PUBLIC ISSUES IN EARTH SCIENCE

OUR CHANGING LANDSCAPE

Indiana Dunes National Lakeshore

U.S. GEOLOGICAL SURVEY CIRCULAR 1085

COVER: "Windforms" at the top of Mount Baldy. Photograph by Bob Daum.

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OUR CHANGING LANDSCAPE

Indiana Dunes National Lakeshore

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FOREWORD

The National Parks of the United States have been called the jewels in the crown of our Nation's public lands. On the occasion of the 75th anniversary of the National Park Service and the 25th anniversary of one of its premier recreational and scientific jewels—Indiana Dunes National Lakeshore—the Department of the Interior, through the U.S. Geological Survey and the National Park Service, is pleased to present this photographic essay on some of the environmental challenges facing this park. The earth-science issues facing Indiana Dunes mirror national issues faced by other parks and public lands.

Wise use and careful stewardship of our Nation's parks and public lands depend on the assimilation of accurate and timely earth-science information. With this information in hand, resource managers and land-use planners have the necessary tools to make informed decisions and to plan for the effective use and conservation of natural resources and public lands.

When gathering this information, we develop an understanding of the physical processes that have shaped and continue to shape our land and natural resources. The processes at work today are the same ones that shaped the Earth hundreds, thousands, and millions of years ago.

Understanding the physical processes of the Earth is quite difficult. Almost 400 years ago, Francis Bacon said "Nature, to be commanded, must be obeyed." To be obeyed, nature must first be understood. By identifying earth-science concerns that affect our National Parks and by gathering the necessary information to address those issues, we are providing the basic understanding by which we can obey nature's dictates and yet most effectively command the fullest use and benefit of these national treasures.

In this photographic essay, we describe issues of global change, land use, wetlands, coastal erosion, and contamination, all of which are environmental concerns that are being faced daily at local, State, and national levels. Using Indiana Dunes National Lakeshore as the microcosm, we have provided a national perspective as well on each area of concern. As we mark these significant anniversaries, we challenge our readers to take an interest in these issues and to seek positive action to address them at the local level. Welcome to the exciting world of the earth sciences, and welcome to Indiana Dunes National Lakeshore.

Dallas L. Peck
Director, U.S. Geological Survey

James M. Ridenour
Director, National Park Service

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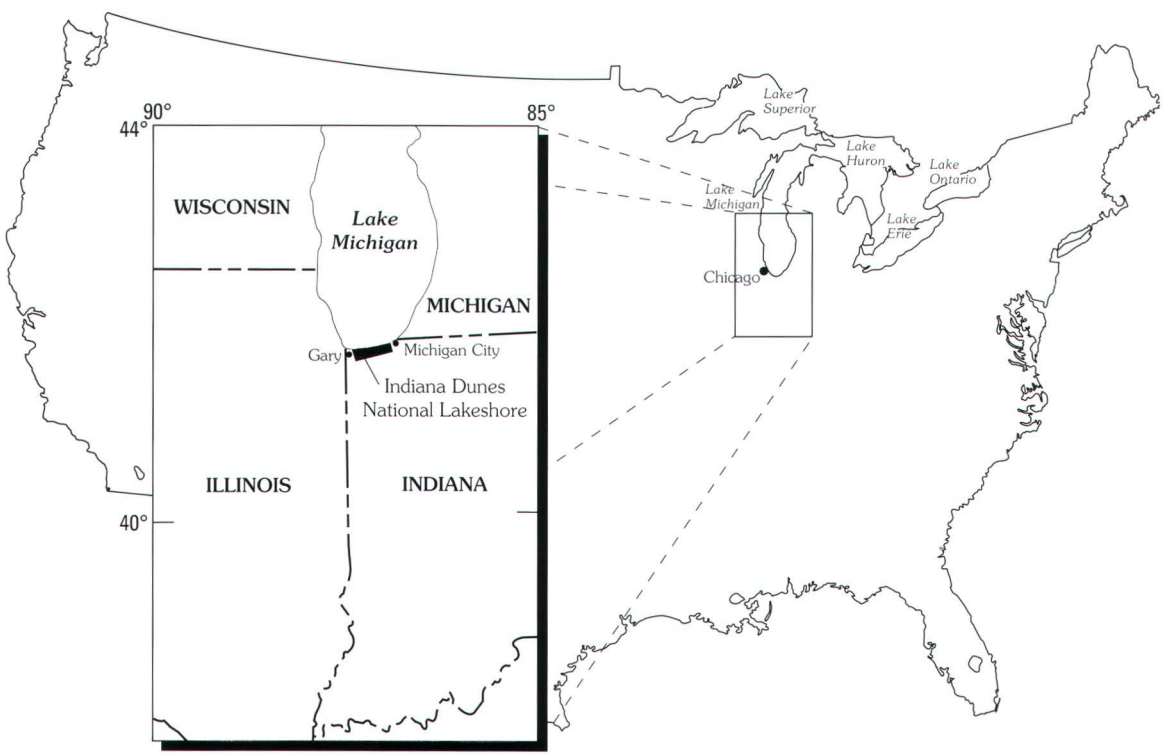
Edited by John M. Watson



"The Dunes of Northern Indiana are almost within a stone's throw of perhaps one of the greatest industrial communities of the world. It is the only landscape of its kind within reach of millions . . . ."

Jens Jensen, arguing for the establishment
of a Sand Dunes National Park in 1916

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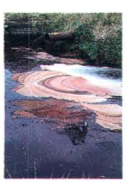
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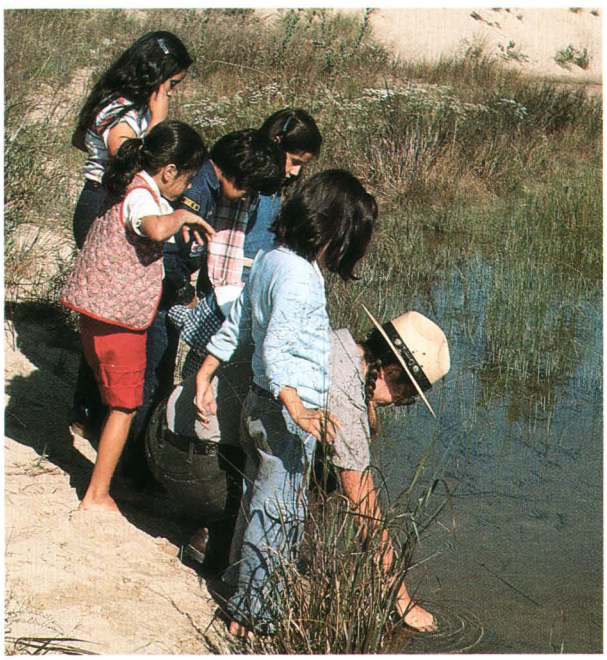
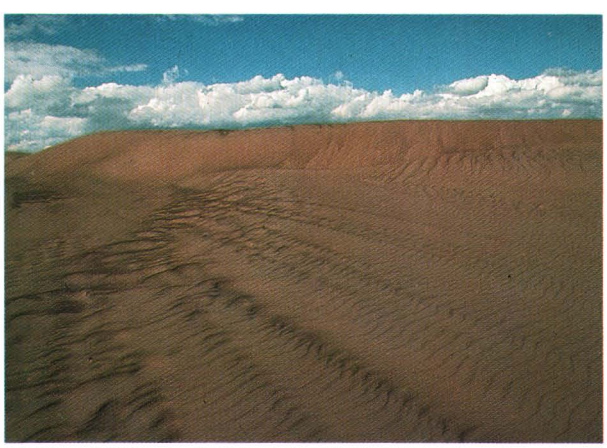
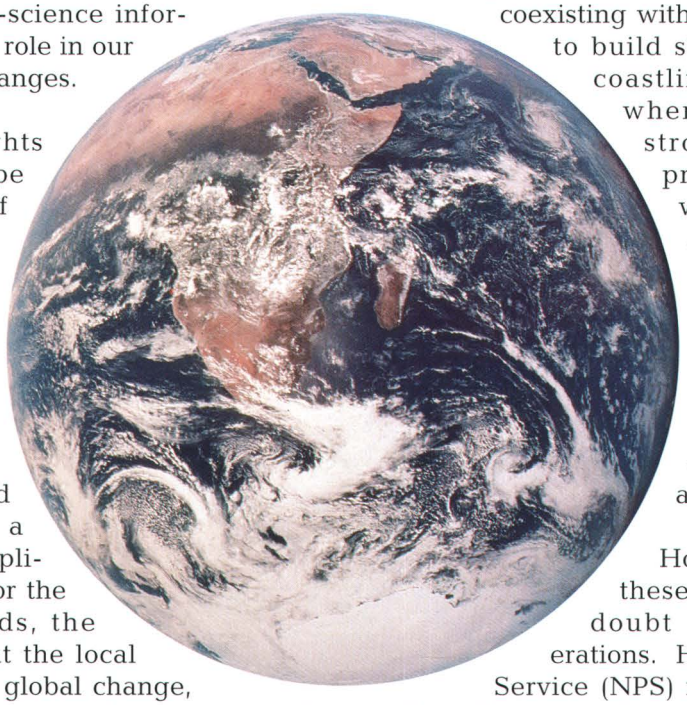




NATIONAL PERSPECTIVE AND LOCAL REALITIES

Our landscape is constantly changing in response to forces both natural and artificial. The actions of wind, water, and people all change the land surface. Some changes occur over centuries, whereas others occur within weeks. Changes may be global in extent or have only local effect. Regardless of the type of change or length of time over which the change occurs, earth-science information plays a critical role in our adaptation to these changes.



This report highlights some of the landscape changes and some of the processes taking place at one of our parks—Indiana Dunes National Lakeshore. With each earth-science issue addressed, a national or global perspective is presented first, followed by a description of the implication the issue has for the park—in other words, the reality of that issue at the local level. The issues are global change, land use, wetlands, coastal erosion, and contamination. With each of these issues, human involvement has played some role. The concept of living in harmony with nature is challenged daily.

The first section, "Global Change," explains that change is a natural process, not just a process caused by people's insensitivity to the environment. Human activities, however, influence the rate at which these global changes are taking place. The section "Land Use" shows the diverse imprints people have left on the landscape. In the "Wetlands" section, the many functions that wetlands serve and the threats being imposed upon wetlands by human activity are discussed. The section "Coastal Erosion" explains that erosion, too, is a natural process and is one that human activity can accelerate. Millions of dollars are spent each year because we have difficulty coexisting with nature. We continue to build structures near or on coastlines and lakeshores, where they may be destroyed by the natural processes of wind and water. Although there are natural sources of contamination, in the section "Contamination" we show that most of the threats to the quality of our air and water are related to human activities.

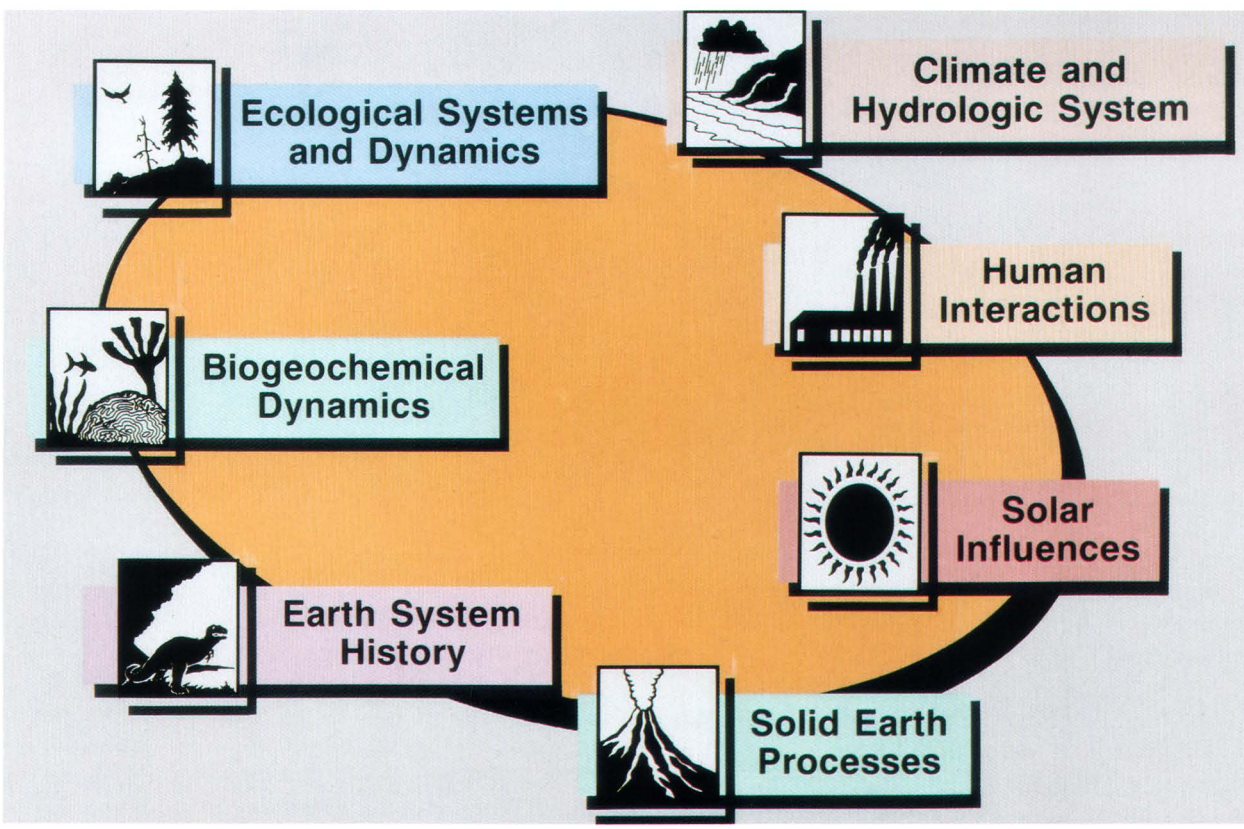
How society deals with these issues today will no doubt affect future generations. How the National Park Service (NPS) manages these issues within the boundaries of Indiana Dunes National Lakeshore will affect the park for many years. Information is the key to responsible management of global, national, regional, and local earth-science issues. Indiana Dunes has a unique geologic setting. Its landscape has been shaped by dynamic processes of wind, waves, water, and ice. One of the guiding principles in the study of the Earth is the theory that the present is the key to the past. The ongoing natural processes are similar to those that shaped the Earth hundreds, thousands, even millions of years ago.

The concept of living in harmony with nature is challenged daily.

Earth-science information teaches us that

- Lake Michigan was created as a result of natural global climate change
- The natural progression is for wetlands eventually to fill in with sediment
- The surface water in wetlands is a mixture of rainfall and ground water that has resurfaced
- Shorelines shift in response to the actions of wind and water; water levels and wind speed and direction respond to global climate changes
- Ground water can travel over very long distances and take hundreds of years to do so
- Dune migration is a natural process, and rates of movement can sometimes be predicted

Our ability to make responsible decisions in managing natural resources depends upon our ability to predict future changes. Without adequate and timely earth-science information, we will not be able to predict changes. This report discusses several earth-science issues of national and local significance and also presents earth-science information that will help us effectively and wisely manage our natural resources for future generations.



Earth-science information is essential for making responsible land-management decisions.

Global change

Land use

Wetlands

Coastal erosion

Contamination

GLOBAL CHANGE

The surface of the Earth is ever changing. During the past million years, massive ice sheets advanced and retreated repeatedly over North America. Massive sand dunes, such as those in the Middle East today, have migrated across eastern Colorado and Nebraska. Today, this area is part of the "breadbasket" of the Nation. Vegetation stabilizes the dunes. When human activities or changes in precipitation alter the vegetation, the dunes can become unstable. The "Dust Bowl," which drove thousands from their farms, was caused by severe drought in the 1920's and 1930's and by land-use and agricultural practices. A change in the temperature of the Earth's atmosphere can alter the climate significantly, including where and how much precipitation (rain and snow) will fall.

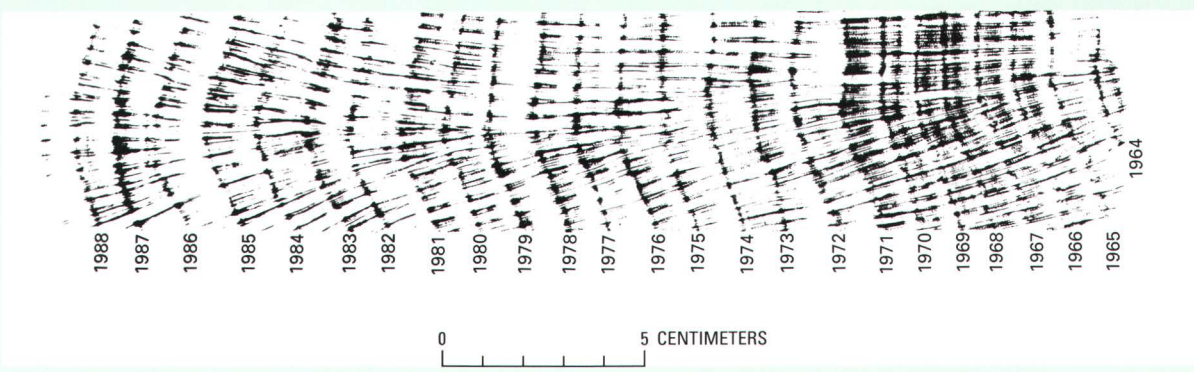
Certain gases in the atmosphere of the Earth (such as water vapor, carbon dioxide, methane, and nitrogen oxide) are called greenhouse gases. These gases behave like glass panes in a greenhouse. They permit the passage of short wavelength radiation from the sun but trap energy reradiated from the Earth's surface. The Earth's atmosphere warms more than would be expected under normal conditions. These greenhouse gases occur naturally, but human activities, such as the burning of oil and gas for heat, light, and transportation, also contribute to the amount of greenhouse gases in the atmosphere. Sediments, rocks, and glaciers record past changes in the Earth's environment and atmosphere. They often contain annual layers, and in special situations even contain seasonal layers. Corals produce annual growth bands similar to tree rings. These coral bands record temperature changes and changes in water runoff from land. Ocean, lake, or bog sediments can be banded (varved). These bands record

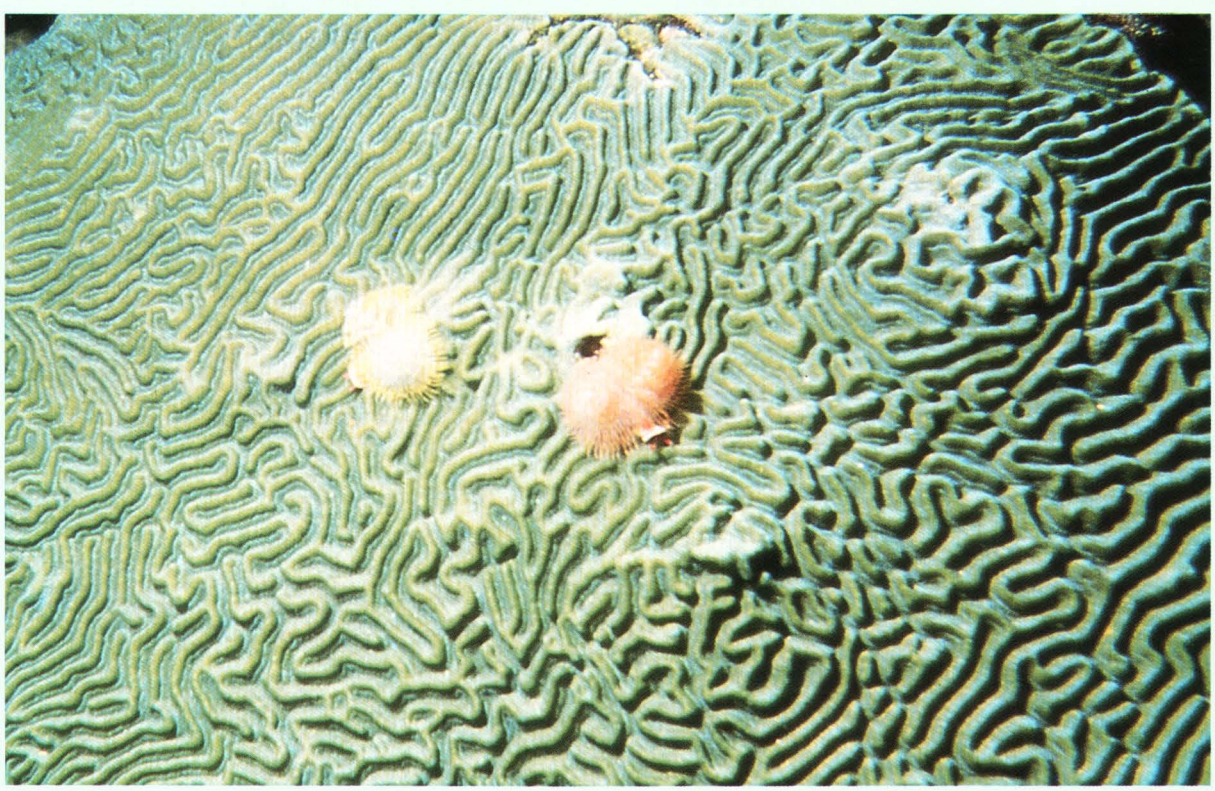
Changes in storm frequency and tracks, as well as the resulting variations in the amounts of rainfall and evaporation, can change lake levels.

RECORD OF CLIMATE CHANGE

The study of tree rings (dendrochronology) has greatly enhanced our knowledge of climate changes that occurred during the past several thousand years. The counterpart of trees in the marine environment is the corals, which also have annual growth bands. Climate-change information can also be obtained by the study of corals (sclerochronology). For example, thick, dark density bands can be correlated with very cold winter temperatures. High rainfall and subsequent land runoff increase the organic material in coastal waters. The corals incorporate some of this organic material in their annual growth band and thereby provide a record of the variation in rainfall on the adjacent land.

Corals, as indicators of past environments, are especially useful in determining past sea levels. Some types of coral, such as this brain coral, must live close to the sea surface. As sea level rises with the melting of the ice sheets, the corals must grow upward to survive. If the age of the corals can be determined, the past rate of sea-level rise can be estimated. As the ice sheets melted rapidly during the latest ice age, sea levels rose at a rate of 8 feet in 100 years.

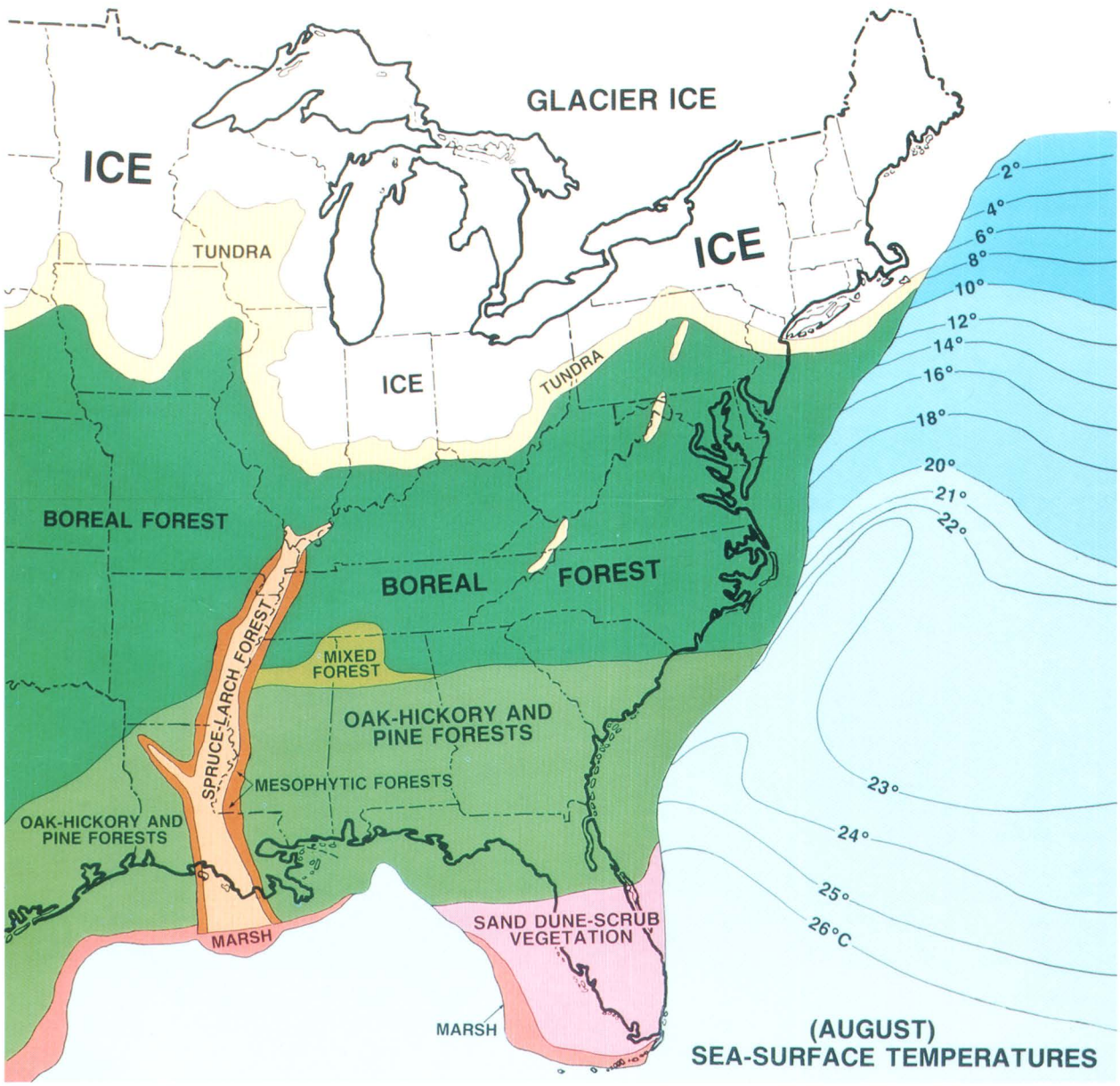




the seasonal changes in sediment accumulation and thus reflect temperature and amounts of rainfall and runoff. Sediments often contain skeletal remains of organisms and pollen from plants, which both provide valuable information about past climates and environments. Changes in composition of the Earth's atmosphere are preserved in the ice of glaciers and ice sheets. Atmospheric gases, wind-blown dust, and volcanic ash are contained within the annual accumulation of snow, which eventually becomes layered glacier ice.

Anticipation and prediction of the changes in climate are necessary for evaluation and design of mitigation strategies. For example, if the precipitation pattern for the United States changes, the Nebraska Sand Hills could again begin to migrate, destroying farm land and covering the wetlands between the hills. The wetlands are an essential part of the central-flyway ecosystem for migratory birds.

Changes in sea level are closely linked to changes in the temperature of the Earth's

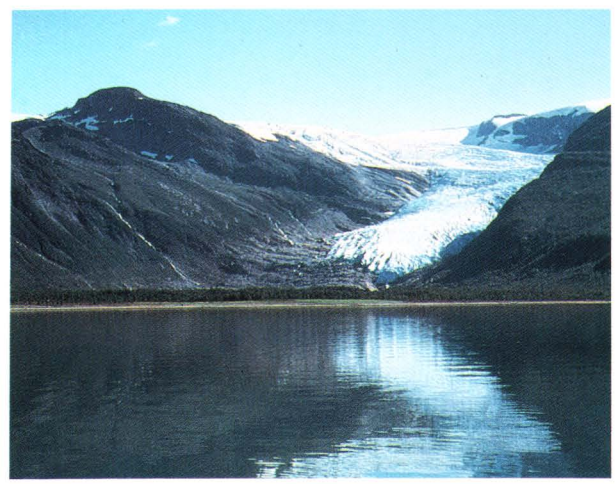


Patterns of vegetation, glaciers, and sea-surface temperatures were very different 18,000 years ago. During cold periods, a considerable volume of water was stored in ice sheets. As a result, sea level was 410 feet lower than present-day sea level. Note the size of Florida as compared to today.

atmosphere. During cold periods, such as that of 18,000 years ago, water was stored in ice sheets and sea level was 410 feet lower. As the great ice sheets in North America and Eurasia melted, sea level rose as rapidly as 8 feet per century. During the last 16,000 years, sea level has been rising. It is still rising (about 8 inches in the past century), possibly in response to global climate warming. The continuing rise intensifies the concern for coastal erosion nationwide.

Even in the Great Lakes, water levels change. In 1986, water levels in the Great Lakes

If our present climate changes, Indiana Dunes may well be one of the first places to reflect these changes.

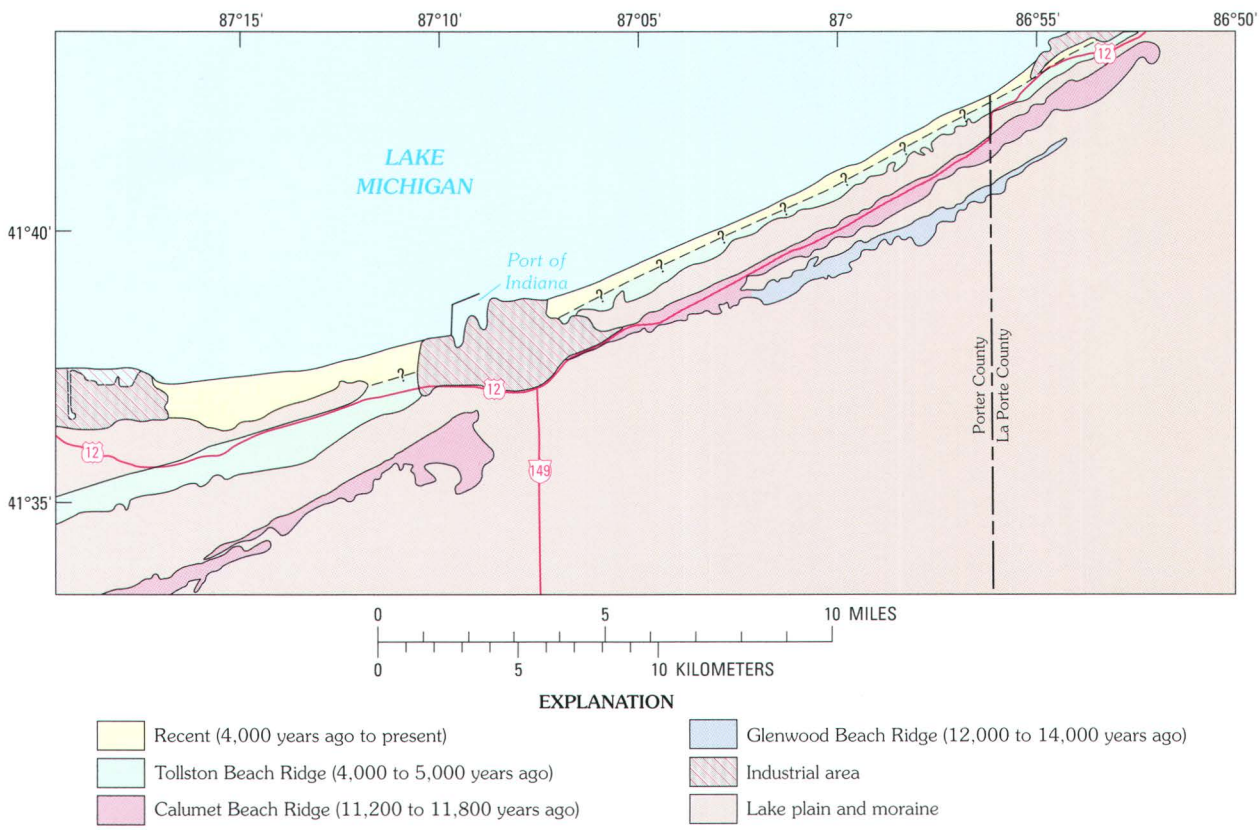


Left: Atmospheric gases, windblown dust, and volcanic ash are incorporated into glaciers with the annual snowfall, such as near Anchorage, Alaska. An annual record of the Earth's atmosphere is present within glaciers. The greenhouse gas carbon dioxide is increasing in the atmosphere and is believed to be contributing to global warming. The present concentration of carbon dioxide in the atmosphere is 25 percent higher than it was at the beginning of the industrial era, in the 1700's. Changes in sea level are closely linked to the melting of glaciers as the temperature of the atmosphere rises, such as the Engabreen Glacier in Norway (top right) and glaciers in the Chugach Mountains in Alaska (bottom right).

reached their highest levels in this century. Within Indiana Dunes, four bands of dunes record geologic evidence demonstrating that lake levels in the recent geologic past, several hundred to several thousand years ago, exceeded present-day and known historic levels.

Indiana Dunes contains the geologic history of the past 14,000 years. This history documents that global change occurred as the massive North American ice sheets melted and retreated northward when the climate warmed. Each successive band of dunes is younger and records a progressively lower lake level, starting with the southernmost Glenwood Beach Ridge (approximately 14,000 years old) and continuing to Mount Baldy on the present lakeshore (approximately 1,000 years old).

Indiana Dunes is ecologically unique. Here the Canadian conifers meet the temperate hardwood forests of the Northern and Eastern United States, as well as the tallgrass prairies of the Midwest. If our present climate changes, Indiana Dunes may well be one of the first places to reflect these changes. Some changes have already occurred. In the 1800's, old growth white pine was logged in the Indiana Dunes area. The regrowth of white pine has not done well, possibly as a result of the burning of fossil fuels (coal) in the 1880's and the advent of industrialization. Their tree rings record a reduced growth, and the few white pine seedlings that are produced today are quickly eaten by deer. Not only is the land surface ever changing, but associated plant communities often can reflect even the most subtle changes in climate and environmental conditions.

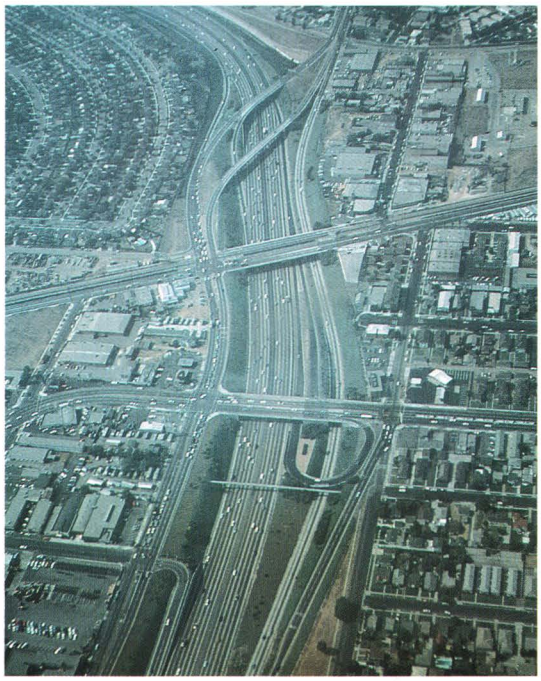


Location of dunes and ridges showing historic lake levels at Indiana Dunes National Lakeshore.

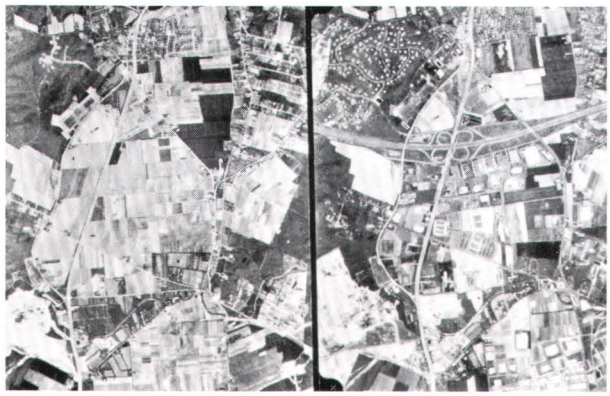
LAND USE

The European colonists, who arrived in North America in the early 1600's, used resources from the land and sea just as the Native Americans had been doing for centuries. As the colonies expanded, the need for new land and mineral resources grew also. In less than 300 years, the colonies were transformed into an industrial power. Demands for natural resources became sophisticated; land-use needs became ever more complex.

As our population continues to grow and our material needs become more complicated and urgent, an area will prosper only if it can accommodate these increased needs for a



Top left: The Pearl River in Louisiana serves as a transportation corridor for shipping of bulk materials. Top right: Major transportation facilities, such as this highway system in Los Angeles, are vital to our cities' welfare. Bottom: Airports need to be expanded as the demand on them increases. This "people mover," in Chicago's O'Hare Airport, helps speed travelers on their way.



These aerial photographs show results of decisions made by land-use managers over time.

Coastal areas have long attracted large urban populations, as evidenced by cities such as Chicago.

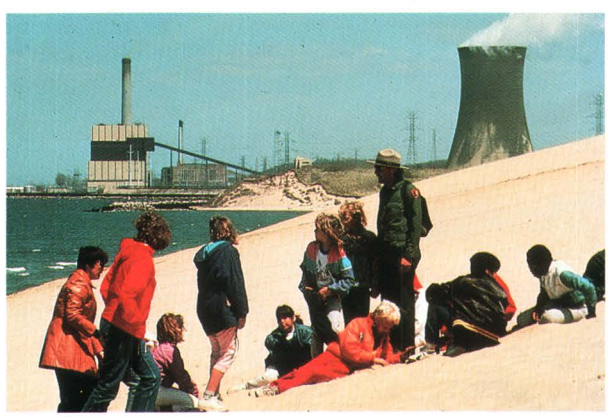
long time and if it has a secure and adequate natural resource base. For instance, transportation facilities, such as pipelines, powerlines, tunnels, bridges, waterways, roads, railroads, and airports, serve to move us and the many products that are vital to our cities' welfare. Knowledge of the geology of the land is essential to ensuring efficient, reliable, and safe transportation systems.

Hundreds of daily activities require energy and mineral resources. It is estimated that each American requires 40,000 pounds of new minerals every year to maintain his or her current standard of living. Proper management of our Nation's resources and a balanced approach to land use allow us to use the land while sustaining the economy. Earth-science information identifies the location of natural

The semiarid Los Angeles Basin, in California, as seen on this color-infrared photograph, is an example of a highly urbanized area that continues to be challenged by complex land-use and land-management decisions. Accessing and distributing water to an ever-growing population is also a difficult challenge.

This color-infrared aerial photograph shows a major part of Indiana Dunes National Lakeshore. Vegetation is shown in red.

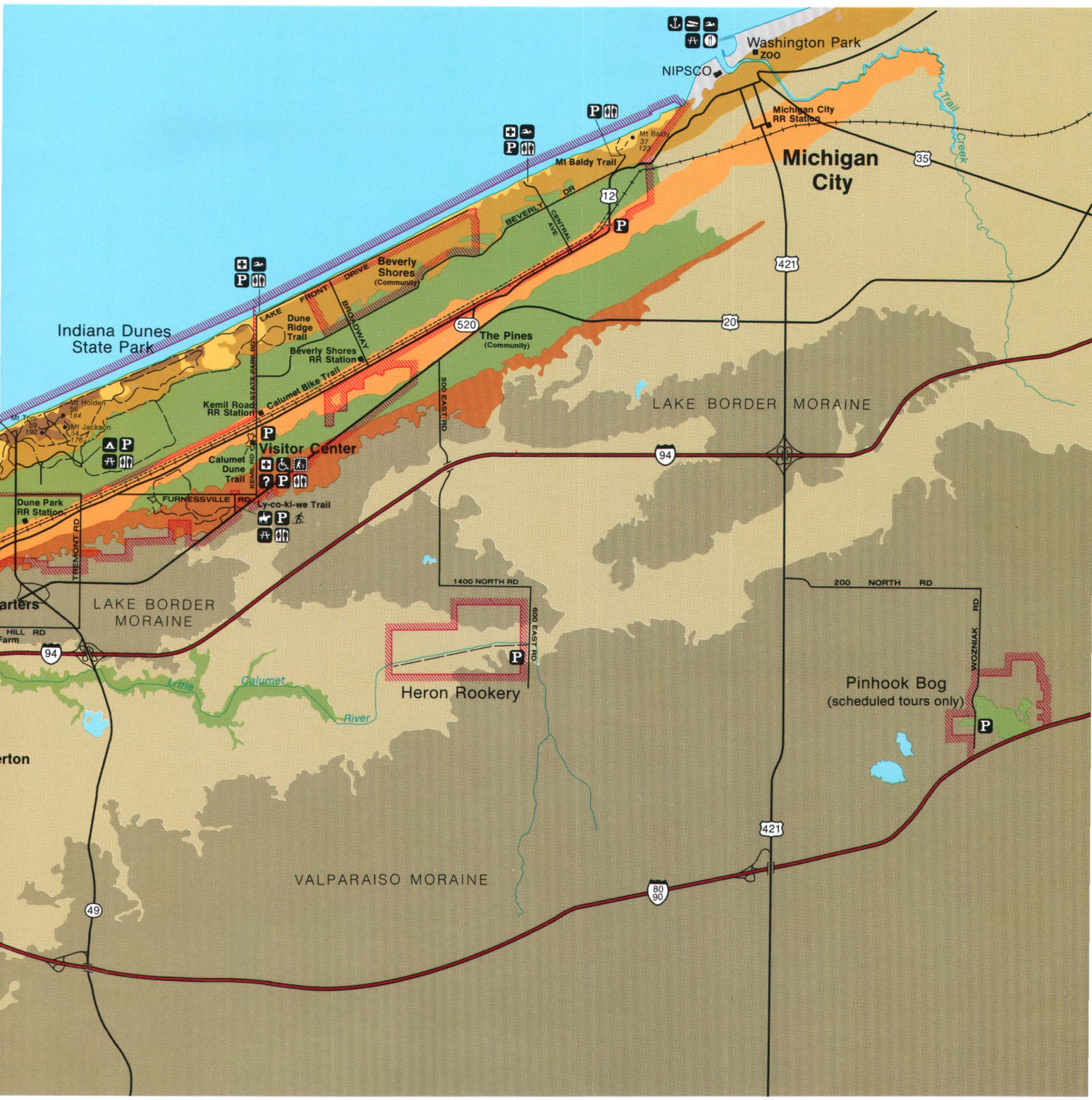
resources—information critical to land management. The land manager has to recognize a variety of user needs and develop a management plan to accommodate those needs while still sustaining and maintaining the land and its resources. Parks such as Indiana Dunes National Lakeshore provide a unique setting in which to learn how lands and resources might be managed and preserved in harmony with surrounding communities and industrial sites that make intensive use of the land.



A park ranger explains how proper management of natural resources may allow nature and industry to coexist.

Map of Indiana Dunes National Lakeshore.

Horse trail
Information
Ranger station
Parking
Restrooms
Lifeguarded swimming area
Picnic area
Campground
Handicap access
First aid
Snack bar
Interpretive trail
Cross-country ski trail
Boat ramp
Marina



The region south of Lake Michigan has grown from an area of small fishing villages and farming communities to a major industrial center and transportation avenue for the United States. This growth was originally spurred by the presence of Lake Michigan, the sixth largest lake in the world, which provided a dependable source of water suitable for most uses. Today, this region is a major transportation corridor, with shipping ports, vast railroad systems, international airports, and interstate highways.

At one time, Highway 12, which runs through Indiana Dunes, was the major highway between the Eastern and Western United States. Now, Highway 12 has been superseded by several interstate highways and the St. Lawrence Seaway, transportation facilities that are critical to the area's industry. Steel mills with 20 percent of the Nation's steel-making capacity are adjacent to Indiana Dunes, as are electric generating stations that burn fossil fuels.

Lake Michigan is a major recreational resource.

Fragmentation of the park land by urban areas can create islands of natural ecosystems and can disrupt the natural movement of plants and animals.

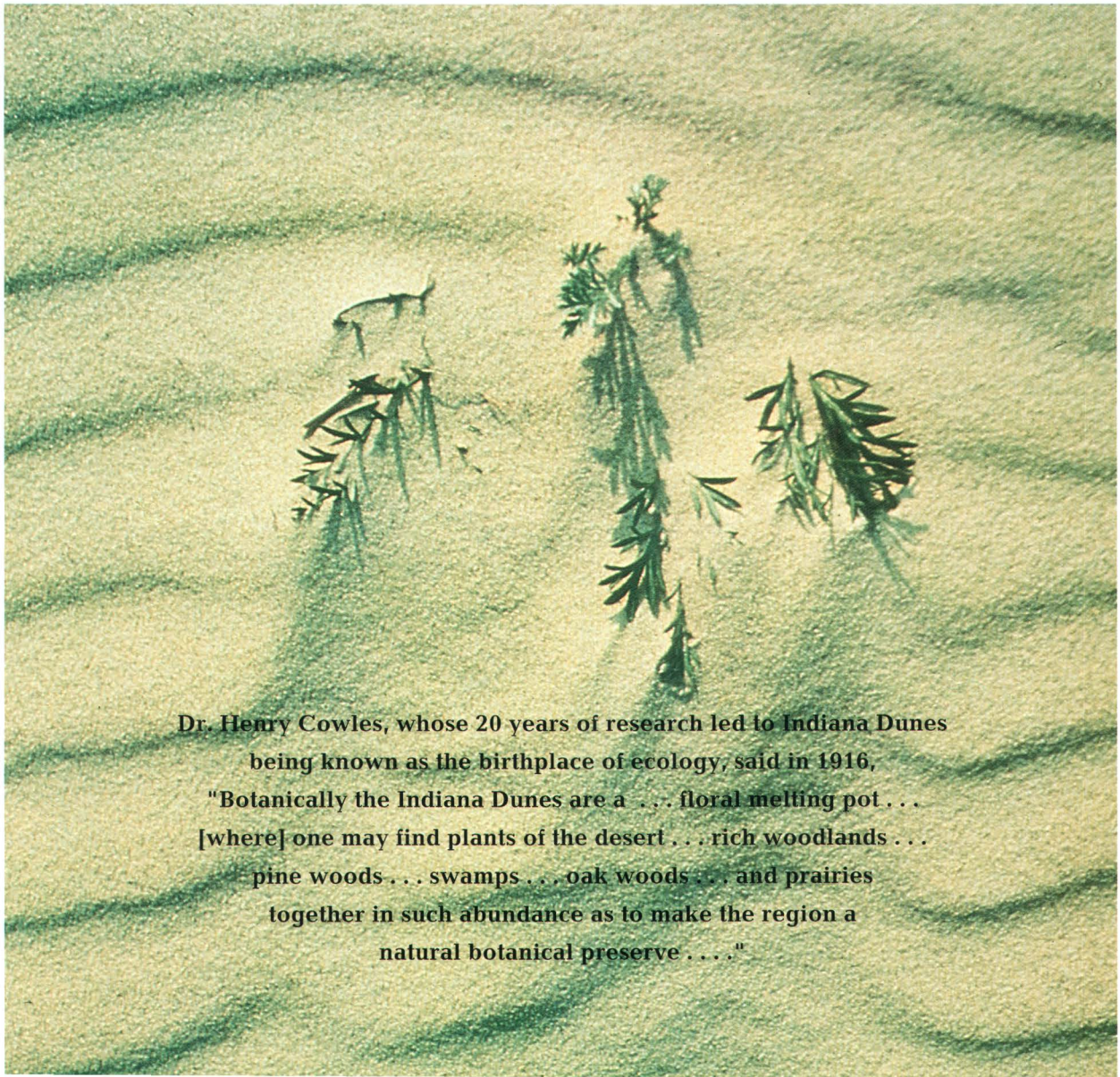
As the area has developed commercially and residentially, Indiana Dunes has become an increasingly popular recreation spot. Annual visitation to the Indiana Dunes National Lakeshore has risen from several thousand in 1966, the year in which it was established by Congress, to nearly 2 million in 1990. These numbers are not surprising, because approximately 8.5 million people live within a 90-minute drive of the park.

The growth of Indiana Dunes National Lakeshore has occurred in stages that have resulted from four separate laws enacted by Congress. These laws, passed in 1966, 1976, 1980, and 1986, gave the National Park Service the authority to purchase land and establish the

park. Because parcels of land have been added to Indiana Dunes since the original 1966 purchase, the boundaries of the whole park have become irregular, with several areas fragmented or isolated from other park areas. Currently, Indiana Dunes is divided into nine land units, many of them "islands" surrounded by industry, transportation facilities,

Indiana Dunes is most unusual in that its 14,000 acres are home to 1,445 species of plants.

Dune plants help stabilize and prevent sand from being blown away by the wind.



Dr. Henry Cowles, whose 20 years of research led to Indiana Dunes being known as the birthplace of ecology, said in 1916, "Botanically the Indiana Dunes are a . . . floral melting pot . . . [where] one may find plants of the desert . . . rich woodlands . . . pine woods . . . swamps . . . oak woods . . . and prairies together in such abundance as to make the region a natural botanical preserve . . . ."

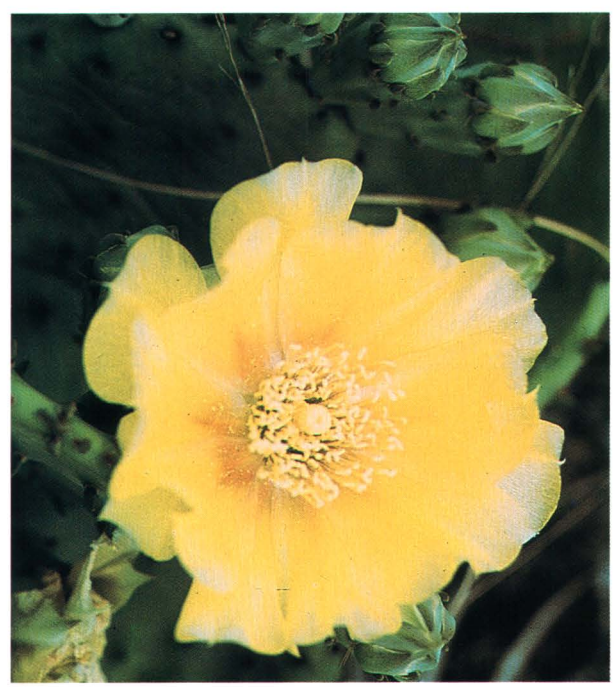
agricultural areas, or municipalities. This fragmentation creates barriers that disrupt the ecosystem by impairing the natural movement of plants and animals.

Indiana Dunes is most unusual in that its 14,000 acres are home to 1,445 species of plants. Only two national parks have more plant species: Great Smoky Mountains (1,485) and Grand Canyon (1,474). Each of these two parks has more than a half million acres of land—35 times as much land as at Indiana Dunes.

Ecosystem Fragmentation

Most ecosystems are recognized as being open systems, subject to energy inputs and outputs and immigration and emigration of species. Natural communities are protected within the park boundaries, but the park has little control outside its boundaries. Thus, the natural ecosystem processes are subject to disruption, and the park functions as an "island." Indiana Dunes is a classic example of an "island park," because it is surrounded by industry, major transportation corridors, agriculture, and municipalities. In addition, within the park, roads have been built, ditches cut, and other barriers created, all of which disrupt natural processes. The result is ecosystem fragmentation.

Although not well understood, ecosystem fragmentation has the potential to disrupt the flow of energy or the natural movement of species and species diversity. For example, studies have shown forest patch size to affect the local variety of bird species. Other studies have shown that roads and agriculture can act as barriers to gene flow among small mammal, reptile, and amphibian populations. In addition, the size of the "island ecosystems" limits their use only to those plant and animal species that can survive and reproduce within the limited area. If the plant or animal species cannot survive in the "island" fragment, it will disappear from the area.

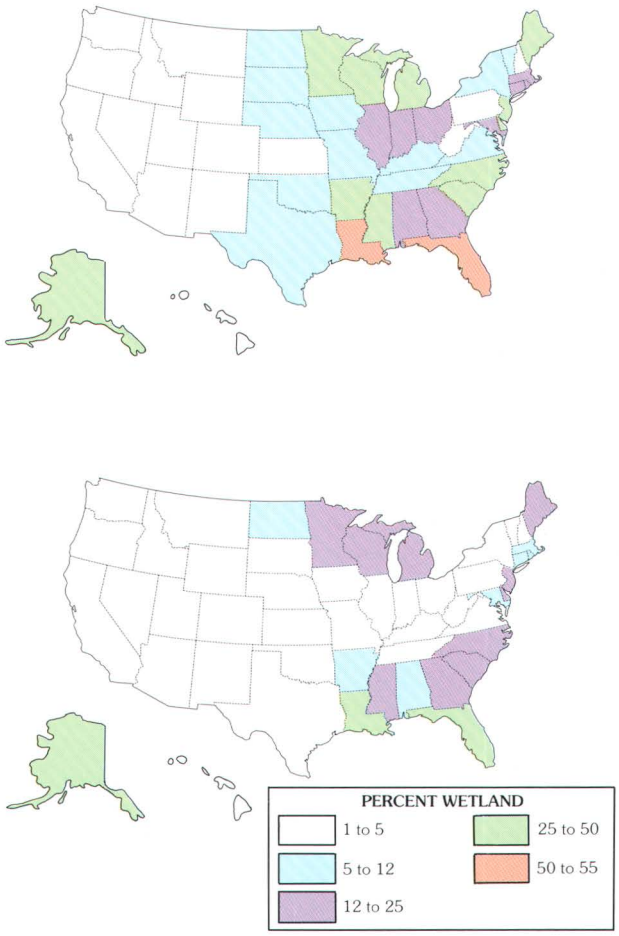


The unique environment of Indiana Dunes supports a large variety of vegetation, such as the white trillium (left) and the prickly-pear cactus (right), and is home to animals such as Canada geese, turtles, six-lined racerunners, opossums, and raccoons (opposite page).

WETLANDS

America's wetlands are decreasing in area every year. During colonial times, about 200 years ago, the contiguous United States had an estimated 221 million acres of wetlands—an area roughly the size of Texas and Oklahoma combined. Today approximately 100 million acres of wetlands remain—an area about the size of Montana. It is estimated that over the 20 years between the mid-1950's and the mid-1970's, net wetland losses from natural processes and human activities averaged 450,000 acres annually. There are many reasons for this loss, including urban and agricultural development and coastal erosion. Recognizing the vital importance of wetlands to the commercial and recreational sectors of our economy, as well as to the biological diversity of our Nation, many agencies currently are making efforts to protect, maintain, and restore wetlands.

Wetlands can be found near coastal areas or in the middle of the Nation, miles from any coast. They comprise about 4 percent of our Nation's land area within the contiguous United States. Alaska has the largest proportion of wetlands area of all the States, much of it in tundra regions. Because wetlands are found in both coastal and inland areas, the water can be salty, brackish, or fresh. Wetlands occur along rivers, ponds, bays, and inlets—wherever the ground water is at or near the land surface, or where the land is covered by shallow water during part of the year.



Wetland distribution around the 1780's (top) versus wetland distribution around the 1980's (bottom). (Modified from Dahl, 1990.)

Wetlands have many beneficial purposes, such as helping store and purify water and acting as natural filters. The U.S. Bureau of Mines has created artificial wetlands to treat acid-mine drainage; more than 300 wetlands have been constructed and successfully used to date. Wetlands also are habitat for fish and wildlife. In fact, coastal salt-marsh wetlands produce more plant and animal life than any other natural habitat known. Freshwater wetlands rank third in number of total plant and animal species behind saltwater marshes and tropical rain forests. Eighty percent of the Nation's coastal commercial and recreational fisheries depend upon wetlands for spawning, hatchery, and nursery activities. Some wetlands can store large volumes of water and can thereby serve as natural water reservoirs and as ground-water discharge areas. The presence of wetlands in a flood plain can reduce the size of floods by as much as 80 percent.

Wetlands provide a wonderfully productive and generally safe breeding ground and home for millions of birds, mammals, reptiles, and plants. More than one-third of the 564 plant and animal species listed as threatened or endangered in the United States live in wetland habitats during some part of their lives.

Lake Michigan, the historic reason for the economic development of northern Indiana, is the result of glacial retreat about 14,000 years ago. As the glacier retreated, a series of lakes (the Great Lakes) formed, and areas of dunes and wetlands developed. In fact, there are so many wetlands at Indiana Dunes that it could

Wetlands are important nesting sites for birds.

The many types of wetlands include swamps, bogs, marshes, ponds, and peatlands.

Wetlands are commonly adjacent to dunes, such as in Indiana Dunes.

More than one-third of the 564 plant and animal species listed as threatened or endangered in the United States live in wetland habitats during some part of their lives.

Great Marsh, in Indiana Dunes, has undergone a change in plant communities. Possibly as a result of human influence on the water levels, duckweed and cattails are now dominant.

just as easily have been named "Indiana Wetlands National Lakeshore." This varied topography—from wetlands to dunes—is one of the main reasons for the amazing biological diversity found in Indiana Dunes. The variation in topography, soil type, and moisture provides many niches for a variety of organisms to inhabit.

Indiana Dunes has many types of wetlands, including swamps, bogs, marshes, peatlands, and interdunal ponds. The type of wetland that develops in a specific location is dependent on numerous factors including the amount of water. A wetland type may change as water levels vary from season to season and year to year. Other factors determining the type of wetland include the level of dissolved oxygen, the relative acidity of the water (pH), and the amount and rate of water exchanged between the wetland and the surrounding environment. The type of wetland often determines the plant species present. Pinhook Bog is a good example. Here, species have adapted to the low mineral content, high acidity, and low oxygen levels of a wetland that has no output of water, except evaporation, and whose input of water is limited to the rain that falls directly on it. Many of the species that grow in this bog grow nowhere else in the dunes.

Fire!

Even the hottest of fires leaves the promise of life in its wake. Nature has endured fire just as it has endured rain, sunshine, and wind. If fires ceased to burn, certain communities of plants in the dunes, such as those in prairies, oak savannas, and sedge meadows, would cease to exist. Animals that have adapted to open prairies, such as the rare legless lizard, would eventually lose the habitat necessary for their survival. The animals and plants of Indiana Dunes have adapted to periodic fire, and without it many of them would perish.

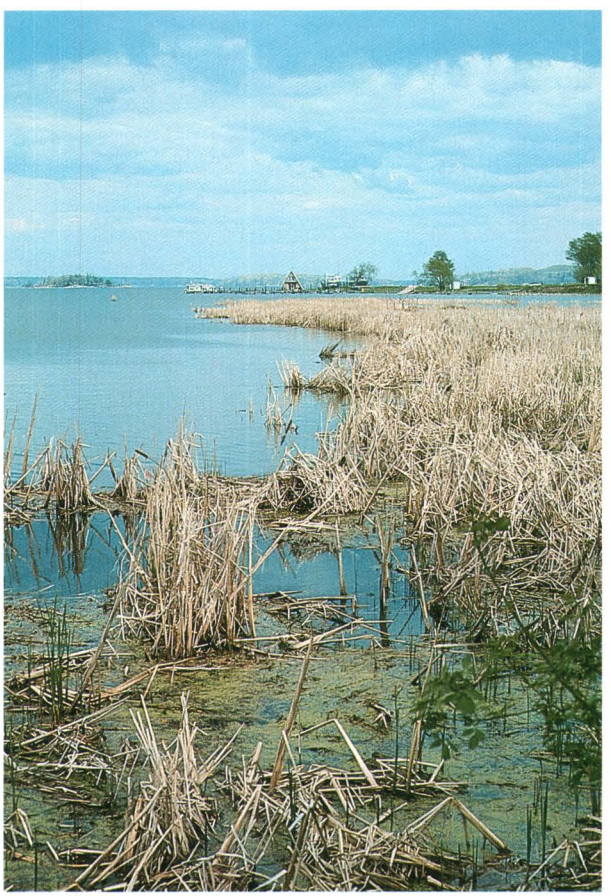
Wetlands are valuable because they store and purify water. Coastal wetlands are among the most biologically productive regions on Earth because they serve as the nursery area for many species.

This dunal pond at West Beach, in Indiana Dunes, is a rare ecosystem because it has very shallow water and a sandy bottom. It hosts a rare community of plants.

Although the Indiana Dunes has many wetlands, a considerable number were lost or altered by humans before the establishment of the park. Since the late 1800's, wetlands have been drained or filled, and streams have been channelized to "reclaim" areas for agricultural, residential, and industrial development. Many wetlands now protected in the park need to be restored, but restoration in some areas will require the elimination of artificial drainage ditches. Unless carefully planned, their removal could impact nearby communities.

Activities outside the park have the potential to adversely affect park wetlands. Continued channelization of upstream portions of waterways outside the park can damage downstream portions within the park by increasing flow rates, flooding, streambank erosion, and siltation. Residential and agricultural developments adjacent to these same waterways could contaminate them with chemical and other residues and wastes.

The National Park Service is working to preserve and protect the valuable wetlands of the Indiana Dunes. However, as with so many other plans for resource protection at this complex park, the success of these efforts depends largely on what happens outside the park on neighboring lands.



The location of wetlands can be coastal or inland. They are frequently used as resting places and refuges for birds as they migrate seasonally.

COASTAL EROSION

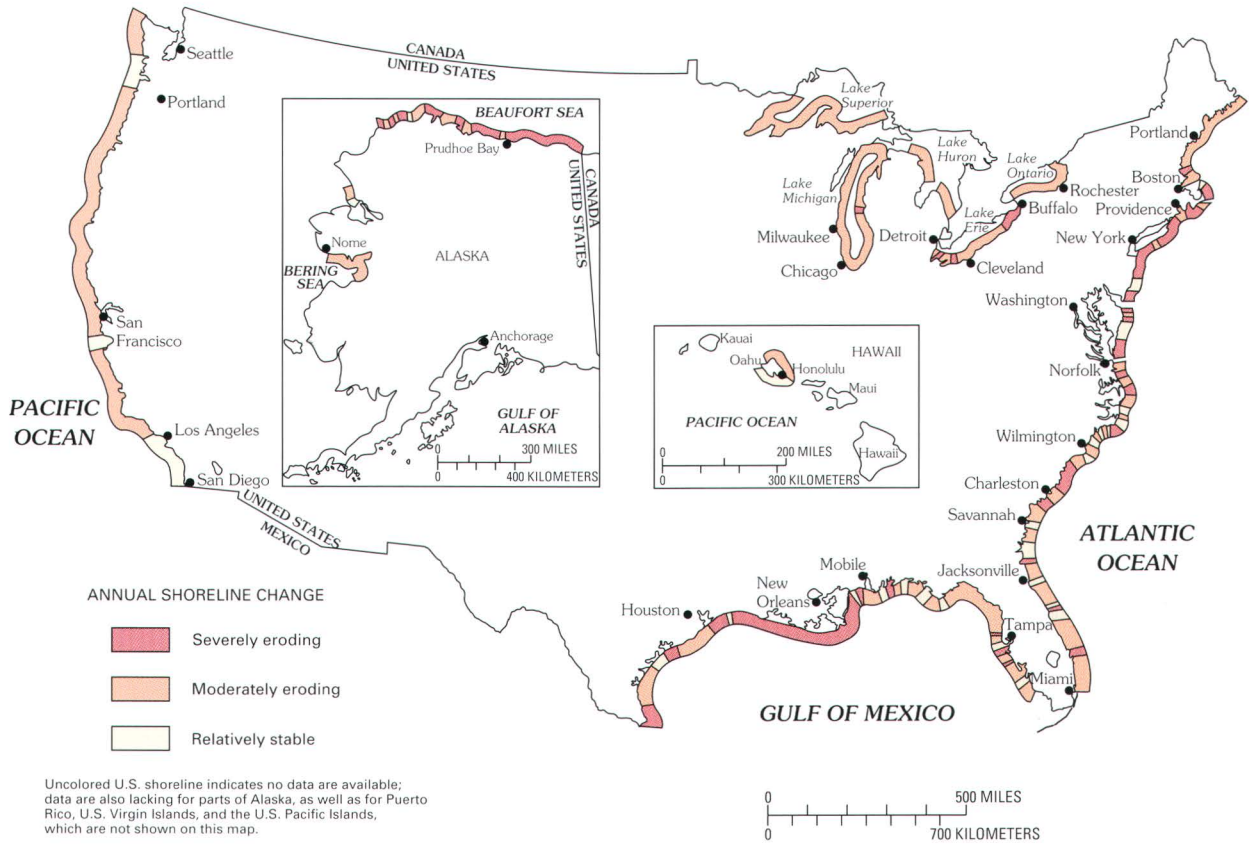
Our Nation's coastal lands are dynamic environments. The natural appeal of coasts has attracted people for centuries by providing a pleasant living environment, access to natural resources, and ease of transportation. Presently, more than half of the population of the United States lives within 50 miles of a coast. By the year 2010, it is estimated that 75 percent of the U.S. population will live within an hour's drive of a coast. Of the 10 largest metropolitan areas of the United States, 9 are located in coastal regions.

Coastal environments, whether adjacent to an ocean or a large lake, are constantly changing shape and location in response to natural processes and human activities. Waves, currents, and wind are natural forces that combine to continually reshape the beaches, dunes, and shoreline. The Nation's beaches, especially its national seashores

This small pocket beach on a rocky coast is less susceptible to erosion than barrier islands are.

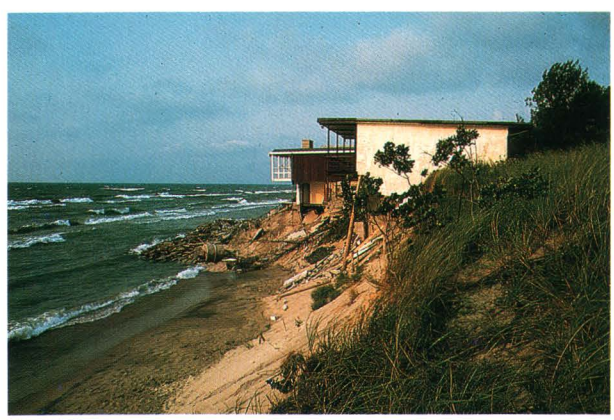
and lakeshores, are among the Nation's most important natural assets. Storms, whether frequent winter events that last for days or single intense events, such as hurricanes, can greatly modify the shape of the coastal area and can damage or destroy structures such as roads, buildings, homes, and piers.

Coastal erosion is a national problem because it affects all 30 coastal States and all of the U.S. island territories. Beaches are categorized into three types: (1) mainland beaches that stretch for miles along the edge of major land masses (such as along the coast of Washington, Oregon, and California), (2) pocket beaches formed between rocky cliffs (such as along the coast of Maine), and (3) barrier island beaches, which are part of a complex system that includes marshes, bays, tidal flats, and inlets (such as along the Gulf of Mexico and the east coast). Louisiana's barrier islands are eroding the fastest of any coast in the Nation, at a rate that in places reaches 60 feet per year. Understanding the processes that shape and change coastal regions is critical if we wish to live in harmony with the natural coastal environment.



All 30 coastal States are experiencing coastal erosion. (Modified from Dolan and others, 1985.)

Storms with high winds and waves create steep, narrow beaches, like this one at Indiana Dunes, where winter storms are frequent and especially destructive.



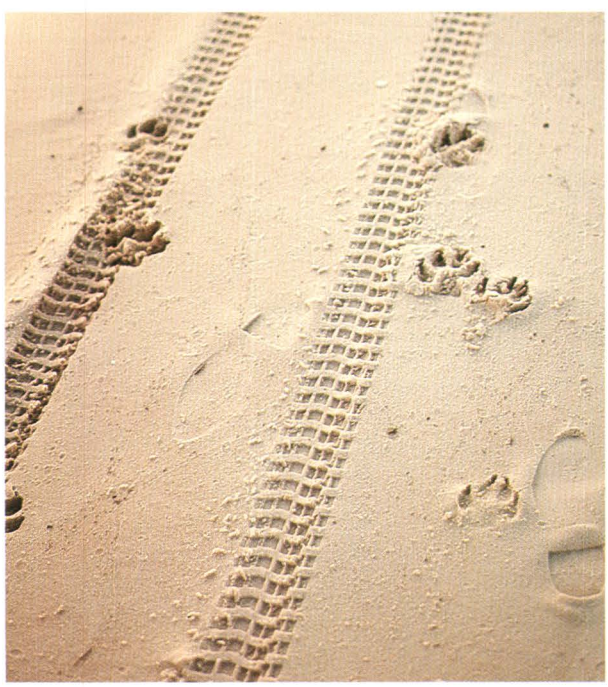
Coastal erosion causes large amounts of public and private property damage every year. This house was built close to a Lake Michigan beach that was eroding quickly.

By the year 2010, it is estimated that 75 percent of the U.S. population will live within an hour's drive of a coast.

The coastal system is a dynamic environment. Coastal erosion claims acres of beach and wetlands every year.

The coastal system extends from the offshore lake bottom or sea floor and overlying water (tens of miles from the land) to the onshore beaches, dunes, lagoons, estuaries, and wetlands. Sediment (sand and mud) is derived from rivers and the coastal area itself. Where sediment accumulates, it can build land; where it is removed, dry land can be converted to sea floor or lake bottom. The beach environment is

Erosion of dunes occurs when the beach is narrow because the source of sand for the dunes is diminished and the waves can break at the base of the dunes, as shown here at Mount Baldy in Indiana Dunes.



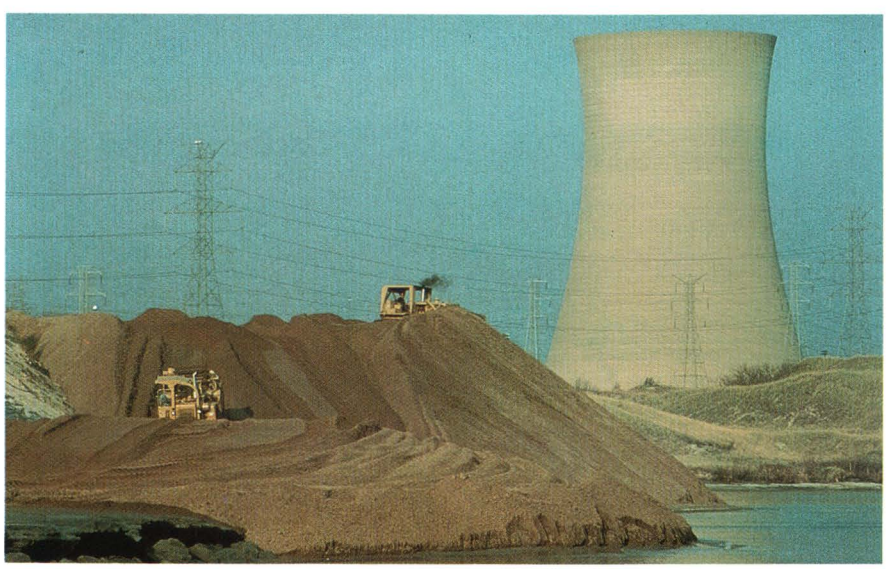
With the passing of time, foot traffic and off-road vehicles can erode the face of dunes (left) and beaches (above), especially when the same trail is used repeatedly, because vegetation cannot grow.

dynamic, changing through the seasons of the year. Beach width and slope change with the seasons as wave energy changes. High-energy waves and strong winds in winter form a narrow, steep beach covered with coarse sand and gravel. In the summer, smaller waves and gentler winds produce a broad, gently sloping beach covered with fine sand.

Structures can be destroyed easily by the effects of storms.

Dunes are an integral part of the beach environment. They form behind the beach as the wind picks up the fine beach sand and deposits it in ridges. Dunes, ranging in height from several feet to hundreds of feet, help protect the beach by preventing storm waves from washing inland and transporting sand out of the beach environment. Dunes are nature's protection for the wetlands and lagoons behind a beach. They also protect structures people have built. Dunes are complex but fragile and can be destroyed easily by trampling, off-road vehicles, construction, or mining. Coastal erosion is a significant natural process in the Great Lakes, occurring at an average rate of 28 inches per year; land is gained in some places, lost in others. This gain and loss of land is of great concern to population centers built at lake's edge, such as Chicago.

In Indiana Dunes, the 18-mile shoreline retains much of its natural character. Adjacent to the park's beaches, however, the shoreline has been altered by the construction of harbors and industrial complexes and the use of rip rap (large boulders) to protect the shore. Of the 41 miles of shoreline between Michigan City, Ind., and the Illinois border, more than half have been altered to protect private residential or industrial properties. Structures, such as the jetties at Michigan City, Burns Harbor, and U.S. Steel, interrupt the normal longshore (parallel to the beach) transport of sand. The beach is built up as sand accumulates on the updrift side of structures; the beach erodes as sand is then removed on the downdrift side.



In an attempt to slow or prevent coastal erosion, engineers place sand on the beach of Mount Baldy to maintain the beach and prevent erosion of the dune.

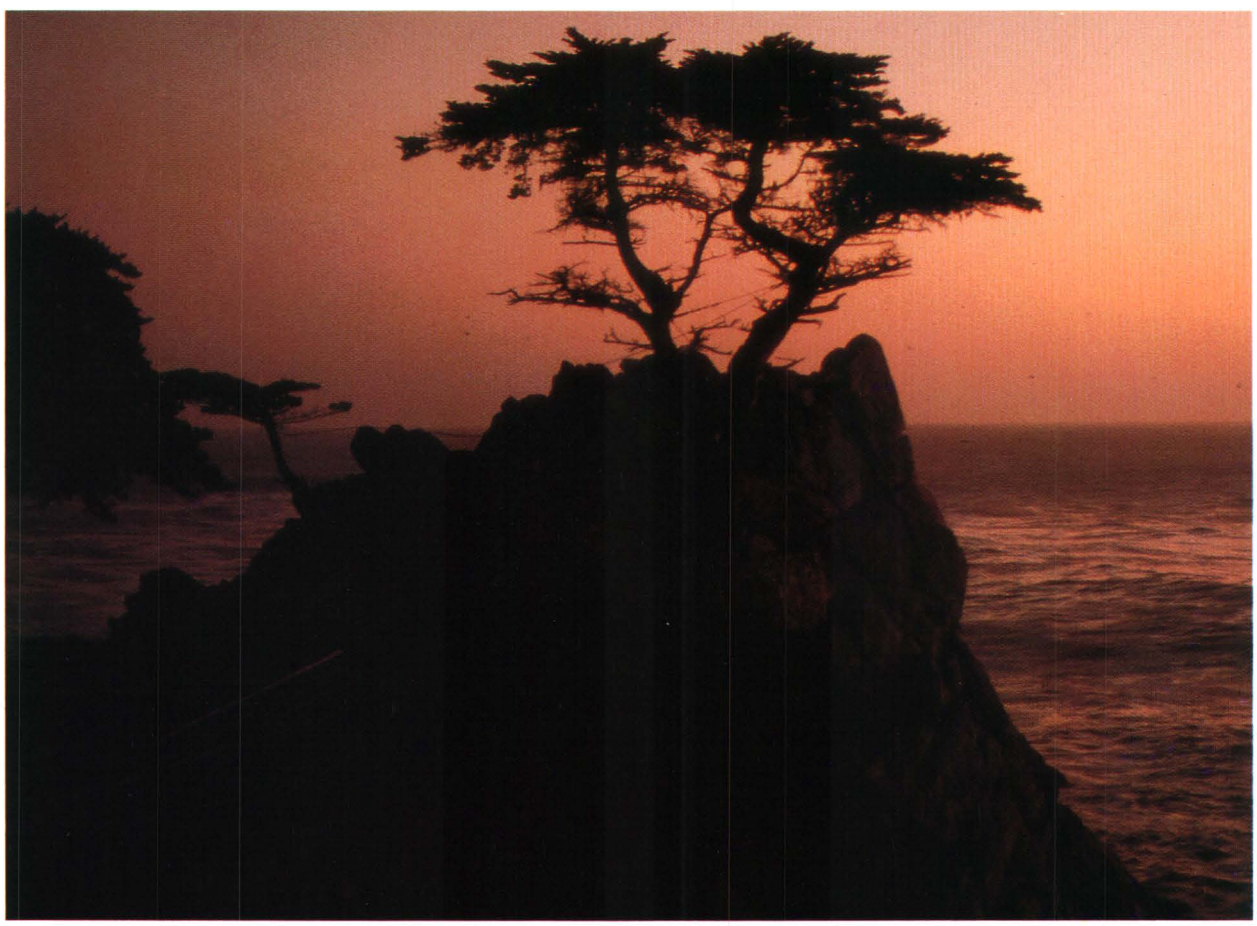
Shoreline erosion in the park results especially from storms in the early spring and late fall and during mild winters, when ice on Lake Michigan does not freeze

to the shore. In March 1964, Lake Michigan began rising until it reached a record high for the century in 1986. When lake levels are high, the beaches become narrow. The waves break at the base of the dunes and erode them. Narrow beaches provide less space for the 2 million visitors who use the beaches during the summer. People are forced onto the foredune, where they interfere with the plants and animals present and cause trail erosion. High lake levels and their resultant narrow beaches also reduce the sand supply available to replenish and build the dunes.

In order to prevent Mount Baldy from eroding, the U.S. Army Corps of Engineers placed 120,000 tons of sand in front of it in 1981. This placement of sand, called beach nourishment, must be continued to provide protection. By spring 1984, all the sand that had been placed on the beach was gone, and the waves were again breaking on the base of the dune.

Just as people can delay, but not reverse, natural processes, people can also accelerate such processes. A case in point is the use of breakwaters in the vicinity of Burns Ditch and Michigan City. When the transport of sand is interrupted along a coast, erosion can increase, such as occurs to the west of the breakwaters at Burns Ditch, and sediment deposition can increase, such as occurs on the east side of Bethlehem Steel on Cowles Bog Beach. The Michigan City breakwaters cause deposition on the city's Washington Park beach while causing erosion of the beach in front of Mount Baldy.

Plants, such as marram grass, help stabilize the dunes. As people create footpaths in the dunes and the grass dies, the wind picks up the sand and moves it farther inland, where it buries woodlands. Blowouts and depressions in the dunes occur where large volumes of sand have been removed. Thus, a seemingly harmless action, such as the passage of feet alone, can change the face of the dunes.



Beaches are among our Nation's most valuable assets.

CONTAMINATION

Contamination of our environment is becoming an increasing threat. We worry about the quality of the air we breathe and the water we drink; the quality of each is threatened by a multitude of activities. Factories discharge airborne pollutants through their smokestacks; pesticides become airborne during application. Almost any activity above or below the land surface has the potential for contaminating soil or water. Although some sources of contamination are natural, contamination generally is a result of human activity.

Examples of sources of environmental contamination include:

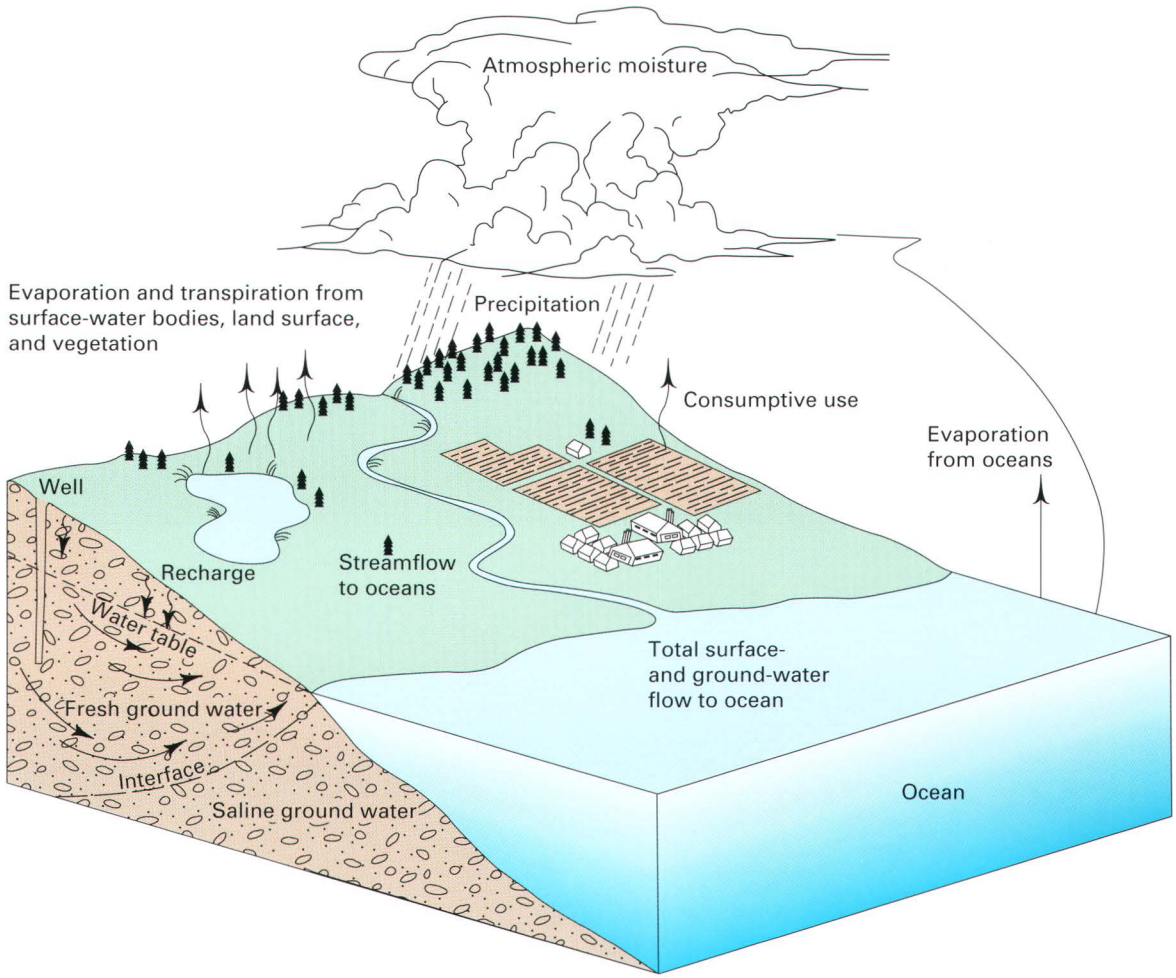
- salt stockpiles
- urban runoff
- sewage overflows
- slag piles
- wastewater ponds or lagoons
- wastewater injection wells
- landfills
- salvage yards
- septic systems
- drain cleaners or other household chemicals
- motor oil
- fertilizers or pesticides
- animal feedlots and stockyards
- automobile exhaust

Above: Industrial fires, such as this storage tank fire in Houston, Tex., can introduce contaminants into the atmosphere.

Left: Airborne particles can originate from natural sources such as volcanic eruptions. These eruptions can release large quantities of ash, gases, and aerosols, which can circle the globe in the stratosphere.

Often, we do not realize that a contamination problem exists until it is too late. In air and surface-water resources, it is likely that we can see the contamination. With our ground-water resources, however, the flow of water occurs below the land surface, and problems go undetected until that water reaches the surface—either naturally (as discharge to a lake, river, stream, or wetland) or artificially (as discharge from a well).

Water is constantly moving through the global hydrologic cycle, which includes water as precipitation and snowmelt. Water moves on the land surface toward lakes, rivers, streams, and wetlands (runoff) or goes into the ground (infiltrates) to become ground



Water is constantly moving through the hydrologic cycle.

water. Ground water moves much more slowly than surface water does. Ground water moves through aquifers (water-bearing sediments) toward lakes, rivers, streams, and wetlands. Ground water can flow toward deeper aquifers and ultimately flow to the ocean. Evaporation of surface water and water returned to the atmosphere by plants (transpiration) provide the atmospheric moisture for rain or snow and complete the flow of water through the hydrologic cycle.

If water becomes contaminated as it moves through the hydrologic cycle, the path it takes can determine the degree to which it is contaminated and the time it will take to be cleansed. One concern with ground-water contamination is the very slow flow rate. Whereas surface-water flow rates are commonly measured in feet per minute, ground-water flow rates are commonly measured in feet per year. These slow rates of movement become significant when we are waiting for an aquifer to naturally flush out contaminants, or purge itself. It is not uncommon for a contaminated aquifer to take decades to clean out. Prevention of ground-water contamination in the first place is preferable to cleaning up ground-water resources after they have been contaminated.

Activities that take place at the land surface in one location can affect water-quality conditions over a much larger area. Homeowners who apply fertilizers or pesticides to their lawns incorrectly can contaminate ground water easily, which can flow to their wells or to neighbors' wells. A landfill at the edge of a town can contaminate ground water flowing to an adjacent town's well field; agricultural application of pesticides in one State can easily contaminate ground water or surface water in an adjacent State.

Scientific information pertaining to the hydrologic cycle and the stresses on the cycle plays a critical role in the management of our water resources at local, regional, national, and global scales. For example, scientific information is needed to quantify the potential effect of contamination, to document areas where air or water resources have been contaminated, and to predict recovery times for the contaminated areas.

Although the potential sources of contamination mentioned previously are national issues, their presence at Indiana Dunes has also made them regional issues. As indicated in the "Land Use" section of this report, the southern shore of Lake Michigan is one of the largest industrial centers in the Nation and is a major transportation corridor for the Midwest. Agricultural land, which has a contamination potential from fertilizer and pesticide use, is being converted to suburban or urban land, which has a different contamination potential (septic systems and urban runoff).

Fertilizers and pesticides can be sources of water and air contamination.

Indiana Dunes National Lakeshore lies east of and within a vast urban and industrial complex. The park also contains "islands" of industrialization within its boundaries. Indiana Dunes, located within the "prevailing westerlies"—a region of the country where winds blow primarily from the west—is essentially downwind from Chicago and Gary

The ground water in Indiana Dunes is vulnerable to contamination from industrial landfills and other sources.

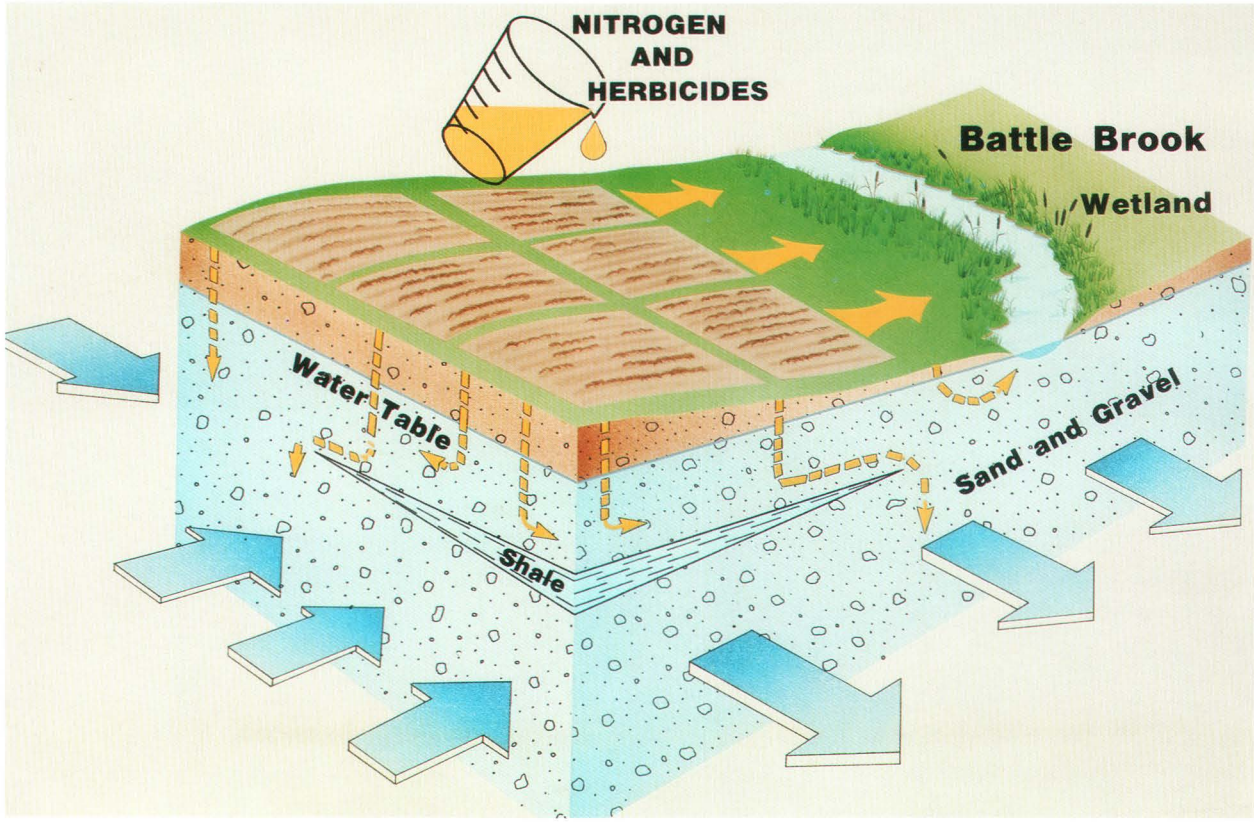


Diagram showing some of the effects of agricultural land use on the quality of soil and water. Large arrows show the direction of ground-water flow.

and receives airborne contamination from these sources. Airborne particles containing heavy metals enter lakes, streams, rivers, or wetlands by falling with rain or snow. In order to estimate historical air contamination, park scientists collected cores of peat from Cowles Bog. Cowles Bog was selected for study because it is not fed primarily by streams; thus, any metals detected in the core could be attributed to airborne contaminants. It was concluded from the study of the cores that, as industrialization occurred upwind from the park, the deposition of contaminants rose dramatically in relation to presettlement levels. The first rise in metal accumulation above presettlement levels (1850–90) is probably related to coal burning on steam locomotives, residential fires, and rapid growth of the iron and steel industry. Continued growth of the iron and steel factories during this century and operation of coal-fired powerplants brought increased metal accumulations. The parts of the cores that represent the years postdating 1978 contain lower metal concentrations, perhaps because of a reduction in steel production or an increase in emission controls.

Industrialization is important to our Nation's well-being but causes air and water contamination if preventive measures are not used.

Other air pollutants, including ozone and various sulfur compounds, have been shown to be toxic to selected plants. Effects on growth

Bogs can be affected by contaminants that are transported by air or water. As an example, highway deicing salts stored nearby had an adverse effect upon the plants in Pinhook Bog.

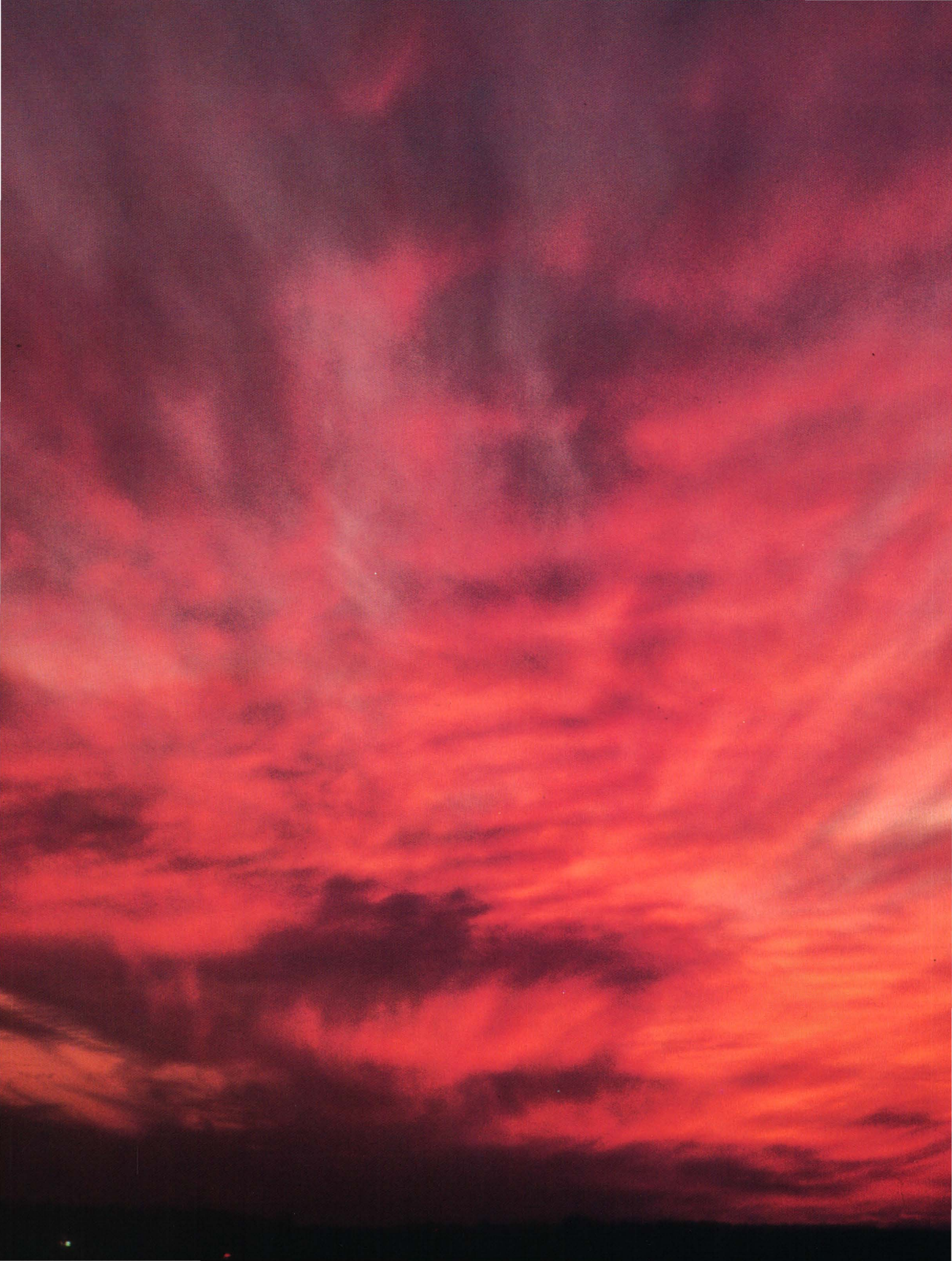
and reproduction, particularly of the white pine, have been documented through studies of tree rings. Lichens in Indiana Dunes have decreased in number by about 90 percent since the turn of the century.

Other changes in vegetation may be caused by acid precipitation. The pH of rainfall at Indiana Dunes is 4.5, which is approximately 15 times more acidic than uncontaminated rainfall, which has a pH of 5.7.

Water quality has also been adversely impacted at Indiana Dunes. Neighboring industrial, agricultural, and residential activities all present water-quality hazards. Major water-quality concerns at Indiana Dunes include bacterial contamination at swimming beaches, road-salt contamination, parking lot and highway runoff, industrial landfill contamination, seepage into the Little Calumet River and drainage ditches from sewage systems, industrial outflows, treatment ponds, and agricultural runoff. Heavy metals and high levels of nitrates and PCB's (polychlorinated biphenyls) have been found in surface water and in ground water. High bacterial levels, a danger to human health, have resulted in the closing of some beach areas and placed some restrictions on use of the Little Calumet River. Pinhook Bog was severely affected by highway deicing salts until the salt, which was stored nearby, was removed.

Another water-quality concern is litter, trash, and general dumping. Hazardous materials dumped with trash or spilled during accidents pose a threat to water quality.

General dumping poses a threat to water quality.



SUMMARY

The actions of wind, water, and people all change the land surface. Earth-science information plays a critical role in determining how well we adapt to the changes and, in the longer term, whether we can live in harmony with nature. All of the earth-science issues discussed in this report are global issues. Indiana Dunes National Lakeshore also faces the challenges presented by each of these issues. Following are some challenges we must face.

- Human activities, such as the burning of coal, oil, and gas, contribute to the amount of carbon dioxide (a greenhouse gas) in the atmosphere. A warming of the Earth's surface may result.

- As our population grows and our needs for natural resources (including land and water) increase, an area will have to accommodate these increased needs if it is to prosper.

- It is estimated that each American requires 40,000 pounds of new minerals every year to maintain his or her current standard of living.

- It is estimated that over the 20 years between the mid-1950's and the mid-1970's, the net wetland losses averaged 450,000 acres each year from natural forces and human causes.

- By the year 2010, it is estimated that 75 percent of the U.S. population will live within an hour's drive of the coast—a dynamic and fragile environment that will likely be changed by the increased population stresses.

- Almost any activity above and below the land surface has the potential for contaminating soil or water resources. This contamination can spread over large areas and take decades to be detected and removed.

The natural processes discussed in this report have been occurring for millions of years. Earth-science information provides us with estimates of extent and rates of change. We need this information to transform the challenges presented here into opportunities for locating new or additional land, water, and mineral resources; for emphasizing prevention of contamination rather than cleanup; and for increasing our ability to live in harmony with nature.

Responsible stewardship of our natural resources requires the balancing of human needs and expectations with resource realities. Although in theory many of these resources are renewable, they are renewed at very slow rates—often not in our lifetimes. Responsible stewardship accommodates these limitations.

Coordinated multidisciplinary efforts and increased cooperation among Federal, State, and local agencies, universities, and the private sector will help ensure that lessons learned at one scale or in one location will be communicated to people working at a different scale or in a different location.

Research and field investigations by the U.S. Geological Survey and the National Park Service have enhanced the understanding of the processes affecting the Earth, but more work is needed. Through concerted efforts, earth scientists will be able to provide decisionmakers and the public with the information and interpretation they need in order to plan wisely for future generations.

CHOICES . . .

If we are going to live in harmony with our changing landscape, we must manage it and use it wisely.

CHALLENGES . . .

Our challenge is to reduce our dependence on energy and minerals and to reduce the pollution and contamination that are byproducts of our consumption.

FURTHER READING

INDIANA DUNES

Cockrell, Ron, 1988, A signature of time and eternity, the administrative history of Indiana Dunes National Lakeshore, Indiana: National Park Service, 480 p.
A comprehensive history of the process and the people that led to the establishment of Indiana Dunes National Lakeshore.

Engle, J.R., 1983, Sacred sands: The struggle for community in the Indiana Dunes: Middletown, Conn., Wesleyan University Press, 288 p.

Franklin, Kay, and Schaeffer, Norma, 1983, Duel for the dunes: Land use conflict on the shores of Lake Michigan: Urbana/Chicago, University of Illinois Press, 302 p.

Waldron, Larry, and Daum, Robert, photographer, 1983, The Indiana Dunes: Eastern Acorn Press, 39 p.
A nontechnical publication about Indiana Dunes with beautiful photographs of the park.

GLOBAL CHANGE

McKee, E.D., ed., 1979, A study of global sand seas: U.S. Geological Survey Professional Paper 1052, 429 p.
Illustrates the processes contributing to the formation of sand dunes and dune fields on a global basis. Photographs and satellite images show the distribution of major sand dunes around the world. A good reference text.

National Geographic Society, 1988, Earth '88; Changing geographic perspectives: Washington, D.C., 392 p.
Summary of the Centennial Symposium convened by the National Geographic Society, which addressed critical issues facing our planet today, such as population, pollution, ecological changes, climate change, water management, and energy.

Schneider, S.H., 1989, Global warming. Are we entering the greenhouse century?: San Francisco, Sierra Club Books, 317 p.
Examines the causes of worldwide climate change and the greenhouse effect. Also provides an entertaining look at the science, personalities, and politics behind the problem of global warming.

Scientific American, 1989, Managing Planet Earth: Special Issue, v. 261, no. 3, September 1989, 190 p.
Offers a series of articles that address the various aspects of global change from the perspective of the hydrosphere, atmosphere, and biosphere. Proposes a series of strategies to deal with agricultural, energy, and manufacturing needs.

LAND USE

Robinson, G.D., and Spieker, A.M., eds., 1978, "Nature to be commanded . . .": U.S. Geological Survey Professional Paper 950, 95 p.
Illustrates the use of maps of earth-science information for decisions related to land and water management.

WETLANDS

Chabreck, R.H., 1988, Coastal marshes; ecology and wildlife management: Minneapolis, University of Minnesota Press, 138 p.
Part of a series on wildlife habitats; this volume describes the coastal marshes of the United States with particular emphasis on the northern Gulf of Mexico coastline. Environmental influences, plant and animal communities, and the reasons for alteration and loss of marshes are clearly explained for the nontechnical reader. Sections on marsh management and the future of marshes give the author's suggestions for minimizing damage to this ecologically valuable environment.

Cowardin, L.M., Carter, Virginia, Golet, F.C., and LaRoe, E.T., 1979, Classification of wetlands and deepwater habitats of the United States: U.S. Department of the Interior, Fish and Wildlife Service, FWS/OBS–79/31, 131 p.
Describes different types of wetlands across the country. A technical presentation of each type of wetland, with photographs.

Dahl, T.E., 1990, Wetlands losses in the United States 1780's to 1980's: U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., 13 p.

Documents the historical wetland loss nationwide. A compilation of existing data from a variety of sources.

Mitsch, W.J., and Gosselink, J.G., 1986, Wetlands: New York, Van Nostrand Reinhold, 539 p.

This textbook reviews different structures and functions of wetlands and discusses their ecological characteristics. A reference for scientists, engineers, and planners involved in the management of wetlands.

Watson, J.R., and Carney, Dave, 1988, Crisis on Louisiana's coast . . . America's loss: U.S. Army Corps of Engineers, New Orleans District, in cooperation with the State of Louisiana, 13 p.

Explains the economic and ecological importance of Louisiana's wetlands, the causes of their loss, and the steps being taken by the State and six Federal agencies to address this critical problem, in an easy-to-read style.

COASTAL EROSION

Dolan, Robert, Anders, Fred, and Kimball, Suzette, 1985, Coastal erosion and accretion: U.S. Geological Survey National Atlas, scale 1:7,500,000.

Dolan, Robert, and Lins, Harry, 1986, The Outer Banks of North Carolina: U.S. Geological Survey Professional Paper 1177–B, 47 p.

Analyzes highly urbanized Fenwick Island and the less developed islands of North Carolina to demonstrate the processes and hazards associated with coastal barrier islands. The intended audience includes land-use planners, managers, and developers.

Morrison, H.R., and Lee, C.E., 1981, America's Atlantic Isles: Washington, D.C., National Geographic Society, 199 p.

Beautiful photographs and readable text describe the wide variety of islands found along the U.S. shoreline from Maine to Florida, as well as the range of wildlife and human communities that inhabit this region.

Pilkey, O.H., and Neal, W.J., ser. eds., variously dated from 1983 to 1991, Living with the shore: Durham, N.C., Duke University Press.

This series currently contains 14 volumes, each of which examines the shoreline of an individual State (Florida has two volumes, for east and west Florida). The books are intended for a nontechnical audience. They review the geologic history, the history of development, the coastal processes affecting the shoreline, human intervention on the shore, government programs affecting coastal real estate, and safeguards to take when buying or building to prepare for storms and hurricanes. The books also contain a detailed analysis of the entire shoreline with recommendations of where to buy shore property.

Williams, S.J., Dodd, Kurt, and Gohn, K.K., 1990, Coasts in crisis: U.S. Geological Survey Circular 1075, 32 p.

This nontechnical publication describes our Nation's varied coastal environments and the natural processes and human actions that modify them. Its purpose is to highlight the importance of earth-science information in addressing this vital issue.

CONTAMINATION

Council on Environmental Quality, 1989, Environmental trends: Washington, D.C., Government Printing Office, 152 p.

Provides information on the current and foreseeable trends in the quality, management, and utilization of the environment and the effects of environmental trends. It is a wealth of statistical information in graphical presentation.

Johnston, R.H., 1986, Water quality issues; factors affecting ground-water quality, *in* U.S. Geological Survey, National water summary 1986—Hydrologic events and ground-water quality: U.S. Geological Survey Water Supply Paper 2325, p. 71–86.

Discusses the important factors affecting ground-water quality. Natural processes, human activities, hydrology, and climatic setting are all involved.

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This booklet provides general information on ground water, types of wells, and ground-water quality issues of interest to rural homeowners.

ADDITIONAL INFORMATION

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U.S. Geological Survey
Center for Coastal Geology
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