SURFACE-WATER HYDROLOGY

The surface water resources of the Lake Michigan Region include Lake Michigan; the Little Calumet, Grand Calumet, and Galena Rivers; Trail Creek; an extensive network of smaller tributary streams and ditches; several natural and man-made lakes; ponds and man-made excavations; and scattered remnants of marshes, swamps, and other wetlands.

These surface-water features comprise a considerable part of the hydrologic cycle (figure 2). The hydrology of lakes, streams, and wetlands is not only closely related to precipitation, but also to topographic, geomorphic, and hydrogeologic conditions.

HISTORICAL PERSPECTIVE

The present surface-water hydrology of the Lake Michigan Region is markedly different from the natural drainage conditions that existed prior to permanent settlement of the area. Extensive industrialization and urbanization of the region during the 1800's and 1900's led to considerable alteration of the original landscape and the natural surface-water hydrology.

The most extensive changes include modification of the Lake Michigan *nearshore* and *lakeshore* areas and channelization of the Grand Calumet and Little Calumet Rivers. After the construction of harbors and canals in the region, industries expanded lakeward as submerged areas in the northwestern part of the Region were filled in with slag. In addition, lakeshore lowlands containing swamps and marshes were filled with sand from nearby dune and beach complexes.

Significant changes in the surface-water hydrology of the interior parts of the Lake Michigan Region also occurred. Most of the changes were confined to central Lake County, where large ditches were constructed to improve drainage. Several residential communities are built on areas that were poorly-drained.

Early and recent history

Until the latter part of the 19th century, the natural character of the Lake Michigan Region hydrology was little altered from what existed when the present shoreline of Lake Michigan was formed 2,500 years ago. Headwater streams flowed from the crest of the Valparaiso Moraine to join sluggish rivers which traversed areas of gentle relief in the Calumet Lacustrine Plain, then emptied into Lake Michigan. The courses of the lowland streams were influenced by a series of dune-capped beach ridges which provided the only major topographic expression on the otherwise featureless lake plain. Water tended to collect in the long strips of narrow land lying in the shallow valleys between the ridges to form ponds, marshes, swamps, and languid rivers.

A history of fluctuating lake levels and *paleoshorelines* of ancestral Lake Michigan are recorded in the dune-beach complexes which occupy the Calumet lake plain. Three relict beaches capped by sand dunes (figure 16), and the modern dunes of present day Lake Michigan extend across the Calumet Lacustrine Plain approximately parallel to the Lake Michigan shoreline. From south to north and oldest to youngest, the dune-beach complexes are the Glenwood, Calumet, Toleston and the Lake Michigan sand hills. Additional details about ancestral Lake Michigan and its shorelines may be found in the chapters on **Physical Environment** and **Coastal Environment**.

Between the Calumet Beach Ridge (figure 16) and the Lake Michigan sand hills lay a broad level wetland. While patches of marsh and swamp dotted the Calumet region both further inland and among the sand hills, the wetland north of the Calumet Beach Ridge was distinctive in its shape as a single continuous strip. From Michigan City west through the Indiana Dunes National Lakeshore lay the Great Marsh, which averaged half a mile in width and included a northern rim of timbered swamp and a broad, grassy wetland. The Great Marsh was centered on Dunes Creek, which flowed into Lake Michigan through a channel between the dunes (Cook and Jackson, 1978). To the west of the Great Marsh, the wetland was reduced to a narrow strip approximately one-quarter mile wide which included wet grassland and a white pine swamp. Still further west, the wetland broadened again to encompass the lower meanders of the Little Calumet River where the river breached the Calumet Beach Ridge and skirted its northern slope. The vast wetland evolved primarily as shallow backwaters of Dunes Creek and the Calumet rivers and as long shallow lagoons left between high beach ridges when lake levels of ancestral Lake Michigan dropped. The Great Marsh still exists, but most of the wetland further west is only a memory.

The sand hills or dunes near Lake Michigan lay to the north of the Great Marsh and the marshes of the Little Calumet River. Between the sand hills, depressions scoured out by the wind held pockets of wetlands. A remaining example of such intradunal ponds may be found behind the foredunes on present-day West Beach near Ogden Dunes. There were also parallel beach ridges with intervening swales which contained classic interdunal wetlands such as the ones found in Miller Woods at Gary. Geographically part of the sand hill area, the inter- and intradunal wetlands were separated by higher topographic contours from the broad marshes of the Little Calumet and the Great Marsh to the south. Through most of the nineteenth century, the sand hills or dunes near Lake Michigan were isolated from the rest of the region by the intervening marshlands of the Great Marsh and the marshes of the Little Calumet River.

Wetlands were generally considered wastelands, unsuitable for development or farming, except for pasture and water-tolerant crops. The earliest extensive use people made of the vast Calumet wetland areas was for the plant and small animal life to be found there. Hunting, trapping, and gathering of native plant life thrived. Small mammals of the marsh and swamp were important to the fur trade in the early years of the nineteenth century. The first and only permanent white settlement in the early history of the area was a trading post established by Joseph Bailly in 1822. The common muskrat was the staple, but otter and mink, and other small wetland mammals lived on into the twentieth century to provide food and sport for area residents (Cook and Jackson 1978).

In addition to mammals, an abundance of wild fowl attracted hunters to the many wetlands of the Calumet region. Wild rice attracted birds to the marshes. The Lake County marshes of the Little Calumet became especially famous for water birds. The lagoons around the old Indiana mouth of the Grand Calumet also became famous for birds, providing a resting place for migratory swans as late as the 1960's. Although the Great Marsh did not achieve equal fame for wild fowl, it too attracted nesting and migratory birds. In spite of hunting and reduced habitat, most bird species have survived in the area including the sandhill crane and great blue heron (Cook and Jackson, 1978).

Useful plants were also available in the wetland areas including a wide variety of herbs and spices such as wild peppers, mints, and ginger. The shrub layer contained a wide variety of berry-bearing species including wintergreen, blackberries, huckleberries, blueberries and cranberries. A large cranberry marsh, measuring about one-sixth of a mile from north to south, once existed in the southeast part of the town of Dune Acres until it was drained to make way for a golf course.

In 1850, Congress gave the "swamp lands" of the country to individual states in which they were located. The swamp lands were to be sold and the money used to drain and "reclaim" the lands. Swamp land in the Calumet region sold for an average of $1.25 per acre and has since been drained extensively for various types of development.

Because the beach ridges of the Calumet Lacustrine Plain were high and dry in an otherwise relatively impenetrable wetland area, they became major transportation routes, first as Native American trails and later as railroads. The first substantial modification of the Calumet region began in 1851 as railroad tracks were constructed through the Calumet lake plain to link the rapidly-growing city of Chicago with older cities such as Fort Wayne, Indianapolis and eastern seaboard cities.

Growth of the Chicago and Gary areas, advances in transportation, and development of technologies intensified the pressure on the once isolated wetland areas. Improved transportation systems made the areas easily accessible for recreational, residential and industrial development. Sand mining and dredging became a major activity in the Calumet lake plain.

During the twentieth century, however, conflicts arose over land use of the lakeshore region and the accompanying dune complexes. Industry was interested in port development on Lake Michigan, and many residents were interested in preserving the natural beauty of the area.

The first official act to preserve part of the dunes and wetlands along the south shore of Lake Michigan was the creation of Indiana Dunes State Park in 1925 between Dune Acres and Beverly Shores. In 1966, Congress devised a compromise between the two conflicting uses by creating both the Port of Indiana and Indiana Dunes National Lakeshore.

The Calumet River System

The Little Calumet and Grand Calumet Rivers have a long history of channel modifications, flow reversal and diversions. Both rivers were parts of a single river called the "Calumet River", which flowed sluggishly westward through the Calumet Lacustrine Plain from its headwaters in LaPorte County, Indiana (Cook and Jackson, 1978). The Calumet River made a hairpin turn near present-day Blue Island in Illinois and flowed eastward, back into Indiana, before discharging into Lake Michigan at present-day Marquette Park Lagoon in Gary. Another, much smaller "Calumet River" in Illinois drained Lake Calumet into Lake Michigan.

The two "Calumet" rivers were thought to have become connected more than a hundred and fifty years ago (Moore, 1959) by a channel created by Indians pushing and pulling canoes through the marshes between Wolf Lake and Lake Calumet. During the early 1800's the larger and smaller Calumet Rivers were permanently connected by a canal which was built at the site of an Indian portage in Illinois (Cook and Jackson, 1978).

Segments of the modified drainage network were given the present-day names "Grand Calumet River" and "Little Calumet River" as early as 1821 by surveyor John Tipton (Indiana Historical Bureau, 1942). The segment of the larger Calumet River upstream from the canal is the present-day mainstem of the "Little Calumet River", and the segment between the canal and its mouth in Gary is the present-day "Grand Calumet River". The river that drains Lake Calumet into Lake Michigan is presently called the "Calumet River", although Tipton considered it part of the Grand Calumet River (Cook and Jackson, 1978).

Following construction of the canal, the mouths of the Calumet and Grand Calumet Rivers frequently became clogged with sand, refuse, and weeds. The mouth of the Calumet River in Illinois was cleared during development of the Calumet Harbor at Chicago in the 1870's, promoting greater flow toward Illinois. Eventually, the mouth of the Grand Calumet River near the present-day Marquette Park Lagoon became permanently closed (Cook and Jackson, 1978). The present outlet for the Grand Calumet River was created in the early 1900's when the Indiana Harbor Ship Canal in northwestern Lake County was completed.

Large-scale modification of the watershed of the Little Calumet River began in 1850 when Hart Ditch was excavated from the town of Dyer to a site near Munster to improve local drainage. The Upper Plum Creek Basin in Illinois, formerly drained by Thorn Creek, became part of the Hart Ditch watershed. In the early 1900's, the watershed of Hart Ditch was increased when the Cady Marsh and Spring Street Ditches were constructed to drain marshlands. The drained areas are now occupied by parts of Highland, Griffith and Schererville.

A drastic change in the hydrologic regime of northwestern Indiana occurred after 1922 following construction of the Calumet Sag Channel in Illinois. This new channel connected the Little Calumet River at its hairpin turn in Illinois to the Chicago Sanitary and Ship Canal. Runoff from part of the Little Calumet River watershed was diverted out of the Lake Michigan drainage basin via the Calumet Sag Channel and into the Mississippi River Basin.

Further changes to the watershed of the Little Calumet River occurred in 1926 when Burns Ditch was constructed between Deep River in Lake County and Salt Creek in Porter County to improve local drainage. This area was traditionally known as "the marshes of the Little Calumet" because the river had no definable banks in the midst of swampy or marshy wetlands, and in some places the river widened into lake-like sheets of water that exceeded one mile in width (Cook and Jackson, 1978).

Excavation of Burns Waterway from Burns Ditch to Lake Michigan in 1926 caused flow from the eastern part of the Little Calumet River to be diverted directly into Lake Michigan.

Periodic dredging is required in the Calumet River System to maintain navigational channels at authorized depths to accommodate large, deep-draft commercial ships. The dredged sediments, however, are polluted and pose a disposal problem. Discussion on dredging activities in the Region may be found in the **Surface-Water Quality** section of this report.

The Little Calumet River watershed still contains many poorly-drained areas. The floodplain of the main river and its tributaries is one of the most flood-prone areas in the state.

Levees and flood control

The Little Calumet River Basin

The Calumet Lacustrine Plain in northwestern Indiana and the adjoining region in northeastern Illinois contain areas that are highly susceptible to flooding. Areas lying close to the mainstem of the Little Calumet River and its tributaries in northern Lake County have one of the most critical flooding problems in Indiana.

In general, floods in northern Lake County occur almost every year and may last up to a few weeks.

Limited flood protection along the Little Calumet River historically has been provided to some extent by banks of dredge spoil from early channelization and ditching. Additional low-stage flood protection has been provided by small levees along the residential and industrial communities located along the western part of the river in Lake County.

The U.S. Army Corps of Engineers (1984b) reported that levees along the Little Calumet River at Hammond, Highland and Munster can provide protection from only the 2-year to 8-year floods. Not surprisingly, the levees have performed unsatisfactorily during past flood events. In general, flood peaks can be intensified in residential and urban areas because buildings, roads and parking lots promote runoff which rapidly over fill the surface drainage networks.

In tributary basins of the Little Calumet River, areas of farmland are partially protected against flooding by agricultural dikes and spoil-bank levees formed by dredge material (spoil) from ditching and channel maintenance projects. Ridges of spoil banks can act as levees, but the degree of flood protection can be quite variable, particularly in areas bordered by agricultural dikes. Spoil-bank dikes and levees vary greatly in dimensions, materials, stability and effectiveness of flood protection because of a lack of engineering design, poor construction and unacceptable maintenance.

In many places, spoil bank levees are interrupted by drainage ditches, abandoned stream channels, roads and railroads. Moreover, the sandy debris-laden dredge spoil is highly susceptible to seepage and erosion. These factors, combined with limited local maintenance and clogged drainage ditches can result in the failure of spoil bank levees during floods.

Major developments

Environmental aspects of the problems in the Little Calumet River Basin were first addressed by the Lake Michigan Region Planning Council during its study of the Little Calumet River in 1968. The council sought to: 1) demonstrate potential benefits of planning beyond the immediate problems; 2) help local governments realize the necessity for comprehensive and well-coordinated efforts; and 3) stimulate the public demand for and responsibilities associated with developing a quality environment.

In 1969, the Little Calumet River Advisory Committee was created under executive order to study the needs of communities with respect to flood control, drainage, stream pollution, recreation and recreational navigation in the Little Calumet River. The Committee presented recommendations that emphasized the development of goals, objectives and policies.

Recommendations by the Committee were later adopted by the Little Calumet River Basin Commission to coordinate the development of over 320 square miles or almost 83 percent of the Little Calumet River Basin. The Commission sought to: 1) eliminate flooding; 2) establish effective recreational activities; 3) control water pollution; and 4) establish land conservation practices. The Commission's essential objectives, though slightly modified through time, include: 1) to participate and coordinate with the U.S. Army Corps of Engineers to bring about a realistic flood control program; 2) to seek favorable federal and state approval and funding; 3) to prepare a plan for securing non-federal share of funds from state, county and local sources; 4) to prepare land and water conservation programs in coordination and cooperation with other agencies; and 5) to prepare appropriate new legislation as required. In fulfilling its responsibility, the Little Calumet River Basin Commission must work in cooperation with the Northwestern Indiana Regional Planning Commission, and the Indiana Department of Natural Resources.

The Little Calumet River Basin Commission initiated and completed minor flood-control measures which included localized dredging of the river channel, clearing culverts and installation of riprap. Costly flood-control projects requiring high expenditures could not be undertaken because funds came only from the individual communities that paid into the Commission.

In 1980, the Little Calumet River Basin Development Commission was created by state statute to provide non-federal sponsorship and funding for flood control, recreation and recreational navigation improvements along the Little Calumet River in Lake and Porter Counties. To fulfill its duties, the Development Commission works with the Federal Government, the U.S. Army Corps of Engineers, and state agencies for project development, approval and implementation.

The state statute pertaining to the Little Calumet River Basin Development Commission was amended in 1984 to include changes on the Development Commission's membership requirements and its geographic area of jurisdiction and contained a new section on regulations concerning drains. However, the main responsibilities of the development commission were not changed.

The first major role of the Little Calumet River Basin Development Commission is active participation in the Little Calumet River Project, which was authorized for construction by section 401 of the 1986 Water Resources Development Act (P.L. 99-662).

The flood control and recreation project, as authorized, consists of replacing existing spoil bank levees with new levees, floodwalls, closure structures and appurtenant drainage structures; the construction of new set-back levees with closure structures and appurtenant drainage structures; modification of portions of the existing channel with accompanying bridge relocations; and a water control diversion structure. The project is designed for a 200-year level of flood protection. A recreation trail with five support areas consisting of parking, sanitation, picnicking and play facilities; nature observation overlooks; and canoe launches will also provide recreation opportunities. In addition, upon project completion and certification, numerous structures will be removed from the floodplain hazard area, resulting in increased property values and elimination of expensive flood insurance premiums.

Work on the 6-year Little Calumet River Project began in September of 1990. At the present, a few features of the project are completed.

Trail Creek

Trail Creek, a small stream that drains the northwestern part of LaPorte County directly into Lake Michigan, became important during the 1830's when its mouth was selected as the site for a commercial harbor. Although natural harbor conditions at the mouth of Trail Creek were far from ideal, there was no better or comparable harbor site on the Indiana portion of the Lake Michigan shoreline.

Early reports on Trail Creek described it as a sluggish stream that was obstructed by a bar at its mouth. Based on an 1835 survey report, Trail Creek was 30 feet wide and one foot deep at its mouth, but was as much as 120 feet wide and six feet deep further upstream (Munger, 1979).

Work on the harbor at the mouth of Trail Creek began as a federal navigation project in 1836 with construction of east and west piers which were extended periodically through 1869 (U.S. Army Corps of Engineers, 1990). A detached breakwater was constructed in 1889, but was replaced during the period 1903-1904.

The federal project was essentially completed by 1910; however, frequent dredging of the mouth and lower reaches of Trail Creek continues because of recurring sedimentation. Both the channel and mouth of the river have been dredged within the past five years.

The U.S. Geological Survey, under contract with the U.S. Army Corp of Engineers, began a study in 1990 to characterize suspended-sediment in Trail Creek at Michigan City, Indiana. The information will be used to assess whether the upland areas of the basin are contributing enough sediment to cause the sediment deposition problem in the harbor (Crawford and Jacques, 1992).

Because some sediments in Trail Creek channel are polluted with nutrients and arsenic and unsuitable for open lake disposal, disposal of dredged sediments is cause for concern. Additional discussion on disposal of contaminated sediments may be found in the **Surface-Water Quality** section of this report.

One of the few tributaries to Lake Michigan in Indiana, Trail Creek is very important to recreational boaters and commercial fishing operations. Most of the activity centers on salmon and trout fishing in Lake Michigan. Because of a salmonid stocking program managed by the Indiana Department of Natural Resources, Trail Creek is Indiana's most noted salmonid stream.

Local concern for maintenance of the harbor and channel and improvement of water quality in Trail Creek has resulted in formation of a coalition to address and rectify continuing sedimentation and water quality problems. The coalition, comprised of individuals, interested private groups, and various city, county, state, and federal representatives, is called Trail Creek Improvement Program (TIP).

The stated goal of TIP is to develop and implement a multi-faceted restoration project for the Trail Creek waterway. TIP plans to improve water quality and reduce sedimentation and nonpoint source pollution within the Trail Creek watershed. To achieve these goals, Michigan City and TIP have acquired U.S. Environmental Protection Agency (EPA) federal grant funds through Section 319 of the Federal Water Pollution Control Act by a Memorandum of Understanding with the Indiana Department of Environmental Management. Among the planned projects of TIP are development of a Watershed Management Plan and installation of a demonstration silt trap to decrease sedimentation within the channel of Trail Creek. Additional discussion about TIP may be found in the **Surface-Water Quality** section of this report.

Galena River

A small area at the headwaters of the Galena River is one of nineteen wetland conservation areas in the state (Indiana Department of Natural Resources, [1989]). The Galena River has not been significantly impacted by human influence.

SURFACE-WATER RESOURCES

Lake Michigan provides abundant quantities of water for withdrawal uses such as industrial, energy production and public supply in northwestern Indiana. Water for non-withdrawal uses such as instream recreation is provided by Lake Michigan, in addition to the other lakes and many streams in the Region. Wetlands and the smaller lakes in the Region are not considered potential water supply sources, but their occurrence and regulation directly affect land use and its associated water resources development.

Wetlands

Wetlands are a major hydrologic feature of the Lake Michigan Region. In general terms, wetlands occur where the ground-water table is usually at or near the ground surface, or where the land is at least periodically covered by shallow water. Because the presence of water creates a unique environment, wetlands support plants and animals specifically adapted for life in water or saturated soil.

Wetland types in Indiana can be grouped according to the classification scheme used by the U.S. Fish and Wildlife Service (Cowardin and others, 1979; Cowardin, 1982: U.S. Fish and Wildlife Service, 1986). The structure of this classification is hierarchical, progressing from the most general levels of systems and subsystems to the more specific levels of classes and subclasses. The latter two levels in the hierarchy can be further subdivided according to water regime (duration and frequency of flooding), water chemistry, soil type, and dominant plants or animals.

Wetlands in Indiana belong to three of the five major wetland systems identified by Cowardin and others (1979). **Lacustrine** wetlands include permanently flooded lakes or reservoirs of at least 20 acres, and smaller impoundments whose maximum depths exceed 6.6 feet at low water. **Riverine** wetlands are contained within a natural or artificial channel that at least periodically carries flowing water. **Palustrine** wetlands are associated with areas and/or shallow bodies of water which usually are dominated by wetland plants. Palustrine wetlands include not only vegetated wetlands commonly called *marshes, swamps, bogs, sloughs,* or *fens*, but also isolated catchments, small ponds, islands in lakes or rivers, and parts of river floodplains. Palustrine wetlands also may include farmland that would support *hydrophytes* if the land were not tilled, planted to crops, or partially drained.

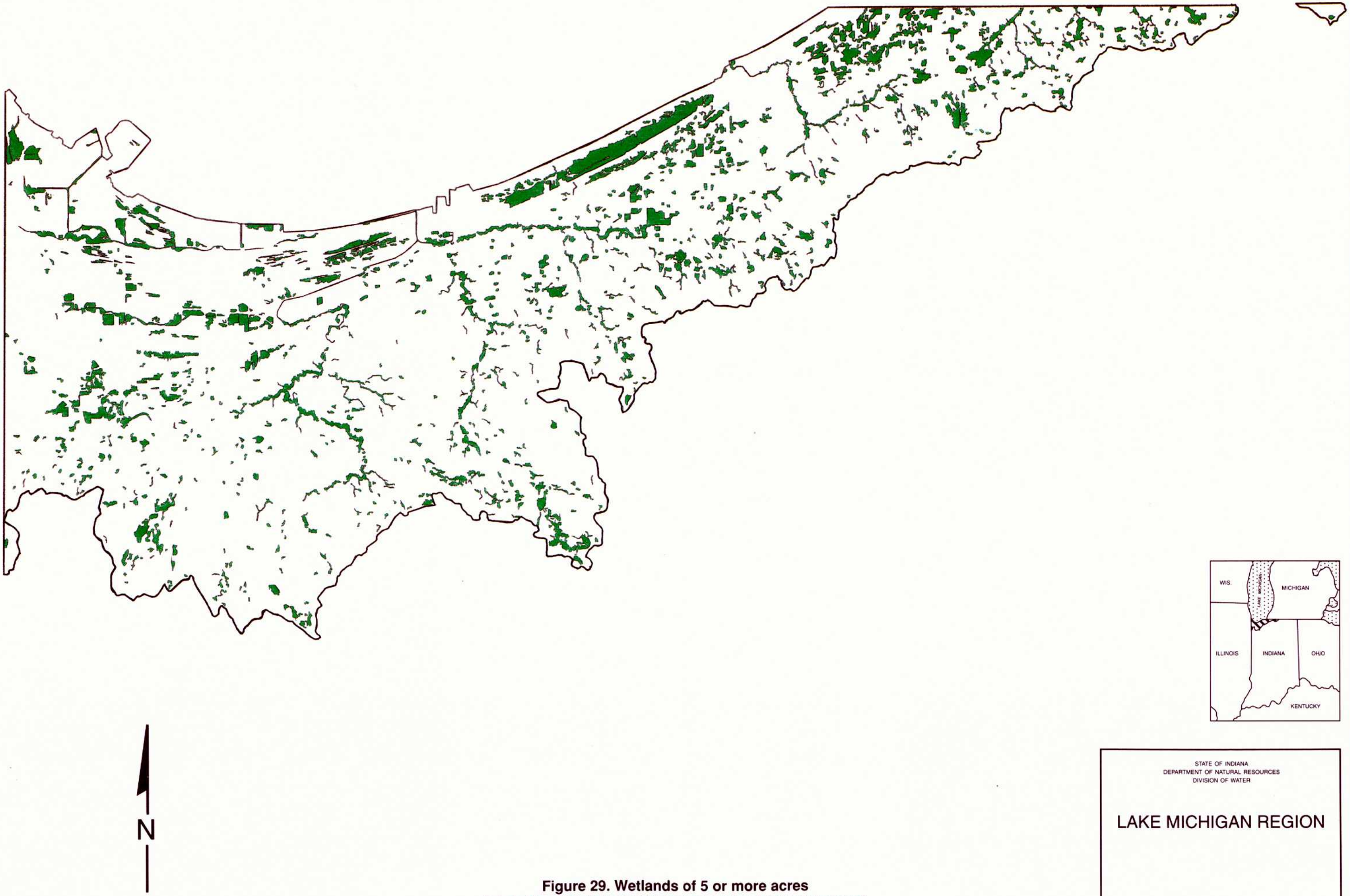
A comprehensive inventory of Indiana's wetlands was initiated in 1981 by the U.S. Fish and Wildlife Service as part of its National Wetlands Inventory. The inventory process involves identifying and classifying wetlands from high-altitude aerial photographs, then transforming the photographs into detailed maps (1:24,000 scale). The location and classification of each wetland is then digitized and stored in a computer. The computerized data for Indiana is now accessible for analysis through the use of a geographic information system (GIS).

Inventory of basin wetlands

According to an analysis of the computerized data, the Lake Michigan Region contains about 7,242 wetlands covering a total of approximately 65 to 68 square miles (table 9), or roughly 11 percent of the Region's total land area (figure 29). Although Lake Michigan and its harbors also are classified as wetlands, these water bodies were excluded from the analysis.

Palustrine wetlands constitute about 98 percent of the Region's wetlands, and about 92 percent of the total wetland area. Riverine and lacustrine wetlands account for about 2 and 6 percent, respectively, of the Region's total wetland area.

Palustrine forested and palustrine emergent wetlands together constitute about 59 percent of the Region's wetlands and about 76 percent of the wetland area (table 9). Staff of the IDNR have preliminarily



STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

LAKE MICHIGAN REGION

Figure 29. Wetlands of 5 or more acres
(adapted from U.S. Fish and Wildlife Service national wetlands inventory)

Table 9. Estimated number and area of Region wetlands

{Values were determined from a computerized data base of the U.S. Fish and Wildlife Service National Wetlands Inventory.}

Wetland classification: Classification follows the system described by Cowardin and others(1979).

Wetland Classification	Estimated number	Percent of total	Estimated area (sq mi)	Percent of total
Palustrine, aquatic bed	303	4.2	1.0	1.4
Palustrine, emergent	2758	38.1	20.5	30.1
Palustrine, forested	1543	21.3	31.1	45.8
Palustrine, scrub shrub	430	5.9	4.9	7.2
Palustrine, unconsolidated bottom/shore	2058	28.4	5.2	7.7
Riverine, unconsolidated bottom/shore	35	0.5	1.2	1.7
Lacustrine, aquatic bed	1	>.1	0.1	0.1
Lacustrine, emergent	1	>.1	>.1	0.1
Lacustrine, unconsolidated bottom/shore	113	1.6	4.0	5.9
Total	7242	100	68	100

identified these wetland classes as state priority wetland types (Indiana Department of Natural Resources, 1988c).

Palustrine forested wetlands are characterized by large, woody vegetation that is at least 20 feet tall. Palustrine emergent wetlands, commonly called marshes, meadows, fens, or sloughs, are characterized by erect, rooted, *herbaceous* hydrophytes, excluding mosses and lichens. In emergent wetlands, hydrophytic vegetation is present for most of the growing season in most years.

The largest contiguous tracts of palustrine forested and palustrine emergent wetlands in the Lake Michigan Region occur in a 1- to 3-mile-wide band located just south of Lake Michigan and extending from Michigan City westward to Gary. This area once was occupied by a vast marsh including the Great Marsh along Dunes Creek and the marshlands of the Little Calumet and Grand Calumet Rivers. Many of the wetlands in this band are part of the Indiana Dunes National Lakeshore and the Indiana Dunes State Park.

Scattered palustrine wetlands also are common along the Region's major streams, particularly the Little Calumet and Grand Calumet Rivers and Deep River. Notable areas include Clark and Pine Nature Preserve.

Wetlands in the Lake Michigan Region can be further characterized by the duration and timing of surface inundation, using the classification scheme described by Cowardin and others (1979). About one-half of the Region's wetlands are either seasonally flooded (37 percent) or temporarily flooded (16 percent). About 21 percent of the Region's wetlands are semi-permanently flooded, and about 12 percent are either saturated or permanently flooded. The box on this page describes these five wetland categories.

Wetlands in the Lake Michigan Region also can be described by size category. About 40 percent of the Region's individual wetlands are one acre or smaller; 48 percent are between one acre and 10 acres; 10 percent are between 10 and 40 acres; and 2 percent are greater than 40 acres.

Lacustrine wetlands include Wolf Lake, George Lake and several other lakes, ponds, and gravel pits. As noted previously, Lake Michigan and its harbor areas also are categorized as lacustrine wetlands.

Wetland protection programs

Once perceived as "wastelands", Indiana's wetlands historically have been ditched, dredged, tiled or filled to allow for agricultural production and other economic development. Many of the wetlands in the Lake Michigan Region have given way to industrial and urban development.

Although the perception of wetlands as barren or useless land still persists, there is a growing awareness of the valuable functions of wetlands. Wetlands not only play a role in the hydrologic cycle (figure 2), but also provide a wide range of benefits, including floodwater retention, water-quality protection, erosion control, fish and wildlife habitat, and recreational and aesthetic opportunities (see box on following page).

In general, wetland values have largely been overlooked until recent years, when state and federal agencies developed or expanded programs that at least indirectly afford some protection for wetlands. These state and federal programs generally are designed to balance the need for wetland protection with developmental and drainage needs. Appendix 5 summarizes selected programs having a good potential for protecting the wetlands of northern Indiana, including the Lake Michigan Region.

A number of local entities in the Lake Michigan Region are considering or have already adopted wetland protection ordinances. The town of Beverly Shores has adopted an ordinance, and Porter County has an ordinance for its unincorporated areas. The city of LaPorte, which lies just outside the boundary of the Region, also has a wetland protection ordinance.

Because the number and extent of wetlands protected through regulatory programs are limited, non-regulatory programs involving land acquisition and voluntary measures often are the major factors in wetland protection.

Changes in land use are limited on lands acquired for specific purposes, such as parks or nature preserves. Moreover, many public-private partnership programs discourage certain developments or land-use changes that would harm wetland habitats.

In the Lake Michigan Region, significant wetland tracts totaling about 12,258 acres (Dolak, 1985) are being protected on state- and federal-owned properties, the Indiana Dunes National Lakeshore and Indiana Dunes State Park (IDNL/IDSP). These tracts include fragile fens, intradunal ponds, and bogs.

Water regime of wetlands in the Lake Michigan Region

Seasonally flooded wetlands contain surface water for extended periods, especially early in the frost-free crop growing season, but usually become dry by season's end. When surface water is absent, the ground-water table often is near the land surface.

In **temporarily flooded** wetlands, surface water is present for brief periods during the growing season, but the ground-water table usually lies well below the land surface for most of the season. Plants that grow both in uplands and wetland are characteristic of the temporarily flooded regime.

Semi-permanently flooded wetlands contain surface water throughout the growing season in most years. When surface water is absent, the ground-water table is usually at or near the land surface. The region's semi-permanently flooded wetlands typically are found along river corridors or adjacent to the larger lakes.

In **saturated** wetlands, such as fens, ground water is at the land surface for extended periods during the growing season, but surface water is seldom present.

In **permanently flooded** wetlands, water covers the land surface throughout the year in all years. Riverine and lacustrine systems constitute the majority of permanently flooded wetlands.

Lakes

Lake Michigan and the Great Lakes Systems

The Great Lakes, which include Lake Michigan, are the dominant hydrologic feature in midcontinental North America. The Great Lakes System, extending over 2,000 miles and having a surface area of 95,000 square miles, is the largest fresh water lake system in the world (see figure 30). Four of the five Great Lakes are boundary waters dividing the United States and Canada. Of the 298,000 square miles in the entire Great Lakes Basin, approximately 115,000 square miles constitute the tributary area within the United States and 88,000 square miles lie within the borders of

WETLANDS VALUES AND BENEFITS[1]

Wetlands as a landform provide a unique **water storage** function in river basins by temporarily retaining water in upstream reaches and slowing its release to downstream reaches. During flood periods, the storage capacity of the low-lying areas characteristic of wetlands can help to decrease floodwater velocity and increase the duration of flow, consequently reducing flood peaks. During dry periods, some of the stored water may discharge into the main river channel, thereby helping to maintain streamflow.

In the present day Lake Michigan Region, the floodwater storage provided by wetlands and other depressional areas helps reduce the velocity of overland runoff and attenuate flood peaks. Because some depressional areas have no defined drainage outlet they do not contribute directly to surface runoff during flood events. Many of these noncontributing areas may contain lakes, ponds or other wetlands.

Under certain conditions, water from wetlands may supplement **ground-water recharge** at certain times of the year. Local ground-water recharge may occur at times in the vicinities of the interdunal wetlands and potentially in the upland morainal wetlands such as Pinhook Bog.

In most of the Lake Michigan Region, however, lakes and other wetlands primarily act as areas of **ground-water discharge**. These wetlands typically have formed where the ground surface intersects the water table. Wetlands are most likely to serve as ground-water discharge points at depressional lakes and along major river systems where regional ground-water flow patterns are toward the main channels. Ground-water discharge into floodplain wetlands is especially significant during dry periods because the ground-water seepage helps to maintain streamflow. Similarly, ground-water discharge into lacustrine and palustrine wetlands can help to maintain water levels in these systems.

Wetlands can play an important role in **water-quality maintenance** and improvement by functioning as natural filters to trap sediment, recycle nutrients, and remove or immobilize pollutants, including toxic substances, that would otherwise enter adjoining lakes and streams. Although natural wetlands in Indiana cannot be used for wastewater treatment, a few artificial wetlands have been created to filter wastewater effluent.

Wetlands play a role in **erosion control** along lakeshores and streambanks by stabilizing substrates, dissipating wave and current energy, and trapping sediments. Lakeshores frequently subjected to wave action generated by heavy boat traffic can especially benefit from the stabilizing effect of adjoining wetlands.

The value of wetlands as **fish and wildlife habitat** has long been recognized. Most freshwater fish species can be considered wetland-dependent because 1) almost all important game fish spawn in the aquatic portions of wetlands, 2) many fish use wetlands as nursery grounds, and 3) many species feed in wetlands or upon wetland-based food.

Hundreds of species of vertebrate animals found in Indiana require wetlands at some time in their lives. Muskrats and beavers are examples of common Indiana furbearers that are totally dependent on wetland environments.

The popularity of waterfowl hunting relates directly to the importance of wetlands as feeding, nesting, resting, and wintering grounds for waterfowl.

Wetlands provide the natural habitat necessary for the survival of some endangered species. In Indiana, more than 120 plant species and 60 animal species that depend on wetlands at some time in their lives are considered as either endangered, threatened, rare or of special concern.

Many **recreational activities** take place in and around wetlands, including hunting, fishing, nature study and birdwatching. Because of the aesthetic quality of wetlands, these lands often are key features of public parks and outdoor recreation areas. In the Lake Michigan Region, wetlands are an important visitor attraction at most state-owned properties and at many public and private parks, recreation areas, and natural areas.

[1] Portions of this discussion were adapted from a report by the Division of Outdoor Recreation (Indiana Department of Natural Resources, 1988c).

Canada (Great Lakes Basin Commission, 1975c).

The Great Lakes consist of Lakes Superior, Michigan, Huron, Erie, and Ontario. The lakes form a chain of reservoirs with each draining to the next. Lake Superior, the largest, is the uppermost and westernmost. It drains to Lake Huron by way of St. Mary's River. Lake Michigan also drains to Lake Huron.

From Lake Huron, water flows to Lake Erie by way of the St. Clair River, Lake St. Clair and the Detroit River. The outflow of Lake Erie, the second smallest and the shallowest of the Great Lakes, is mainly through the Niagara River to Lake Ontario. Lake Ontario water then flows into the St. Lawrence River which carries the total outflow of the Great Lakes some 541 miles to the Gulf of St. Lawrence thence, to the Atlantic Ocean.

Lake Michigan, the Great Lake within the boundary of this report, is the only Great Lake which lies entirely within the United States. Having a length of 307 miles, a breadth of 118 miles, and average natural depth of 279 feet, Lake Michigan is connected to Lake Huron by the Straits of Mackinac. Because the Straits are wide and deep, Lake Michigan and Lake Huron respond to precipitation and changes in levels and flows as if they were one lake. Direction of currents in the Straits alternates from east to west depending upon barometric pressure and wind conditions; however, the net flow is eastward.

Additional information about the origin, early history, and water level fluctuations of Lake Michigan and other Great Lakes may be found in the chapter entitled **Coastal Environment**.

Sources of hydrologic data for Lake Michigan and other Great Lakes

The U.S. Geological Survey is the prime agency

Bogs- relics of the Ice Age

Bogs are Ice Age relics which are often found adjacent to swamp forests. Fairly common in the more recently glaciated landscape of northern Wisconsin, Michigan's Upper Peninsula, and Maine, they are rare this far south. Indiana Dunes National Lakeshore is fortunate to have two within its management boundaries, Cowles Bog west of Mineral Springs Road in Dune Acres and Pinhook Bog south of Michigan City. The two bogs, famous in biological literature, have been dedicated by the National Park Service as National Scientific Landmarks.

Bogs, marshes, and swamps differ basically in substrate and physiography and in plant communities which they support. Bog and marsh communities are dominated largely by herbaceous plants or shrubs that fill depressions with their organic remains. Swamps, on the other hand, are depressions usually occupied by tall woody vegetation.

Bogs are like marshes in that they develop when vegetation fills in space which was once occupied by clear water. Bogs are different in that they have virtually no drainage, a condition that creates highly acid conditions and a low oxygen content that hinders decay. The water of bogs is usually brown; that of marshes tends to have a greenish tinge.

Cowles Bog, once called the "Tamarack Swamp" for its clump of 25-foot tall tamaracks, contains a raised peat mound that supports a unique assemblage of wetland vegetation compressed into a relatively small geographic area. Lying back of the lake front dune belt between the Calumet and Toleston Beach Complexes, the bog is a 56-acre tract located within the west end of the Great Marsh. The main body of the bog is formed from fibrous marsh plants, but there are woody plants encroaching from the dune side.

The complex environments, both natural and man-made in and around Cowles Bog, provide a variety of unusual botanical and geologic features. The diverse ecosystem assemblage of beaches, dunes, ponds, wetlands, and forests and the developed successional patterns of the bog and its surrounding area have attracted scientific interest for nearly a century. Pioneer studies on plant succession were conducted in the bog by Henry C. Cowles in the early 1800's. More recently, the National Park Service and the U.S. Geological Survey have been cooperating in scientific studies of the Lakeshore since 1973, most of which have centered in the Cowles Bog area.

The geology of the bog affects the hydrology, which in turn affects the distribution of plant communities and the development and evolution of the peatland. The geology of the unconsolidated materials in the Cowles Bog area consists of, from bottom to top, a basal clay-rich till which is a part of the Lake Border Moraine, a layer of sand which is overlain by marl containing sand seams and shells, and a top layer of peat. A 1200- by 450-foot mound exists near the center of the bog where the clay-rich basal till layer is breached and sand is present.

Ground water is the primary source of water supplied to Cowles Bog. The hydrology of the bog is complex , but can be simplified into two aquifers; a near-surface aquifer in the sands, marl and peats above the till and a confined aquifer which occurs beneath the till of the Lake Border Moraine.

Ground-water flow in the near-surface aquifer is from the dune-beach complexes toward the Great Marsh, except for short periods of time after large rainfalls when flow direction reversal may occur locally. In the confined aquifer, ground-water flow is generally toward the north. However, in the area of the peat mound where the confining till is breached and the two aquifers are connected, ground-water flow from the confined aquifer is upward (Cohen and Shedlock, 1986 and Wilcox and others, 1986). Despite the upward flow of water, there are no visible springs on the peat mound.

Wilcox and others (1986) indicate that water in and around the mound is from the sub-till aquifer because the low tritium concentrations and relatively high mineral contents of the water indicate that the waters near the mound were recharged prior to the open air hydrogen bomb testing in the 1950's. Water from wells located away from the mound have higher tritium and lower mineral content than the water near the mound, which indicates a shorter residence time. The pH for Cowles Bog is near-neutral; and although officially named a bog, the soil, vegetation, and water-quality characteristics of Cowles Bog indicate that the area is probably better termed a fen (Boelter and Verry, 1977).

Pinhook Bog, located in LaPorte County near the crest of the Valparaiso Moraine, is regarded as the finest bog in Indiana. Pinhook bog represents a landscape feature rare in Indiana, the well-developed sphagnum bog typical of the northern lake states and Canada. At normal water levels there is very little open water in the bog, but the surface mat of peat moss is well saturated. There are several tiny ponds, but no unfilled central pond or lake as found in many bogs (Lindsey and others, 1970).

The bog occupies a deep ice-block depression surrounded by low morainal ridges. It was initially a *kettle lake* with a clay-lined bed. Sphagnum moss and other organic matter from floating plants gradually accumulated and altered the original clear-water kettle lake into a peaty bog. The sphagnum grew rapidly and, with its ability to hold 10 to 20 times its weight in water, it eventually became thick enough to support trees. Although live sphagnum is common, most of the surface soil material in the bog is of fibrous or woody composition.

The source of water in Pinhook Bog, in contrast to Cowles Bog, is solely from surface water runoff or precipitation; hence, there is a difference in plant communities. Poor circulation and the slow decay of the sphagnum moss mats creates an acidic and oxygen-poor environment, which further slows decay of organic matter by inhibiting bacterial growth.

Botanically the bog provides a harsh environment that is low in nutrients. One special adaption to the bog environment is the development of carnivorous plants such as the sundew and pitcher plant. The sundew plant actively traps insects with leaves that are covered with flexible hairs which fold together to encompass the prey. The pitcher plant captures small insects in its pitcher-shaped leaves by attracting them with nectar, trapping them with downward pointing hairs, and digesting them with enzymes and bacteria.

Among the rare floral types found in the bog are orchids such as the yellow fringed orchid and the pink lady slipper.

Peat layers in bogs provide information to scientists concerning past environments. A botanist, G.K. Guennel identified pollen at various depths in Pinhook bog and made interpretations about climatic changes in the past. Based on the pollen study, the climate in the early history of the bog was interpreted to be moist and cold, after which, it became cold and dry; more recently, the climate has become more warm and dry than in previous times.

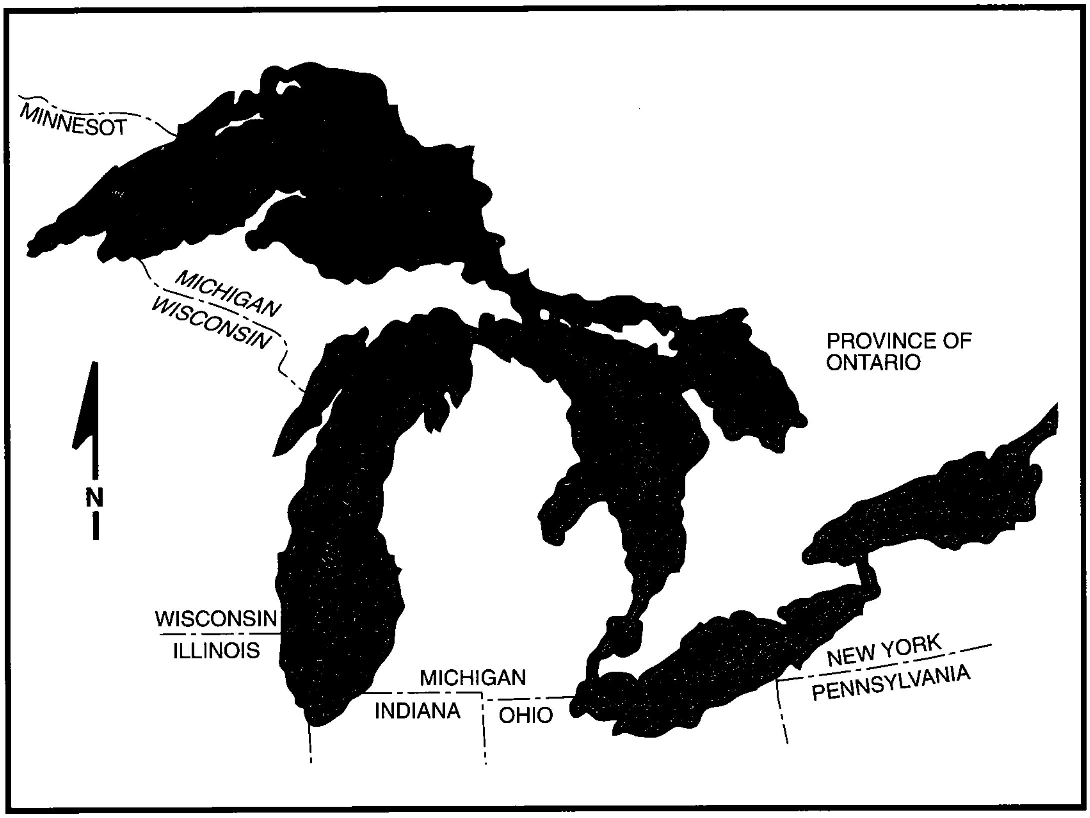


Figure 30. General map of the Great Lakes

responsible for gathering, recording, and publishing data on surface water hydrology within the United States portions of the Great Lakes Basin. The data are collected and prepared for publication in cooperation with other Federal, State, local, and private agencies. To a more limited extent and for specific purposes, many other Federal, State, county and municipal agencies, plus other public and private entities, gather and record surface-water data for the Great Lakes System. Data concerning surface water hydrology generated in the Canadian portion of the Great Lakes Basin are available through Environment Canada, Water Survey of Canada.

Stream-gaging stations, which usually measure water-surface elevation, are used to collect basic data. Much of what is known about the hydrology of the Great Lakes System is learned from stream-gaging stations located on tributary streams. Rating curves are developed for each station to relate measured water-surface elevation to the generally more useful stream discharge data. Rating curves are developed by measuring average stream velocities and cross-sectional areas and relating these data to concurring water-surface elevation. Because the cross-sectional regimen of many stations undergoes constant change, the rating curves are periodically readjusted to reflect the change. The section within this chapter entitled **Streams** contains information regarding the stream-gaging stations within the Lake Michigan Region.

Factors affecting water supply of the Great Lakes and Lake Michigan

Natural cycles of precipitation, runoff, evaporation, and ground-water inflow and outflow affect the amount of water supplied to the Great Lakes System. Inflow and outflow affect water supply of individual lakes. Storage capacity defined by individual lake water levels and geometry determines water availability for differing uses on a sustained basis.

The large surface area and storage volume of the Great Lakes System act as a natural regulator of lake water levels. Therefore, the range from highest quantity stored to lowest quantity stored is only about 1.3 percent of the average volume of water contained in the lakes. This modulating effect means that any change in water supplies to the upper part of the system remains within the system for some time, as much as 15 years, before its full effect is felt on the downstream lakes (Great Lakes Basin Commission, 1976a).

Other lakes

Many fresh-water lakes lie within the Lake Michigan Region. The lakes are located primarily in the urban and industrial areas of northern Lake County and within the Valparaiso Moraine area along the Region's southern boundary.

A number of the lakes in the Region are natural in origin, some of which were formed in depressions left by irregular deposition of glacial drift, while other lakes known as kettle-hole lakes, were probably formed by the melting of isolated masses of buried glacial ice. Still other lakes were formed south of the lakeshore in the long strips of land which lay in the narrow valleys between beach ridges.

Some small shallow lakes remain scattered along the floodplain of the Little Calumet and Grand Calumet Rivers and in the interridge lowlands of LaPorte and Porter counties. The lakes close to the main river channels are remnant *oxbows* of the old river channels, or depressions where the old rivers had no definable banks. The U.S. Fish and Wildlife Service and the IDNR, Division of Fish and Wildlife classify these surface-water bodies as palustrine wetlands because of their shallow depth and because they are not considered part of the main channel. Most oxbow lakes are only temporarily or seasonally flooded, but some may be permanently flooded.

In one sense, the remnant lakes (wetlands) of the Calumet River corridors are man-made because they were formed when the river was dredged and straightened, leaving the original river channel isolated to form oxbows. In another sense, they are considered as natural lakes because oxbow lakes commonly are formed along meandering rivers by natural cut-off processes.

Most of the artificial lakes in the Region consist of old gravel pits, borrow pits, and impoundments of surface drainage networks. The two largest artificial impoundments in the Lake Michigan Region, Lake George at Hobart and Lake Louise in west central Porter County, are the largest lakes that lie entirely within the Lake Michigan Region.

Selected information on both natural and artificial lakes having a known surface area of at least 25 acres is presented in table 10. The list of lakes in the table is not inclusive, but represents lakes for which there is available information from the updated DNR lakes guide (1993b). The locations of most lakes in the Region are apparent from fold-out maps or plates presented elsewhere in this report.

An unknown number of lakes in the Region have been totally destroyed or greatly diminished in size by drainage or infilling. Lakes occupying low-lying areas between beach ridges were once filled with sand from the dune/beach complex to create additional land. Lakes have also been used as disposal places for industrial by-products. In addition, other lakes have been filled-in gradually by natural or man-induced sedimentation and *eutrophication*.

The following paragraphs provide descriptive information gathered from numerous sources on selected lakes in the Lake Michigan Region. Additional information is provided in the **Surface-Water Quality** section of this report.

At the western edge of the Calumet lacustrine plain, three lakes existed prior to land modification. Wolf, George, and Berry Lakes were remains of a former large bay of Lake Michigan. Only Wolf Lake remains intact today, while Berry Lake was drained to allow for development of Whiting and East Chicago, and George Lake has been filled extensively with slag and sand by adjacent industries (Holowaty and others, 1991).

Wolf Lake consists of seven interconnected, artificially-divided basins roughly centered on the Indiana/Illinois border near the southwest shore of Lake Michigan. The Indiana portion of Wolf Lake is separated from the Illinois portion by a levee just west of the state line. Several culverts connect the two halves. The lake has a surface area of approximately 385 acres in the Indiana portion and a maximum depth of approximately eight feet (table 10, columns 3 and 5, respectively).

Although Wolf Lake once flowed north into Lake Michigan, the old channel now ends approximately one quarter mile south of the Lake Michigan shoreline. Prior to industrialization and urbanization in the area, Wolf Lake has been described as one of outstanding natural beauty and a haven of wildlife. It is said to have abounded in fish and small fur-bearing animals, and was a great feeding and resting area for water fowl. When high winds prevailed on Lake Michigan, Wolf

Table 10. Selected data for major lakes

{Data compiled from Glatfelter and others, 1986; Hoggatt, 1975; Indiana Department of Environmental Management, 1986a and 305b 1988-1989 [1990]; and Indiana Department of Natural Resources, Division of Water, revised Guide to Indiana Lakes (1993b) and miscellaneous unpublished files.}

Surface area: Acreage at established level: only lakes having a surface area of at least 25 acres and/or U.S. Geological Survey gage records are tabulated.

Capacity: At average or established level; expressed in million gallons (mg).

Established level: Average normal water level, as determined by local courts; expressed in feet above mean sea level (fmsl).

Period of record: Refers to lake-level data collected by the U.S. Geological Survey under cooperative agreement with the Indiana Department of Natural Resources, Division of Water.

Trophic class and lake management group: Data from Indiana Department of Environmental Management, 1986a and 305b report [1994?].

Lake	Drainage Area (mi^2)	Surface area (acres)	Capacity (mg)	Maximum depth (ft)	Established level (fmsl)	Period of record	Trophic class[1]	Lake management group[2]
LAKE COUNTY								
George (at Hammond)	—	78	—	12	—	—	4	V & VIIA[3]
George (at Hobart)	124	270	879	14	602.23	1946-	3	IV A
Golf	—	30	—	12	—	—	—	—
Wolf (in-basin)	5.7	385	—	8	—	1946-49	3	IV A
LAPORTE COUNTY								
Clare	—	30	—	—	—	—	—	—
Hog	—	59	224	52	—	—	1	VII A
Ron DeNardo	—	40	—	—	—	—	—	—
Swede	—	33	—	15	—	—	2	VII A
PORTER COUNTY								
Louise	2.6	228	645	34	717.0	—	—	—
Mud	—	26	—	—	—	—	—	—
Rice	—	38	58	—	—	—	—	—
Schneider	—	38	—	—	—	—	—	—

[1] Class 1- high-quality lakes assigned a total of 0-25 eutrophy points; class 2— intermediate-quality lakes assigned a total of 26-50 eutrophy points; class 3— poor-quality lakes assigned a total of 51-75 eutrophy points; class 4— remnant natural lakes and oxbow lakes.

[2] Groups of similar lake types were derived from cluster analysis based on lake morphometry and trophic state. Groups applicable to in-basin lakes are summarized as follows:

Group	Surface area (acres)	Mean depth (feet)	Eutrophy points
IVA	26-385	2.0-7.3	50-65
V	30-414	5.5-15.7	2-18
VIIA	25-828	5.0-13.2	18-37

[3] Lake George at Hammond- North Basin is in Lake Management group V; South Basin is in group VIIA

Lake offered a comparatively protected area for huge flocks of ducks, coots and other water birds.

Water from Wolf Lake now flows west over a control structure, into a ditch which empties into the Calumet River. A portion of the old channel that led to Lake Michigan is now occupied by two large industrial plants. Much of the original water area of Wolf Lake is filled with wastes from steel mills and the city of Chicago. Within the state of Indiana, comparatively little of the original water area of the lake remains. Railroads run through and around the area, and a power line bisects the lake. Among the principal industries near the lake are oil refineries, steel mills, soap and soap products factories, and corn processing plants.

In spite of regional urbanization, Wolf Lake remains a somewhat unique ecological and recreational resource in northwest Indiana. Much of the Indiana portion of Wolf Lake's shoreline is owned by the city of Hammond. Development of the shoreline includes a city beach and city-owned boat launching ramp. The lake offers fishing and other recreational opportunities to a large number of people in this highly populated area. Wolf Lake is also still a valuable feeding and resting place for waterfowl.

George Lake (locally known as Lake George) at Hammond is a 78-acre shallow lake, having a maximum depth of approximately 12 feet (table 10, columns 3 and 5, respectively). The present lake, which is bisected by an east-west causeway, represents only a small portion of what was once George Lake prior to extensive filling. However, some significant wetlands remain within and along the shore of George Lake.

Within the narrow strips of land between the beach ridge complexes near the Porter and LaPorte county line, low-lying pockets once contained lakes and ponds. Through the normal progress of ecological succession, most of these open water bodies changed into marsh and swamp. Only four of the pockets seem to have held standing water consistently enough to earn individual recognition as lake or slough. From west to east, these were Long Lake, Mud Lake, Blag Slough, and Little Lake.

Long Lake, on the border between Lake and Porter Counties, was the largest of the interdunal lakes. It may have had a connection with the Grand Calumet River at one time. Surveyors in the 1830's depicted Long Lake as more than three miles long— almost five miles, if one includes the marshes extending from its eastern end. Long Lake was subject to visible shrinkage over the years, and the growth of nearby Gary further aggravated the reduction of the standing water area and the corresponding broadening of the shore marshes (Cook and Jackson, 1978).

Mud Lake lay a few miles east of Long Lake in Porter County. The second largest of the interdunal water bodies, Mud Lake may have had as much as 160 acres of standing water. Beginning in 1960, the lake was drained and filled to accommodate industrial construction.

Blag Slough and Little Lake, the smallest and easternmost of the four ponds, were drained for recreational development for the sand hill town of Dune Acres. They have since been returned to open water bodies as a result of ground-water level changes associated with development of a nearby dike and fly ash ponds.

The natural and man-made processes that have governed the development and demise of the interdunal lakes are complexly interrelated. It is hard to distinguish short-term fluctuations of water levels of the lakes from shrinkage caused by ecological succession, falling Lake Michigan water levels, or the influence of ditching activities drawing ground water away from the ponds and lakes.

Drainage modifications to improve waterway transportation and build railroads, roadways, and industries have also created a number of lakes including the Marquette Park Lagoon, an oxbow lake, and at least two borrow pit lakes which have recreational value.

Marquette Park Lagoon is a 25.6 acre lake located in the sand dune area of northern Lake County. A portion of the east end of the lake lies within the boundaries of a Gary City Park. A large portion of the western end of the lake is undeveloped and owned by IDNL. The lagoon narrows in the middle where Lake Street passes over it. The lagoon was once the mouth of the Grand Calumet River and is now the eastern part of what is referred to on some maps as the Grand Calumet Lagoon.

Another lagoon (also part of the Grand Calumet River) is located west of Marquette Park Lagoon. This lagoon is partially on U.S. Steel property. Although the west end of the lagoon has been filled, much of the area appears unaltered by man. The western lagoon is connected to Marquette Park Lagoon by a shallow channel.

One important oxbow lake is located in Kennedy Park at Hammond. Kennedy Park oxbow, adjacent to interstates 80 and 90, was formerly part of the Little Calumet River. The present lake was formed by levying off a loop of the river channel and digging out the land between the loop. The levee separating the lake from the river is under water during periods of high water. A small culvert also connects both bodies of water at normal water levels.

Two borrow-pit lakes, the Grand Boulevard Park Lake and Rosser Park Lake, were formed during construction of the interstate system. Both lakes have recreational value for the highly populated area of the Region. The Grand Boulevard Park Lake, located adjacent to Interstates 80 and 94 at Lake Station, is a 40-acre borrow pit having a maximum depth of eight feet. The Grand Boulevard city park includes a beach and picnic area as well as a boat ramp. Rosser Park Lake, located on the southeast quadrant of the junction of I-80/94 and I-65, is a 40-acre borrow pit having an average depth of 8 feet and a maximum of 26 feet.

Lake George at Hobart was created by placement of an earth dam across Deep River in 1846 to provide power for a grist mill. The largest lake entirely within the Region, this artificial impoundment has a surface area of approximately 270 acres and an estimated storage capacity of 879 million gallons (table 10, columns 2 and 3, respectively). It was acquired in the early 1920s by the city of Hobart to be used as a supplementary water supply and for recreation and boating. Water quality, however, has interfered with the achievement of fully realizing Lake George's intended use. Discussion on the water quality of Lake George may be found in the **Surface-Water Quality** section of this report.

Sedimentation and organic nutrient problems in the lake led the U.S. Army Corps of Engineers (1990) to recommend that dredging an estimated 90,000 cubic yards of sediment from Lake George would be required to restore storage capacity and water quality. Upland areas were recommended for disposal of the dredged sediments. As of this writing, no such dredging has occurred.

Lake Louise, a private impoundment near Valparaiso, is the second largest lake entirely within the Region. It has a surface area of 228 acres, a maximum depth of 34 feet, and a storage capacity of 645 million gallons (table 10, columns 3, 5, and 4, respectively).

Since 1942, records of the water-surface elevations of many Indiana lakes have been collected by the U.S. Geological Survey through a cooperative agreement with the Indiana Department of Natural Resources (formerly the Indiana Department of Conservation). Gage records of lake water levels are available for only two lakes in the Lake Michigan Region: Lake George at Hobart (1946-present) and Wolf Lake (1946-1949). Before 1976, lake stations generally were equipped with a staff gage which was read once daily by a local observer. Automatic digital water-stage recorders have since been installed at many lake stations, including the station currently gaged at Lake George at Hobart.

Lake-level data today are used primarily to monitor maximum and minimum levels, determine the location of shoreline contours for lakeshore construction projects, and investigate water quality and flooding problems. Gage records also are used in the occasional establishment of normal water-surface elevations, as described in Indiana law (I.C. 13-2-13). Levels have been established at two of the major lakes in the Region (table 10, column 6).

Between 1954 and 1968, the U.S. Geological Survey in cooperation with the Indiana Department of Natural Resources mapped more than 200 natural and man-made lakes in Indiana including Hog Lake in the Lake Michigan Region. Although originally intended for use in the establishment of normal water-surface elevations, these depth contour maps have since been used for many purposes, including fisheries studies and recreation.

Lake-level fluctuations

Within historic time, the water levels of Indiana's lakes have been altered decidedly by nature and by man. Changes in lake levels may occur overnight or over a long period of time. Lake levels also fluctuate with the seasons.

The historic draining and filling projects conducted in the Calumet region since the 1800s have greatly affected the region's natural lakes and their water levels. In general, ditching near a lake can intercept or divert surface drainage which normally would have entered the lake basin, thus reducing the drainage area contributing to the lake. If the ditch is constructed downgradient of a lake, ground-water leakage may be induced from the lake to the ditch. Moreover, lowering the local water table by surface or subsurface drainage or ground-water pumpage can reduce the amount of ground-water inflow to lakes.

State laws enacted since the 1940's have helped protect public freshwater lakes of natural origin from detrimental development and excessive water-level fluctuations (see box titled Lake regulations). Although many lake-level problems have been eased by provisions found in these statutes, undesirable fluctuations continue to occur on some lakes.

Streams

The Lake Michigan Region is drained by streams that once naturally emptied into the Great Lakes/St. Lawrence River basin. However, alteration of the landscape in parts of the Lake Michigan Region has led to considerable changes in the surface drainage patterns.

The principal drainage network in the Lake Michigan Region is presently formed by the Grand Calumet and Little Calumet Rivers. Both rivers, which drain the central and western parts of the Region, were once parts of the Calumet River system which emptied directly into Lake Michigan. However, large-scale changes to the Calumet River watershed, including channelization and construction of canals, have led to considerable alteration of the natural hydrology of the Lake Michigan Region. In addition, surface-water diversion by the state of Illinois transfers water out of the Calumet River system and into the Mississippi River basin.

Several smaller streams drain the eastern part of the Lake Michigan Region, which includes most of northwestern LaPorte County. These drainage networks, listed in order of decreasing drainage areas, include Trail Creek, Galena River, White Ditch, Spring Creek, Derby Ditch and Dunes Creek. The watersheds of Trail Creek, Derby Ditch and Dunes Creek all naturally drain directly into the Indiana portion of Lake Michigan.

Sources of stream-flow data

Stream gages in the Lake Michigan Region monitor the spatial and temporal variations in stream flow in the major watercourses of the Region. A few gages placed in strategic locations monitor the complex hydrologic relationships among the major surface-water systems of the Region. Hydrologic parameters derived from stream-flow records can be used to evaluate the water-supply potential of streams.

The U.S. Geological Survey, in cooperation with other government agencies and public entities, has maintained records of daily flow in several streams in the Lake Michigan Region since 1942. Groups that participate in the cooperative USGS program include the U.S. Army Corps of Engineers, Indiana Department of Environmental Management, Indiana Department of Natural Resources and the Little Calumet River Basin Commission.

Currently, records of daily *mean* discharge are collected at 11 *continuous-record stations* in the Region. Of the 11 stations, six are located on the Little Calumet River and its tributaries, two are on the Grand Calumet River, whereas the Indiana Harbor and Ship Canal, Trail Creek at Michigan City and Galena River near LaPorte each contain one station. Gage height records

Lake regulations

Because water-level fluctuation in lakes can restrict their usefulness for recreation, residential development, flood control and water supply purposes, state and local organizations have attempted to maintain average water levels on many lakes. In accordance with a 1947 state law (I.C. 13-2-13), the Indiana Department of Natural Resources (formerly the Indiana Department of Conservation) is authorized to have normal lake levels established by appropriate legal action. The Department also has the authority to initiate and supervise the installation of dams, spillways, or other control structures needed to maintain the established levels.

Established lake levels typically represent the average water-surface elevation that has prevailed for several years. Once an average normal water level is established by a local circuit court, the average lake level is to be maintained at that elevation. Temporary lowering of a lake level below its designated level requires prior approval from the local court and from the Natural Resources Commission, the administrator of the lake-level law. Such approval typically is granted only for shoreline improvements or lake restoration procedures.

A related lake law (I.C. 13-2-11.1) enacted in 1947 and amended in 1982 requires prior approval from the Natural Resources Commission for any alteration of the bed or shoreline of a public freshwater lake of natural origin. Permits are required not only for minor projects such as the construction of seawalls or sand beaches, but also for larger projects such as channel or lakebed dredging, boat-ramp construction and boat-well construction. In addition, a permit is required to pump water from a public freshwater lake.

Under a law passed in 1947 and amended in 1987 (I.C. 13-2-15), a permit is required for the construction, reconstruction, repair or recleaning of a ditch or drain that has a bottom elevation lower than the normal average water level of a freshwater lake of 10 acres or more, and that is located within one-half mile of the lake.

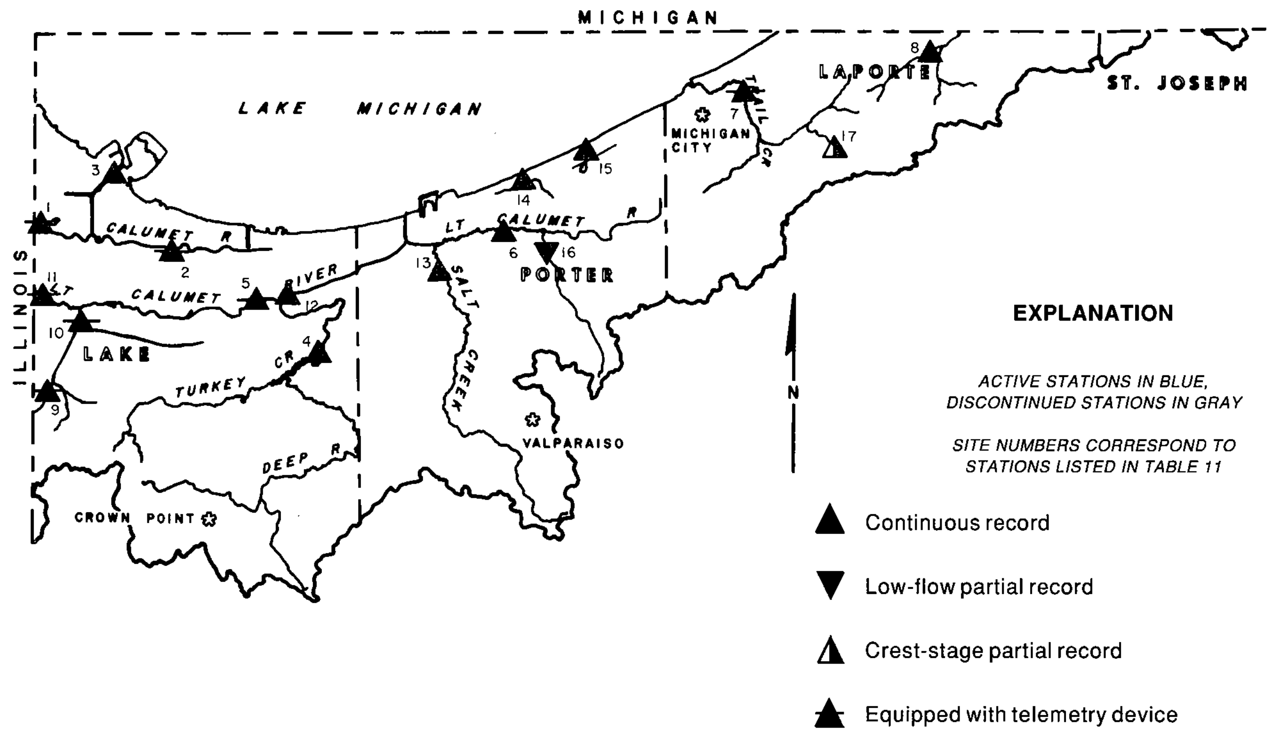


Figure 31. Location of stream gaging stations

are collected at the Little Calumet station at Gary and the Grand Calumet station at Gary (table 11, figure 31).

For automatic reporting of current river stages, seven gaging stations are equipped with telemetering devices (table 11). The instantaneous reporting of stream levels in this part of the state can be invaluable because of the frequent flooding of highly developed areas. River stages recorded at the various stations along the main-stem of the Grand Calumet and Little Calumet River can perhaps suggest flow reversals and diversions, although the complexity of the hydrologic environment preclude accurate determinations. Stream levels and discharges are used for the assessment of proposed flood-control structures and water-quality planning.

A sophisticated new apparatus, the ultrasonic velocity meter (UVM) was recently installed at a gaging station in the Indiana Harbor and Ship Canal to provide information on the hydrologic interaction between the Canal and Lake Michigan. The UVM provides nearly continuous discharge measurements in this complex hydrologic environment, and was the first of its kind to be installed in this country.

In contrast to the continuous-record stations, two gaging stations in the Lake Michigan Region have been operated as *partial-record stations* (table 11). At the low-flow partial-record station on Coffee Creek at Chesterton, flow measurements are recorded during dry periods. In general, a series of low-flow discharge measurements collected at a site can be later correlated with simultaneous daily mean discharges from a continuous-record gage on a stream draining a nearby basin of similar hydrologic characteristics. Using the correlation, the partial-record low-flow frequency characteristics can then be estimated using the frequency characteristics of the discharges collected at the continuous-record gage. Information on low-flow frequency at the partial-record station on Coffee Creek at Chesterton was reported by Stewart (1983).

The other partial-record site in the Lake Michigan Region, located on the East Branch of Trail Creek near Springville, has served as a *crest-stage station*. A crest-stage gage registers the peak stream stage occurring between inspections of the gage. Stage readings can later be converted to discharge values, and flood frequency characteristics can be determined. Table 11 lists the only partial-record station in the Region for

Table 11. Stream gaging stations

Map number: Station locations are shown in figure 31.

Station number: Numbers are U.S. Geological Survey downstream-order identification numbers. Letter abbreviations are as follows: T, telemetered station or data collection platform; UVM, ultrasonic velocity meter; L, low-flow partial-record station, frequency data published in Stewart (1983); C, crest-stage partial-record station, frequency data published in Glatfelter (1984).

Contributing darainage area: Portion of watershed that contributes directly to surface runoff. Total drainage area is shown in parentheses for watersheds with non-contributing portions. Area data are taken or derived from Glatfelter and others (1986), Glatfelter (1984), Stewart (1983) or Hoggatt (1975), depending on station type. Period of record: Refers to calendar year, whether or not data encompasses entire year.

Map no.	Station no.	Station name	Contributing drainage area (sq mi)	Period of record Dates
Active				
1	04092300T*	Grand Calumet River at Hohman Avenue at Hammond	Indeterminate	1991-
2	04092677T	Grand Calumet River at Gary[1]	Indeterminate	1991-
3	04092750UVM	Indiana Harbor Canal at East Chicago[2]	Indeterminate	1991-
4	04093000	Deep River at Lake George outlet at Hobart[3]	124	1947-
5	04093200T	Little Calumet River at Gary	5.8	1958-[4]
6	04094000	Little Calumet River at Porter	66.2	1945-
7	04095300T	Trail Creek at Michigan City	54.1	1969-
8	04096100	Galena River near LaPorte	14.9 (17.2)	1969-
9	05536179T	Hart Ditch at Dyer	37.6	1989-
10	05536190T	Hart Ditch at Munster	70.7	1942-
11	05536195T	Little Calumet River at Munster	90.0	1958-
Discontinued				
12	04093500	Burns Ditch at Gary (continuation of Deep River)	160	1943-92[5]
13	04094500	Salt Creek at McCool	74.6	1945-92[6]
14	04095050**	Dunes Creek at Porter	3.4	1979-82
15	04095100	Derby Ditch at Beverly Shores	4.64	1979-1980
Partial Record				
16	04093900L	Coffee Creek at Chesterton	15	
17	04095250C	East Branch Trail tributary near Springville	.17	

[1] Measures stage only
[2] Ultrasonic Velocity Meter: Measures total discharge to Lake Michigan
[3] Flow subject to regulation by operation of Lake George dam
[4] Period of record: June 1958 to September 1967, October 1968 to September 30, 1971 (discharge); December 13, 1984 to current year (gage heights only)
[5] Period of record: 1943-1991 (discharge); 1992 (gage height only)
[6] Period of record: 1945-1991 (discharge); 1992 (gage height only)
* Station number has been revised to 05536357.
** Records indicate a low-stage partial record station at Dunes Creek near Dune Acres with the same station number may have existed.

which flood frequency data have been reported by Glatfelter (1984).

The U.S. Geological Survey, under contract with the U.S. Army Corps of Engineers, has collected sediment data at the gaging station on Trail Creek at Michigan City for the years 1977-81 and 1990-91. Analyses of the data has been published by Crawford and Jacques (1992).

Factors affecting stream flow

The source of stream flow is precipitation. During a storm event, precipitation that falls on land infiltrates into the ground, or runs off the land surface to become overland flow or evaporates. Infiltration and overland flow rates vary considerably during a storm event, while evaporation rates do not change significantly.

Factors that control infiltration and overland flow rates include precipitation intensity and duration, topography, land use and land cover, antecedent soil moisture and soil permeability. Consequently, changes in land use and land cover, drainage patterns, ground-water levels, and stream geometry produce variations in stream flow.

Time variation in stream flow and its relation to temperature and precipitation can be illustrated by a graph of mean monthly values (figure 32). The difference between precipitation and runoff, which varies considerably during the year, can be attributed primarily to the seasonal differences in evapotranspiration rates, although soil and ground-water conditions also can play an important role.

Differences between precipitation and runoff are greatest during late summer and early fall when warm temperatures cause high evapotranspiration rates. Hence, much of the precipitation that would otherwise be available to streams is lost to the atmosphere. Moreover, ground-water levels are at or near their seasonal low, and base flow may be limited.

Small differences between precipitation and runoff indicate low evapotranspiration rates, which occur in late winter and early spring when temperatures are cool and plants are dormant or very young. In addition, the ground often is either frozen or saturated, and may be covered by melting snow. As a result of these factors,

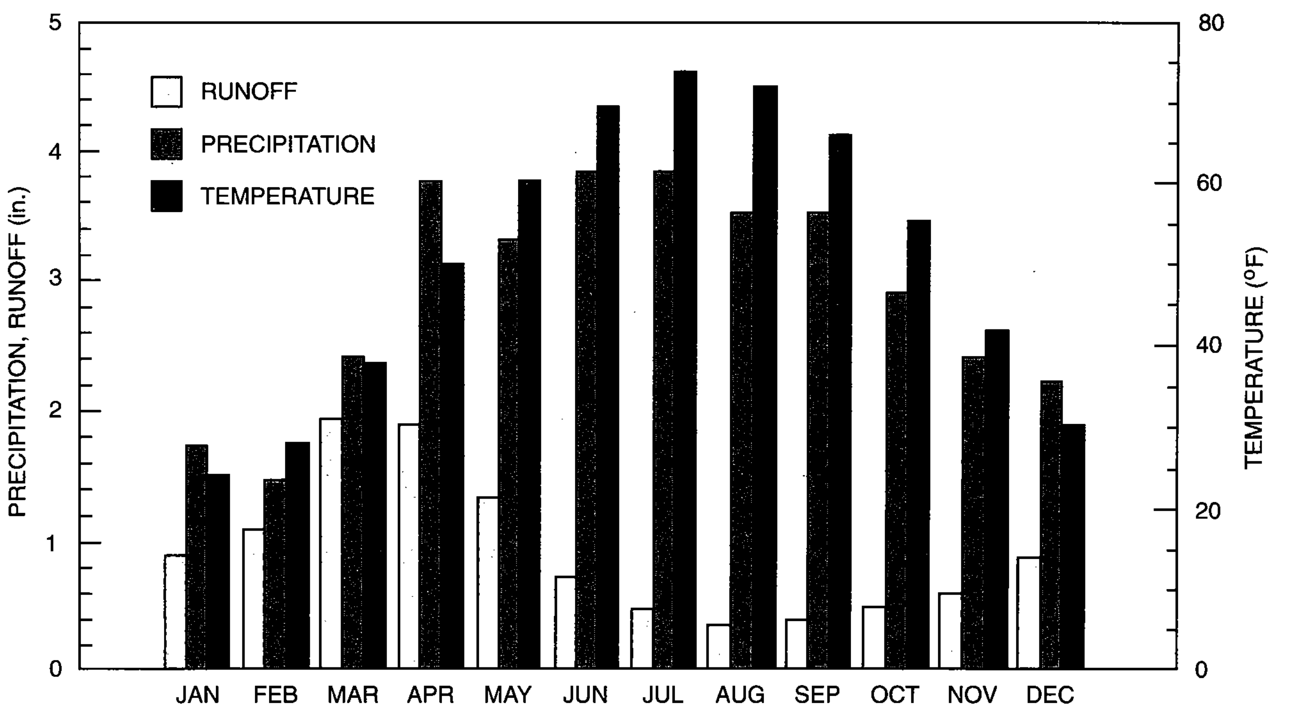


Figure 32. Variation of mean monthly runoff, precipitation, and temperature