to the Grand Calumet River and Indiana Harbor Canal (Indiana Department of Environmental Management, [1990]).