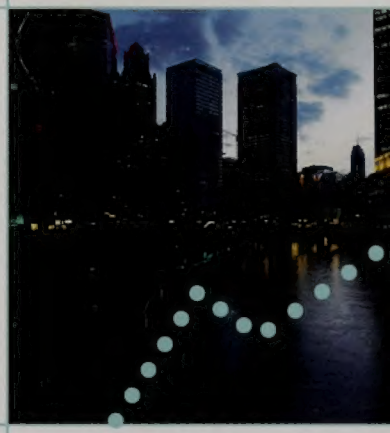
The Changing Illinois Environment: Critical Trends



Summary Report of the Critical Trends Assessment Project

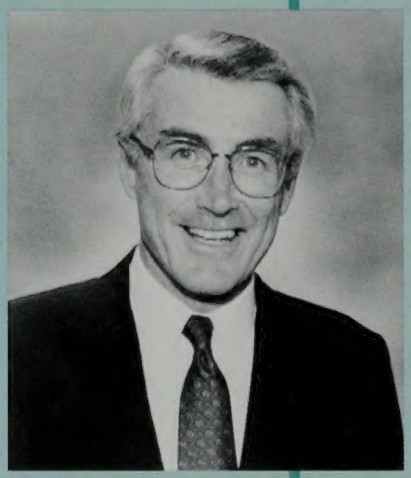
A joint publication of the Illinois Department of Energy and Natural Resources
and The Nature of Illinois Foundation

From the Governor's Desk

1994

Dear Reader:

The first Earth Day in 1970 marked a major turning point with respect to protection of the environment. Over the past twenty-five years significant progress has been made. According to this report, the air we breathe and the water we drink is much cleaner than it was two decades ago. We have made steady progress in reducing regulated pollutants, particularly point source pollution discharged from pipes or emitted from smokestacks.



Yet, this report also points out that on the eve of the 25th anniversary of Earth Day to be celebrated next year, we are still faced with complex environmental problems. The condition of our ecological systems appears to be declining. Habitat fragmentation and competition from non-native species are disrupting the stability of our natural systems.

In order to chart a course for the 21st century that ensures a high quality of life for Illinois citizens, it is critical that we understand both the progress we have made and the problems that remain. That is why I directed the natural resource agencies, led by the Illinois Department of Energy and Natural Resources, to undertake the first comprehensive review of the state of Illinois' environment. This report, *The Changing Illinois Environment: Critical Trends*, summarizes the findings of that statewide environmental assessment.

If we are going to protect our natural resources for future generations to enjoy, then we need to do more. This conclusion is shared by the Water Resources and Land Use Priorities Task Force, a citizen task force that I appointed to develop recommendations on water and land use issues.

An ongoing effort to document environmental trends and monitor ecological conditions will be crucial to making wise decisions on policies that impact the environment. This report will serve as a foundation for a long-term effort to guide the development of environmental priorities and policies. I believe this report will also serve to stimulate further discussions and lead to effective solutions for an even healthier environment and economy for the people of Illinois.

Sincerely,

Jim Edgar

Jim Edgar,
GOVERNOR

The Changing Illinois Environment: Critical Trends

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Reader's Note

Critical Trends Assessment Project (CTAP) investigators drew heavily upon the work of many different agencies. To save space, data and documents drawn from outside sources are credited to the ENR divisions that authored the respective volumes of the CTAP technical report; original sources are credited in full in the volumes listed in *Sources*, page 83.

Printed by the authority of the State of Illinois

ILENR/RE-EA-94/05 (SR)
20M/1994

Printed with soy ink on recycled and recyclable paper

CONTENTS

About the Critical Trends Assessment Project

The Critical Trends Assessment Project (CTAP) is an on-going process established to describe changes in ecological conditions in Illinois. The initial two-year effort involved staff of the Illinois Department of Energy and Natural Resources (ENR), including the Office of Research and Planning, the Geological, Natural History, and Water surveys, and the Hazardous Waste Research and Information Center. They worked with the assistance of the Illinois Environmental Protection Agency and the Illinois departments of Agriculture, Conservation, Mines and Minerals, Nuclear Safety, Public Health, and Transportation (Division of Water Resources), among other agencies.

CTAP investigators adopted a "source-receptor" model as the basis for analysis. Sources were defined as human activities that affect environmental and ecological conditions and were split into categories as follows: manufacturing, transportation, urban dynamics, resource extraction, electricity generation and transmission, and waste systems. Receptors included forests, agro-ecosystems, streams and rivers, lakes, prairies and savannas, wetlands, and human populations.

The results are contained in a seven-volume technical report: *The Changing Illinois Environment: Critical Trends*, consisting of *Volume 1: Air Resources, Volume 2: Water Resources, Volume 3: Ecological Resources, Volume 4: Earth Resources, Volume 5: Waste Generation and Management, Volume 6: Sources of Environmental Stress*, and *Volume 7: Bibliography*. (See *Sources*, page 83.) Volumes 1–6 are synopsized in this report.

The next step in the CTAP process is to develop, test, and implement tools to systematically monitor changes in ecological and environmental conditions in Illinois. Given real-world constraints on budgets and human resources, this has to be done in a practical and cost-effective way, using new technologies for monitoring, data collection, and assessments.

As part of this effort, CTAP participants have begun to use advanced geographic information systems (GIS) and satellite imagery to map changes in Illinois' ecosystems and to develop ecological indicators (similar in concept to economic indicators) that can be evaluated for their use in long-term monitoring. The intent is to recruit, train, and organize networks of people—such as high school science classes and citizen volunteer groups—to supplement scientific data collection to help gauge trends in ecological conditions.

Many of the databases developed during the project are available to the public as either spreadsheet files or ARC-INFO files. Individuals who wish to obtain additional information or participate in CTAP programs may call 217/785-0138. TDD customers may call 217/785-0211. Or individuals may write:

Critical Trends Assessment Project
Office of Research and Planning
Department of Energy and Natural Resources
325 West Adams, Room 300
Springfield, IL 62704-1892

Copies of this summary and the volumes of the CTAP technical report are available to the interested public from the ENR Clearinghouse at 1/800/252-8955. TDD customers call 1/800/526-0844, the Illinois Relay Center. CTAP information and forum discussions can also be accessed electronically at 1/800/528-5486.

FOREWORD

If we could first know where we are and whither we are tending, we could better judge what we do and how to do it...

Abraham Lincoln

Imagine that we knew nothing about the size, direction, and composition of our economy. We would each know a little, i.e., what was happening to us directly, but none of us would know much about the broader trends in the economy—the level or rate of housing starts, interest rates, retail sales, trade deficits, or unemployment rates. We might react to things that happened to us directly, or react to events that we had heard about—events that may or may not have actually occurred.

Fortunately, the information base on economic trends is extensive, is updated regularly, and is easily accessible. Designed to describe the condition of the economy and how it is changing, the information base provides the foundation for both economic policy and personal finance decisions. Typical economic decisions are all framed by empirical knowledge about what is happening in the general economy. Without it, we would have no rational way of timing these decisions and no way of judging whether or not they were correct relative to trends in the general economy.

Unfortunately, this is not the case with regard to changes in environmental conditions. Environmental data has generally been collected for its regulatory and management purposes, using information systems designed to answer very site-, pollutant-, or species-specific questions. This effort has been essential in achieving the many pollution control successes of the last generation. However, it does not provide a systematic, empirical database, similar to the economic database, which describes trends in the general environment and provides a foundation for both environmental policy and, perhaps more importantly, personal decisions. The Critical Trends Assessment Project (CTAP) is designed to begin developing such a database.

As a first step, CTAP investigators inventoried existing data to determine what is known and not known about historical ecological conditions and to identify meaningful trends. The analysis was published in a seven-volume technical report and is summarized in the present volume.

Three general conclusions can be drawn from CTAP's initial investigations:

Conclusion No. 1: The emission and discharge of regulated pollutants over the past 20 years has declined, in some cases dramatically. Among the findings:

- Between 1973 and 1989, emissions into the air of particulate matter from manufacturing have dropped 87% in Illinois, those of sulfur oxides 67%, nitrogen oxides 69%, hydrocarbons 45%, and carbon monoxide 59%.
- Emissions from cars and light trucks of both carbon monoxide and volatile organic compounds were down 47% in 1991 from 1973 levels.
- Lead concentrations were down substantially in all areas of the state over the 1978–1990 period, reflecting the phase-out of leaded gasoline.
- From 1987 to 1992, major municipal sewage treatment facilities showed reductions in loading of biological/carbonaceous oxygen demand, ammonia, total suspended solids, and chlorine residuals that ranged from 25% to 72%.
- Emissions into streams of chromium, copper, cyanide, and phenols from major non-municipal manufacturing and utility facilities (most of them industrial) also showed declines over the years 1987–1992 ranging from 37% to 53%.

Conclusion No. 2: Existing data suggest that the condition of natural ecosystems in Illinois is rapidly declining as a result of fragmentation and continual stress. Among the findings:

- Forest fragmentation has reduced the ability of Illinois forests to maintain biological integrity; in one Illinois forest, neotropical migrant birds that once accounted for more than 75% of breeding birds now make up less than half those numbers.
- In the past century, one in seven native fish species in Lake Michigan was either extirpated or suffered severe population crashes, and exotics have assumed the roles of major predators and major forage species.
- Four out of five of the state's 253 prairie remnants are smaller than ten acres and one in three is smaller than one acre—too small to function as self-sustaining ecosystems.
- Long-term records of mussel populations for four rivers in east central Illinois reveal a large reduction in numbers of all species over the last 40 years, apparently because suitable habitat was lost to siltation and other changes.
- Exotic species invasions of Illinois forests are increasing in severity and scope.

Conclusion No. 3: Data designed to monitor compliance with environmental regulations or the status of specific species are not sufficient to assess ecosystem health statewide. Among the findings:

- Researchers must describe the spatial contours of air pollutant concentrations statewide using a limited number of sampling sites concentrated in Chicago and Metro-East.
- Much more research is needed on the ecology of large rivers, in particular on the effects of human manipulation.
- Stream-gauging records are not generally long enough to identify fluctuations that recur less frequently than every few decades.
- The Sediment Benchmark Network was set up in 1981 with some 120 instream sediment data stations; by 1990 the network had shrunk to 40 stations, the majority of which have collected data for only one to three years.

CTAP is designed to begin to help address the complex problems Illinois faces in making environmental policy on a sound ecosystem basis. The next edition of the Critical Trends Assessment Project, two years hence, should have more answers about trends in Illinois' environmental and ecological conditions to help determine an effective and economical environmental policy for Illinois. ❖

WAVES OF CHANGE

Chapter 1

Beginning roughly in the early 1800s, Illinois has been swept by waves of environmental change as people of successive eras converted the natural environment to economic goods. Page 2

Waves of Change

Humans have always been successful at making the world more habitable for themselves wherever they settled. They have done so by their conscious and increasingly expert manipulation of local ecosystems. In Illinois as elsewhere, landscape disturbance is not a byproduct of human habitation but the point of it.

Change and the Environment

The fact of environmental change has been constant throughout the human occupation of Illinois, but how and why people have changed Illinois has varied with time and with people's expectations of the landscape. Natural Illinois has been perceived variously as wilderness to be quelled, destiny to be fulfilled, and progress to be enjoyed.

Beginning roughly in the early 1800s, Illinois has been swept by waves of environmental change as people of successive eras converted the natural environment to economic goods—and did so not always aware of or concerned with the consequences to ecological systems.

Complex in cause and effect, these waves of change coincided approximately with Illinois' presettlement, agricultural, industrial, and postindustrial eras. Each era had a characteristic system of production (and associated pollution), a characteristic artifact, and a characteristic urban form. The economy of each was powered by a characteristic "general engine" fueled by a characteristic energy source.

For example, in the early 19th century, Illinois' mainly subsistence economy ran on muscle and wood; these provided the energy to scattered farmsteads in a society whose general engine was the human body and whose characteristic "urban" form was the frontier trading post. After 1820 or so, the horse (hitched to plows or wagons) powered a still-dispersed society that had come to consist of developed farms linked economically to rural small towns. After the Civil War, horses fueled by hay and oats were replaced by coal-powered steam engines; the railroad and the factory were the typical artifacts of industrial Illinois, and together they made possible the densely built (and densely polluted) modern city. Since 1920, the "automobile subdivision" has become the typical urban form in a landscape whose characteristic urban artifact is the shopping mall, which functions in a society in which petroleum energy and the internal combustion engine are undoing the urban concentrations of the 19th century.

The Presettlement Era

Beginning some 10,000 years ago, Native Americans of various cultures occupied Illinois. Their economy, during that long tenure, was more closely linked to the local land resource than is that of today's Illinoisans. Summer valley camps, where Native Americans harvested mussels and fish, typically gave way in autumn to equally temporary upland sites, where the people harvested nuts and hunted game, with stops at work camps, where weapons points and tools were fashioned from local deposits of flint.

The European settlers who came to Illinois in the late 17th century were primarily traders, farmers out of necessity rather than training. The focus of their economy was not crops but animals—which they sought as a source of food and furs—or isolated

proto-industries, such as the extraction of salt from springs in far southern Illinois in the 1700s. What farming they did was subsistence agriculture, using methods largely adapted from the Native Americans. Considered in terms of environmental impact, therefore, the Native American era in Illinois may be said to have lasted until the 19th century.

1820 to 1920: Agriculture Takes Root

Beginning with the opening of the Erie Canal in 1835 and ending roughly with World War I, railroads and farm machines made farming more efficient and more profitable. The Illinois interior was made accessible to distant urban markets that absorbed the surpluses made possible through efficiency. Trading in resources began to be done at a distance and in bulk.

The farmers who constituted the second wave of environmental change in Illinois were mainly experienced farmers from northern Europe. Unlike Native Americans and early European farmers who relied on the hoe, farmers of the second wave utilized technology (in the form of the steel plow and, later, the railroad) and production capital (in the form of draft animals, barns to house livestock, and wagons).

As farming changed, so did the Illinois landscape. But while the prairie ceased to be prairie, it did not cease to be grasslands for decades after farmers first ventured out of the woods. Some prairie was left as a hay source, and much plowed prairie was replaced by plantings of "tame" grass such as timothy, producing a simplified version of the mixed forest and grassland ecology the farms replaced.

The mixed grain and livestock farm of the late 19th century was a productive and sustainable system, adapted from land-short Europe by the addition of corn to the crop rotation in place of the wheat grown by earlier farmers. (Corn, an exotic species imported by Native Americans from South America, was better suited to the more extreme weather conditions of Illinois.) On the basis of that farming system, rural Illinois enjoyed historic population growth and prosperity in the decades prior to 1920.

1850-1960: The Concentration of Power

Industrialization was the third wave of environmental change in Illinois. It concentrated people, productive resources, and pollution on small tracts of land. Chicago was the paradigm, not just for Illinois, but for the world. The centralization of grain trade, lumber, and meatpacking at that continental transportation node transformed that city into a colossus, but other Illinois cities boomed as well.

By the end of the 19th century, Illinois was urban in all but physical form, as its economy, politics, and lifestyles were dominated by cities, especially Chicago. The increased scale of the century's new commercial enterprises led to a scaling up of environmental stress.

The concentration of productive enterprise in the cities drew people off the farms looking for—and finding—better wages for less labor. Amassing hundreds of thousands of people in one spot meant accumulating the wastes produced by the organisms, biological and economic, that sustained them. Chicago's buildings were blackened by its own coal smoke. The massive dumping of sewage and other wastes into the Chicago River eventually led to equally massive damage to the upper Illinois River after the flow of the Chicago River was reversed in order to divert pollution from Lake Michigan to the Illinois via the Des Plaines River.

The industrialized central city was a product of this era. So was the rural residential

Farmers of the second wave utilized technology and production capital. As farming changed, so did the Illinois landscape. Page 3

Industrialization was the third wave of environmental change in Illinois. It concentrated people, productive resources, and pollution on small tracts of land. Page 3

Industrial methods came to the countryside, transforming it as fundamentally as they had the cities. Page 4

If the mark of the industrial era was concentration, that of the postindustrial age is dispersal, courtesy of the internal-combustion engine. Page 4

suburb, which evolved as a refuge from the dirt and congestion of the central city. Railroads were the means of suburban dispersal, and pollution was the prod, as wealthier families fled to cleaner surroundings on the still unspoiled countryside.

When industrial methods came to the countryside, they transformed it as fundamentally as they had the cities. Beginning about 1920, a series of innovations released farming from the ancient bounds imposed by nature. New, artificial fertilizers meant that agricultural productivity was now limited not just by a farmer's skill in husbanding the soil but by economically purchased nitrogen, phosphorous, potassium, and sulfur. The old corn-oats-clover crop rotation was abandoned as affordable tractors powered by internal-combustion engines made draft horses and the forage crops needed to feed them unnecessary. The shift from animal husbandry toward specialized row-crop culture simplified farm operations at the expense of concentrated chemical and physical stress on land.

The Postindustrial Era

Pollution has abated considerably in Illinois since the first quarter of this century. The poor condition of its air and water spurred the state on to take the national lead in programs to improve them, from wastewater treatment in the 1920s to bans on open dumps in the 1960s.

Stricter anti-pollution regulations accounted for some pollution reductions. Others were owed to new technologies and changes in the state's economic base, since many of the state's declining industries, such as steel-making and meat-packing, also had been the dirtiest. Pollution has, in effect, been exported to those other nations and U.S. states that increasingly make the things that Illinoisans buy.

By the 1920s the shape of a new, postindustrial Illinois had become clear. If the mark of the industrial era was concentration, that of the postindustrial age is dispersal, courtesy of the internal-combustion engine. Suburbs as an urban form dated back to the mid-19th century in Illinois, but the widespread adoption of suburbs as a way of life had been interrupted by the Depression and World War II. Beginning in the 1950s, the automobile, the truck, and the highway put rural land within reach of an expanding, house-hungry middle class and, later, of businesses.

The 19th-century steam railroad had not made new kinds of cities possible, although it made it possible to build cities in new kinds of places and at unprecedented densities. The car and truck, however, created a genuinely new urban form—the low-density, dispersed "edge city," exurb, satellite city, whose nascent form was the massive new housing constructed on the urban periphery (most of it on former farmland) during the postwar boom. Neither small town, bedroom suburb, nor city, these new places are now the dominant urban form in Illinois. The result is the familiar Illinois landscape of today, in which the 19th-century industrial cities are surrounded by sprawl that is overtaking the 19th-century rural small towns that survive from the state's agricultural heyday.

As Illinois cities began to spread out, their impact on the landscape grew diffuse as well. In a historical irony, the automobile, which was embraced a half-century ago to escape traffic congestion and pollution, has become a cause of both in Illinois' metropolitan fringes. Attempts to alleviate the local effects of pollution, such as building taller smokestacks, have helped create regional, even continental problems; "downstream" impacts such as acid rain are now defined in atmospheric as well as aquatic terms. And Illinois' dependence, since the mid-1900s, on fossil fuels is a local practice that may be having global effects as a result of emissions of so-called greenhouse gases.

The Forces Behind Change

Different as they were in other ways, successive major changes in the Illinois landscape have been caused by the same basic demographic, economic, and technological factors.

The most dramatic change in the Illinois landscape since the start of its European phase is the fact that there are so many more people on it. Illinois' population exploded from a little more than 800,000 in 1850 to well over eight million a century later. Nearly one million people were added to the state's rolls every decade between 1890 and 1930—a period, not coincidentally, that also saw the most dramatic conversion of natural systems to human use.

Census numbers alone are not a dependable measure of the stress that human populations put on natural systems. Relative wealth matters. Total solid waste output in Illinois has outpaced recent population growth.

Technology matters as well. Roughly the same number of people lived in rural Illinois in 1930—around two million—as had lived in rural Illinois since 1870. But the 1930 rural population had an impact on the land that was disproportionate to its size. Whereas 1870s farmers used horses and manure in a system of rotated crops and pasturage, their 1930s counterparts had begun to use tractors and artificial fertilizers for the near-continuous cultivation of high-yield hybrid grains. The result was the elimination of the secondary grasslands ecology that had replaced the original prairie as the dominant system in rural Illinois.

The exhaustion of one resource tends to "create" others by making the costs of developing alternatives worthwhile. Coal was known to exist in Illinois as early as the 17th century, but it was not until trees grew scarce that coal commanded prices high enough to return the higher costs of mining and shipping it.

Similarly, lower-priced alternatives can deplete the economic potential of resources that remain physically intact. Production from Illinois clay pits shrank by 90% between 1965 and 1990 in the face of intense competition from clays and clay products produced in the American South and backhauled at favorable freight rates on trains making return trips after delivering Illinois grain to the Gulf Coast.

Decisions about resource use usually depend on the prices resources can command. Unfortunately, price is a measure of only short-term value. Some economic historians argue that, in the latter decades of the 19th century, Illinois farmers exported to the East wealth produced by Midwestern soils at prices that did not account for the cost of maintaining the resource. Heaviest among these ignored costs were water pollution and topsoil depletion.

Industrialization complicated the arithmetic by which the costs and benefits of resource development had traditionally been calculated. Until the mid-19th century, pollution was a local phenomenon with local effects. When Illinoisans were able to buy goods manufactured outside the state, they shifted the costs of the pollution produced in making them to distant places. The residues from ores used in Chicago's steel mills poisoned Michigan's streams, not Illinois', and houses in Decatur were built of wood from forests being leveled in the southern and northwestern parts of the United States.

But the scaling up of enterprises in the industrial era meant that the pollution that *was* produced locally was produced on an unprecedented scale. Packing meat in a local plant for a thousand customers produced wastes that microorganisms in local streams could usually absorb; packing meat for a million customers nationwide produced wastes so voluminous that no stream could remove them, much less absorb them.

The population in Illinois exploded from a little more than 800,000 in 1850 to well over eight million a century later. Page 5

Some economic historians argue that, in the latter decades of the 19th century, Illinois farmers exported to the East wealth produced by Midwestern soils at prices that did not account for the cost of maintaining the resource. Page 5

Pollution in post-industrial Illinois has become increasingly dispersed and dilute compared to that of the industrial era. Page 6

Few people in Illinois—apart from farmers—perceive that their economic livelihood depends on the natural realm. Page 6

The focus of natural resource policy at all levels of government during the last half-century has been the reduction of the worst pollution of the industrial era. Efforts to curb industrial pollution typically lag behind the economic changes that created it, in some cases by a century or more. It takes time for pollution to manifest itself as a threat to human health, and even longer for political systems to contrive remedies. As a consequence, much of the pollution typical of the 19th-century industrial era lingered in Illinois until the 1960s.

Pollution in the postindustrial era is of a different character. The shift of energy sources from wood to coal to petroleum left polluting residues that are increasingly exotic chemically and whose health impacts are not yet clearly understood. Pollution in postindustrial Illinois has become increasingly dispersed and dilute (and thus less visible) compared to that of the industrial era. Reducing pollution from thousands, even hundreds of thousands of separate small sources such as automobiles has proven to be a challenge both politically and economically, although, here again, the trend is toward cleaner processes. However, research suggests that focusing on pollution as the measure of environmental degradation may have obscured the extent to which natural ecosystems have been compromised in Illinois.

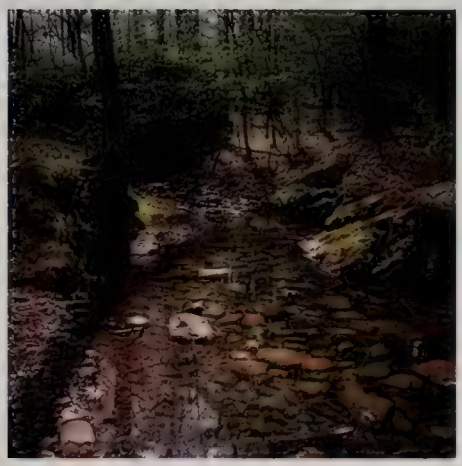
The Next Wave?

Illinois' environment will continue to change as a result of human dominance. Less certain is if or to what extent humans can anticipate and thus control the direction and pace of that change. Perceptions about the Illinois environment vary enormously across eras and across social groups. Change begets change; as each generation of Illinoisans alters the landscape, later Illinoisans see and feel differently about the land, and thus act differently regarding it. Today few Illinoisans—apart from farmers—perceive that their economic livelihood depends on the natural realm.

For the century and a half that Europeans have been present in Illinois, the environment has been seen in mainly utilitarian terms. The only systematic data widely collected about the virgin landscape came from the records of its sale. Large-scale manipulation of the Illinois environment, whatever its very real benefits to the state's human populations, has always preceded our understanding of its impacts. Making Illinois habitable for humans thus has had serious and largely unforeseen impacts on the larger natural world of which humans are a part and on which humans still depend. Having learned that lesson, it seems incumbent on us to try to anticipate the less happy consequences of future change and, through knowledge, to avoid or minimize them while still providing Illinois with jobs, shelter, and recreation. ❖

Findings I: Sustaining Riches

Atmosphere



Streams & Rivers

Land

Chapter 2

In general, air quality in Illinois is improving.

- **Between the years 1978 and 1990, concentrations of seven criteria pollutants and several heavy metals showed either no trend or decreasing concentrations. Page 8**

- **Lead concentrations were down substantially in all areas of the state over the 1978–1990 period, reflecting the phase-out of leaded gasoline. Page 12**

- **Trends in ozone concentrations are down significantly in the Chicago area and statewide, after allowing for the effects of temperature; no ozone trends were detected in the Metro-East area, whether or not temperature effects were allowed for. Page 9**

ATMOSPHERE

The atmosphere above Illinois is not only the source of the air we breathe and the water that sustains us but is also a vast chemical laboratory in which polluting "acid rain" and ozone are manufactured and protective ozone in upper layers is chemically dismantled.

THE CHEMISTRY OF POLLUTION

Sulfur dioxide, carbon monoxide, particulate matter, nitrogen oxides, and lead are among the substances emitted into the air in sufficient quantities to have been targeted as pollutants. Sulfur dioxide (SO_2) can be produced during petroleum refining or when fuels containing sulfur compounds are burned. Oxidized and combined with water in the atmosphere, SO_2 can produce an ultrafine mist of sulfuric acid (H_2SO_4); its presence in air has been correlated with increased rates of human death and disease. (On the more positive side, atmospheric sulfate particles can reduce solar heating.)

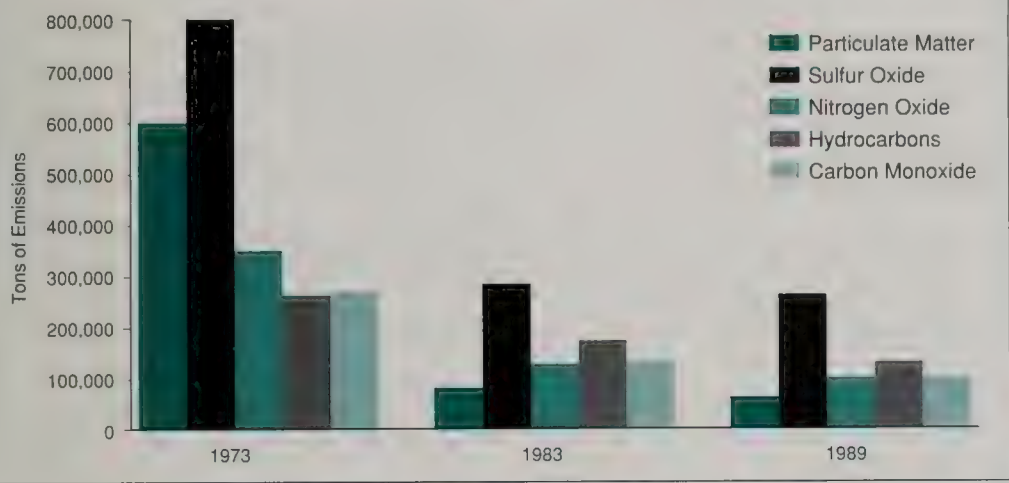
Particles are solids—very small bits of metals, fibers, stone dust, ash, and soot produced by all sorts of activities. Ozone is a pulmonary irritant, a gas created when atmospheric nitrogen dioxide and volatile hydrocarbons are bombarded by ultraviolet light energy from the sun. Assorted compounds of nitrogen are produced when fossil fuels are burned; two of them, nitric oxide and nitrogen dioxide, are quite reactive and are precursors of ozone. Carbon monoxide is a product of the incomplete combustion of virtually all fuels, although most of it comes from motor vehicles.

In general, air quality in Illinois is improving, at least as judged by its concentrations of seven criteria pollutants for which national and or state standards have been set. A CTAP analysis of routine Illinois Environmental Protection Agency air quality measurements carried out from 1978 through 1990, plus a series of nonroutine measurements of certain organic compounds, showed either unchanging or decreasing concentrations of all pollutants. Statewide data were available for twelve pollutants; of these, seven showed signs of decreasing trends. Regionally, only the Metro-East area near St. Louis recorded significant pollutant increases (for iron and manganese).

Manufacturing. Historically, manufacturing has been the major source of air pollution in Illinois. But recent declines in traditionally dirty-air industries, such as steel-making, combined with enforcement of federal clean-air regulations, have measurably improved air quality in Illinois. Between 1973 and 1989, emissions of particulate matter dropped 87% in Illinois, those of sulfur oxides (SO_x) 67%, nitrogen oxides (NO_x) 69%, hydrocarbons (HC) 45%, and carbon monoxide (CO) 59%. (Figure 2-1) Between 1973 and 1989 manufacturing's environmental cost in Illinois—the pollutants produced per million dollars of factory output—declined for all pollutants, from 57% for hydrocarbons to as much as 87% for particulate matter.

As per 1986 federal legislation, certain large emitters among Illinois manufacturing facilities are required to report releases into the environment of more than 300 toxic chemicals and 20 categories of chemical compounds. The quality of the data used to compile this annual Toxic Release Inventory is not perfect, but a general picture of industrial emissions emerges. Data from 1991 show that reported releases into the air via both smokestacks and fugitive emissions amounted to 77.5 million pounds.

Figure 2-1 Statewide Manufacturing Emissions 1973, 1983, and 1989



Source: *Sources of Environmental Stress*, ENR Office of Research and Planning, 1994

Factories are polluting less.

• Between 1973 and 1989, emissions of particles from manufacturing dropped 87% in Illinois, those of sulfur oxides 67%, nitrogen oxides 69%, hydrocarbons 45%, and carbon monoxide 59%. Page 8

Nonetheless, conventional air pollution declined overall even in Illinois' factory districts. Within the Chicago area only one location stood out for its high concentrations of multiple pollutants, and that was the industrial southeast part of the city around Lake Calumet.

Nonmanufacturing Sources. While a relatively few large facilities put the most pollutants into the air, thousands of small individual sources in the wholesale and retail trades, finance and insurance, real estate, and government combine to generate tens of thousands of tons of criteria air pollutants. Trends in emissions of total suspended particles, sulfur dioxide, nitrogen oxide, total hydrocarbons, and carbon monoxide from these sources are downward, that for CO is up, and those for NO_x and HC are steady or up only slightly. Over the last 20 years the Illinois services sector, which is cleaner per unit of output than the manufacturing sector, has shown the most growth (87 %) in output and employment, which explains in part the downward trend in overall emissions.

Chicago and Metro-East do not, however, meet federal Clean Air Act standards for ozone. Ozone precursors include volatile organic compounds (VOC) emitted from paints, solvents, glues, inks, etc., emissions of which have leveled off or declined in recent years. Ozone precursors also include NO_x, which is emitted from home furnaces, vehicles (including construction equipment), structure fires, and lawn mowers.

Output of NO_x and CO in the Chicago area increased overall since 1970, although both fell in Cook County after peaking in 1980. Furnaces and heavy construction equipment produce an overwhelming share of the NO_x (97 %) from smaller sources, and construction and lawn equipment generate about 90% of the CO. (Such machinery is not subject to the strict emissions standards applied to cars and trucks.) High emissions of both would be expected in rapidly building suburban residential areas such as DuPage County, where construction employment increased 444% between 1967 and 1989; unlike factory-related emissions, however, these high concentrations are short-lived.

A majority of Illinois hospitals, crematoriums, veterinary clinics, and other medical facilities continue to burn their wastes on-site, mainly to reduce waste volume prior to landfilling. In addition to criteria pollutants, hospital incinerators tend to emit relatively

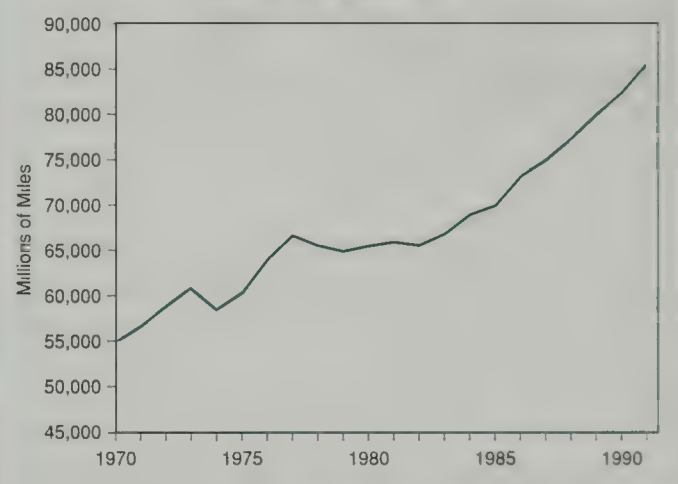
Illinoisans are driving more but polluting less per mile.

• The number of vehicle miles driven in Illinois has grown 30%—from 61 billion miles in 1973 to 86 billion in 1991. Page 12

• Emissions of CO from cars and light trucks in the same period dropped two million tons (47%), emissions of volatile organic emissions were down 315,000 tons (47%), and NO_x emissions were down 25,000 tons (8%). Page 12

more dioxins and acid gases such as hydrogen chloride than do municipal incinerators, in part because of the high concentrations of plastics in hospital waste streams. Currently Illinois regulates only the amount of particulate matter and CO emitted; these incinerators, however, will have to comply with additional medical waste incinerator emission standards expected to be proposed in 1995 under the amended Clean Air Act. Standards will be proposed for particulate matter, sulfur dioxide, hydrogen chloride, oxides of nitrogen, carbon monoxide, lead, cadmium, mercury, dioxins, and dibenzofurans.

Figure 2-2 Number of Vehicle Miles Traveled (VMT) in Illinois 1970–1991



Source: *Sources of Environmental Stress*, ENR Office of Research and Planning, 1994

Energy use

Because most of the byproducts—heat, gases, and particles—are released into the atmosphere, the burning of fossil fuels for transportation and electricity generation has a substantial impact on air quality.

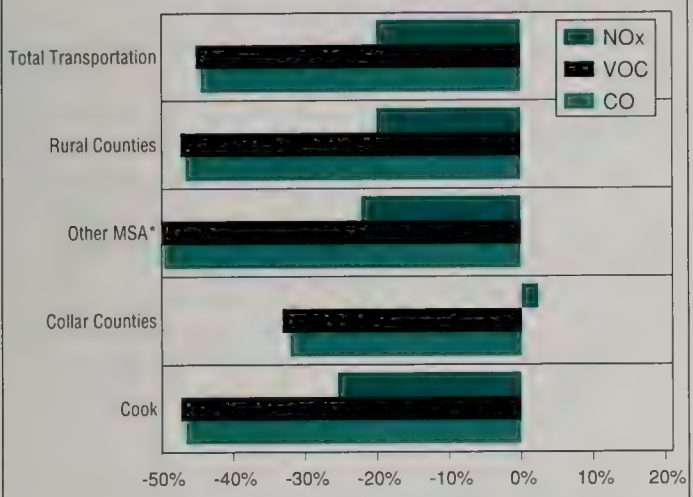
Transportation. Highway vehicles in Illinois are the most substantial source of NO_x, VOC, and CO. The number of vehicle miles traveled (VMT) in Illinois has grown steadily in the last 20 years, from 61 billion miles in 1973 to 86 billion in 1991. (Figure 2-2) Federal clean-air regulations and mileage standards imposed in the 1970s, however, have combined to cut air emissions from cars dramatically. VOC and CO emission rates from cars and light trucks dropped 75% between 1973 and 1991.

The cumulative effect of cleaner, more efficient vehicle engines on transportation air emissions has been positive. Even though VMT grew by 40% between 1973 and 1991, CO emissions dropped 47% (two million tons), VOC emissions were down 47% (315,000 tons), and NO_x emissions (for which strict standards have been in place only since 1983) were down 8% (25,000 tons). (Figure 2-3)

The reduction in car and truck emissions contributed to a reduction in total transportation emissions from 1973 to 1991. (Figure 2-4) Rail generates only 1/100 of the common engine pollutants that highway vehicles generate, although the reductions are due more to reduced freight hauling than new efficiencies. Emissions from airplanes are up overall since 1973, but are down or steady since 1982 in spite of increases in passenger-miles flown. By far the largest percentage increase in VOC and CO emissions came from boats, much of it on Lake Michigan and the Chain-O-Lakes. However, water-based sources remain a tiny part (2%) of total vehicle emissions.

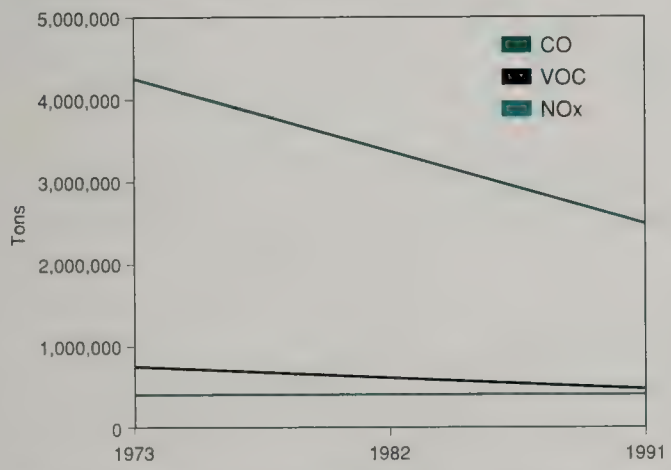
Utilities. The burning of fossil fuels to make electricity is a major source of air pollution in the form of sulfur dioxide, nitrous oxides, carbon monoxide, and particulate matter. In 1973, for example, 1.7 million tons of SO_2 were emitted from Illinois utility

Figure 2-3 Percentage Change in Transportation Emissions 1973–1992



*U.S. Census Bureau Metropolitan Statistical Area, other than Cook and Collar Counties

Figure 2-4 Vehicle Emissions Statewide 1973–1991



Emissions measured: Carbon monoxide (CO), volatile organic compounds (VOC), and nitrogen oxide (NO_x).

Source: *Sources of Environmental Stress*, ENR Office of Research and Planning, 1994

smokestacks along with approximately 356,000 tons of NO_x, 17,000 tons of CO, and 96,000 tons of particulate matter.

Over the subsequent 16 years, however, emissions of all four pollutants dropped dramatically. Annual SO_2 emissions in 1989 were down roughly one-half compared to 1973 levels, to 870,000 tons. Those of NO_x were down almost 20%, those of CO were down by 35%, and those of particulate matter were down 81%. These reductions occurred in spite of the fact that electricity generation (measured in kilowatt-hours) grew by 52% over the same period.

Two trends explain these results. One was the switch to nuclear plants by Illinois' two largest utilities. In 1973, 22% of the state's electricity was generated by nuclear energy; by 1989 the figure was 59%.

The other trend noted was toward cleaner generation, the result mainly of regulations imposed under the federal Clean Air Act. Between 1973 and 1989 the amount of SO_2 emitted per unit of electricity dropped by roughly 32%. Particles showed an even more substantial decline—77%.

Utility emissions dropped dramatically from 1973 to 1989.

• Annual SO_2 emissions were down roughly by one half, those of NO_x almost 20%, and particulate matter 81%—in spite of a 50% growth in electricity generation in the same period.
Page 11

POLLUTION IMPACTS

Human health. Ozone is a reactive gas that has been shown to cause damage to both human and plant tissues (including human lungs) and to other exposed materials. For these reasons both ozone and the chemical "precursors" in the lower atmosphere that create ozone are monitored. (Ozone high in the atmosphere shields the earth's surface from potentially damaging ultraviolet radiation.) Ozone pollution in particular is a

While it is possible to state that indoor air pollution exists, data are inadequate to identify trends in the problem in Illinois. Page 12

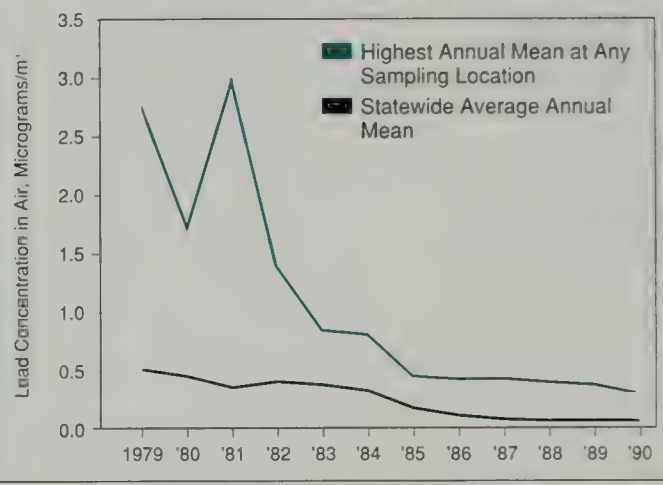
The acidity of precipitation in Illinois apparently decreased during the 1980s.

• In the 1980s, concentrations of acid-buffering airborne calcium in Illinois air decreased, but decreases in sulfate compounds occurring at the same time were even larger. Page 13

product of cities; in recent years ozone concentrations exceeded standards only in seven urbanized counties.

In the 1950s and 1960s, concentrations of atmospheric lead were six to ten times higher in cities than in rural areas. In 1967–69, at least 27 areas of the state registered average maximum lead concentrations higher than two milligrams per cubic meter on a quarterly basis, roughly one-third higher than the legal standard. Most of these readings occurred near busy streets traveled by vehicles using leaded motor fuel.

Figure 2-5 Statewide Trends in Airborne Lead Concentrations in Illinois 1979–1990



Source: *Air Resources*, Illinois State Water Survey, 1994

Human exposure to criteria air pollutants has declined significantly in Illinois since the 1970s. The lead standard has not been exceeded anywhere in the state since sales of leaded gasoline were banned in 1982 (Figure 2-5), and the SO_2 standard not since 1988. The CO standard has been exceeded only once since 1985. Since 1978 exposure to above-standard levels of ozone also has declined in Illinois, although sunny summer weather created unusually high levels in 1983, 1987, and 1988.

Traditional air pollution controls seek to reduce concentrations of criteria pollutants in outdoor air, but these pollutants occur indoors as well. Carbon monoxide and nitrogen dioxide can be emitted by unvented space heaters or leaking furnaces, for example, and lead can be present in the form of lead-based paint. Indoor air also can be fouled by viruses, molds, and fungal spores; smoke from tobacco, fireplaces, or wood stoves; assorted volatile organic compounds from paints, solvents, and cleaners; pesticides and asbestos; and formaldehyde from pressed wood products.

While it is possible to state that the problem exists, data are inadequate to identify trends in indoor air pollution in Illinois. Consider for example the problem of radon. Radon is the term commonly used to describe radon-222, an isotope of radioactive radium-226 and uranium-238. It occurs in trace amounts in most geologic materials, including soils. Radon enters most houses via gases escaping from these soils (for example from crawl spaces) and can build up to potentially unhealthful levels, especially in winter, when houses are tightly sealed against weather. Various surveys by Illinois and U.S. government agencies have come to varying conclusions about the extent of indoor radon levels in Illinois—that concentrations of radon exceeded the U.S. EPA's "action level" in anywhere from 19% to 31% of Illinois homes, that most of the state has a high or moderate potential for elevated radon readings, that only a few areas in Illinois (about 25 zip code areas) show radon concentrations high enough to be called high-risk.

Ozone depletion. Substances produced when chlorofluorocarbons (CFCs) are broken

down in the atmosphere have the potential to react with and destroy ozone in the upper atmosphere that protects living things from the sun's ultraviolet rays. (Ozone-destroying chemicals also are emitted from such natural sources as volcanoes.) CFCs are used in foam packaging, insulation, various kinds of containers and cartons, and refrigeration equipment; halons (chemicals used in fire-fighting equipment) are present in much smaller amounts than CFCs but have a much higher ozone-depleting potential per molecule. An estimated 2,105 tons of CFCs and halons are emitted in Illinois each year.

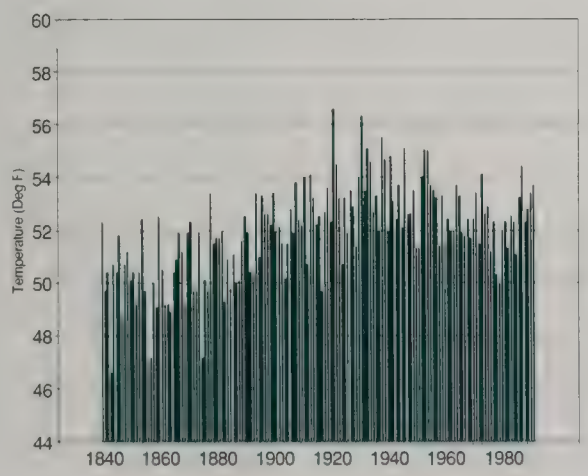
The manufacture of CFCs will soon cease in the U.S. but many CFCs and halons remain in the environment. They are "stored" in appliances and materials that constitute a sizeable CFC and halon "bank." It is estimated that more than 35,000 tons are banked. This inventory is expected to remain unchanged for some years, as the equipment and materials they are part of (such as insulation) tend to be replaced slowly.

Acid rain. Illinois precipitation is a dilute solution of sulfuric and nitric acids. However, these acids are partially neutralized by ammonium and calcium particles from soil and from rock-surfaced roads. In the 1980s, acid-buffering airborne calcium decreased, but decreases in sulfate compounds occurring at the same time were even larger. The result, tests suggest, was a decrease in the acidity of precipitation.

WEATHER

Weather records tend to confirm popular opinion that, over time, the only thing that is predictable about Illinois weather is its variability. Records of temperature and precipitation that in some cases date to the mid-19th century suggest that long-term average temperatures in Illinois increased by four to five degrees Fahrenheit from the mid-to late 1800s to the 1930s and then cooled by about half that amount to the present, consistent with global temperature trends. (Figure 2-6) The 1980s departed from this general trend toward cooler and more benign summers; for example, the 1988 growing season drought in Illinois has been equaled in severity in only two other years since the turn of the century. Episodes of extreme cold were far more frequent from about 1930 until the late 1970s and early 1980s. Tornado frequency over the past three decades has varied dramatically but shows no upward or downward trend.

Figure 2-6 Statewide Average Annual Temperatures for Illinois 1840-1992



Source: *Air Resources*, Illinois State Water Survey, 1994

The possibility that human activity may affect Illinois weather has profound implications. Some research suggests that cities affect weather in areas downwind of them. Cities

Variability has been the only unvarying trait in Illinois weather over the last century or so.

• The long-term trends revealed by the historical record in general vary considerably less than the changes that occur from one year to the next. Page 13

• Episodes of extreme cold were far more frequent from about 1930 until the late 1970s and early 1980s. Tornado frequency over the past three decades has varied dramatically but shows no upward or downward trend overall. Page 13

• From around the mid- to late-1800s to the 1930s, long-term average temperatures in Illinois increased by four degrees Fahrenheit and then cooled by about half that amount to the present. Page 13

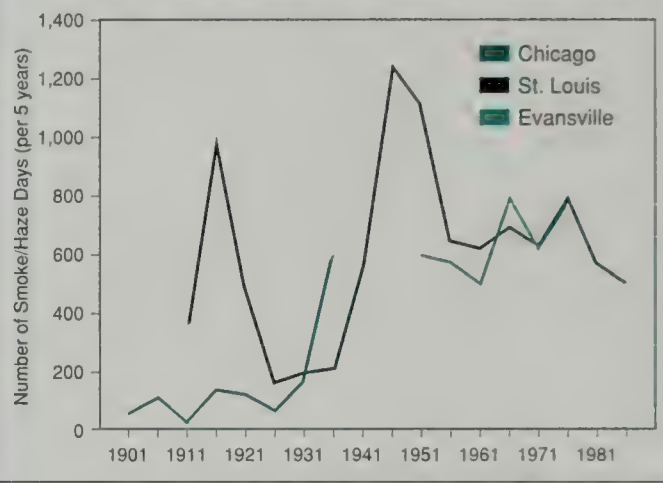
Illinois' output of greenhouse gases, while still high, is growing smaller.

• Illinois' share of annual global carbon dioxide production (237 million tons per year, or 1% of the world total) exceeds by fivefold its share of the world's population. Page 14

• In 1990 adjusted emissions of all three major greenhouse gases from Illinois sources were down 18% from 1970. The ratio of CO_2 produced per unit of energy used also shrank between 1960 and 1990, and projections of CO_2 production from energy use forecast either modest annual increases or small decreases through the year 2000. Page 15

create "heat islands" that disrupt normal temperature and precipitation patterns. Jet airplane contrails have been linked to recent significant increases in the number of cloudy days in cities. Smoky or hazy days were reported at Illinois' major weather stations only a few tens of days each year prior to the 1930s; since then their frequency has been on the order of 100 days per year or more. (Figure 2-7) The source of this atmospheric turbidity may be industrial smoke or increased dust from more extensive or more frequent plowing of farm fields.

Figure 2-7 Number of Days When Smoke and/or Haze was Reported at Chicago, St. Louis, and Evansville

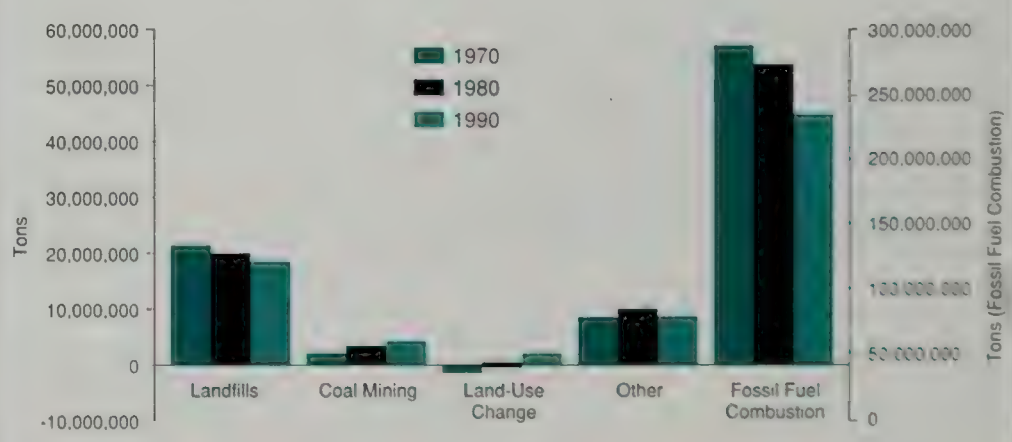


Source: *Air Resources*, Illinois State Water Survey, 1994

Global warming. Five common air pollutants are thought to contribute to global warming—carbon dioxide, methane, nitrous oxide, nitrogen oxides, and carbon monoxide. These gases are produced variously by the burning of fossil fuels and agricultural wastes, by the decomposition of organic matter from livestock and in landfills, by releases from underground mines, and by fertilizer use.

By far the most significant of these sources is fossil fuel combustion. Because it is an industrial state, Illinois' share of the global CO_2 production (237 million tons per year, or 1% of the world total) exceeds by fivefold its proportion of the world's population.

Figure 2-8 Illinois Greenhouse Gas Emissions in CO_2 Equivalents



Source: *Sources of Environmental Stress*, ENR Office of Research and Planning, 1994

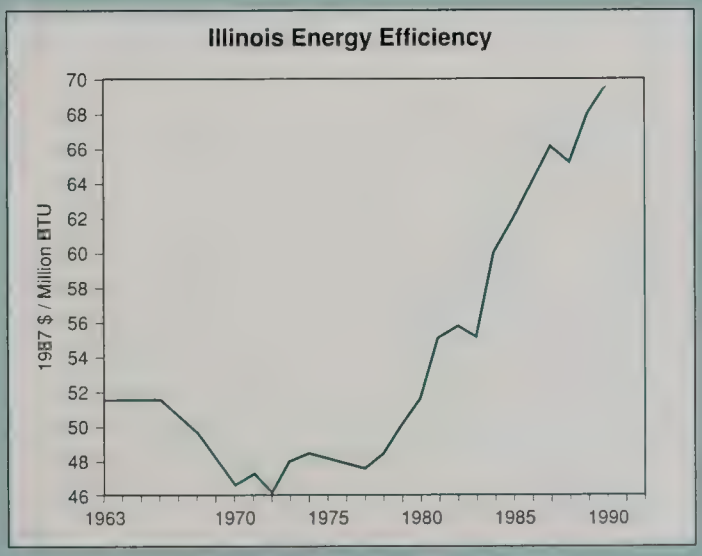
Emissions of greenhouse gases are sometimes measured in "CO_2 equivalents" to adjust for their different heat-trapping potentials. Adjusted emissions of the three major greenhouses gases (methane, CO_2, and N_2O) from Illinois sources in 1990 were some 260 million tons, down 18% since 1970. (Figure 2-8) The decline has several causes, from increased use of nuclear energy to more efficient use of energy overall to recent downturns in the economy; small (and inadvertent) reductions in methane emissions have resulted from more recent bans on the disposal of yard wastes in overburdened landfills. Projections of CO_2 from energy use forecast either small decreases in CO_2 emissions or modest (0.08%) annual increases through 2000. ❖

Energy efficiency has improved steadily in Illinois throughout the 1980s, and energy consumption is showing a downward trend.
Page 15

Doing More With Less

Illinois has been emitting less carbon dioxide (CO_2) per unit of energy used since 1960, and CO_2 generation is expected to remain fairly stable to the year 2000. This has some relevance to atmospheric quality, and thus to human health; the rate at which the atmosphere is loaded with carbon dioxide also is affected.

Those trends reflect relative declines in the use of fossil fuels for electricity generation. The efficiency with which fossil fuels are used also determines how much fossil fuel is consumed. Energy efficiency has improved in Illinois through the 1980s as it has in the rest of the U.S. This trend reverses a marked pattern of higher energy consumption evident since the 1960s. The result has been significant energy economies and cleaner air in spite of substantial increases in vehicle miles traveled. Smaller efficiency gains in buildings and houses should continue as well, although trends in all cases are contingent upon energy prices and government regulation.



Source: *Earth Resources*, Illinois State Geological Survey, 1994

Overall, energy efficiency improved in Illinois by some 46% from 1963 to 1990. These gains were achieved in spite of the fact that "heat rates," or the amount of energy needed to generate a kilowatt of electricity, have decreased by only 10% since the 1960s. Currently, about two-thirds of the energy input at a fossil-fuel-fired electricity generating plant is lost due to inherent inefficiencies in the technology. That means that about one-quarter of all Illinois energy consumption is accounted for by largely unavoidable losses from electricity generation. ❖

Chapter 3

Stream pollution in Illinois is less widespread.

- **The incidence of sores and eroded fins in fish taken from the Illinois River declined markedly between 1963 and 1992. Page 18**

- **Native minnows and green sunfish have returned to the upper Illinois River, and the bluegill has supplanted the carp as the most populous species in the middle and lower Illinois River. Page 18**

- **Sixty-one major municipal facilities reported loadings of ammonia that were 65% lower in 1992 than in 1987; 71 facilities showed a 42% decline in discharges of total suspended solids during that same period. Page 17–18**

Streams and Rivers

By any measure, Illinois is a water-rich state, and most of those riches flow through its streams and rivers. Illinois' ten river basins are drained by more than 26,000 miles of flowing waters. This system of streams, rivers, and creeks supplies humans with drinking water, recreation, transportion, industrial process, and cooling water, and it supplies habitat to Illinois' other living creatures.

Flows

Water moves plentifully through Illinois, but not everywhere all of the time. Previous studies of Illinois' large watersheds show increases in average annual flow for the years 1941–1985, with corresponding increases in peak flows and a doubling of the days in peak flow, all of which correspond to higher rainfall in the watersheds. However, natural streamflows vary considerably, making it difficult to distinguish the ups and downs in streamflow caused by local factors and those that signal longer trends of climate change. Much of northern Illinois has seen a significant increase in average flow and low flow. These changes are strongly correlated to regional fluctuations in average precipitation that attend normal climatic variability. However, most streamflow data was collected after major land-use changes—such as field tiling and the channelizing of streams—in the 1800s.

Low streamflows compromise virtually all the manifold economic and ecological functions that streams serve. From 80% to 90% of the water that is withdrawn for municipal and individual use in Illinois is returned to streams as effluent from wastewater treatment plants; indeed, during droughts the water moving through some streams may be almost entirely effluent, as is the case in many streams in Illinois' urban northeast. (Regulations mandate a required level of wastewater treatment that will not exceed the dilution provided by a given stream even during low flow.)

Of the water drawn from Illinois surface sources, 4% comes directly from border rivers and another 2% comes from its major in-state rivers. With groundwater sources insufficient in some parts of the state, and with high costs making the construction of new surface reservoirs less likely, streams may be tapped more heavily for public drinking water in the future. In the past ten years, public water supply withdrawals from the Fox River on Chicago's western suburban fringe have grown to the point where further withdrawals may require management and/or regulation.

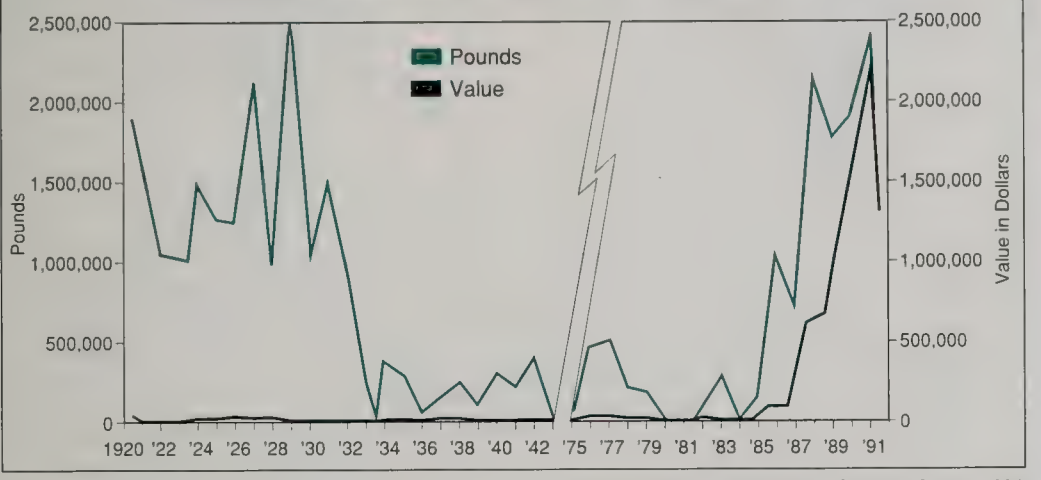
Fishing

Since 1977, angling days statewide have gone up 21%; in 1989 the two million angling days spent on the Illinois River alone are thought to have earned local economies some $40 million. Four Illinois rivers—the Mississippi, the Illinois, the Kaskaskia, and the Wabash—also support significant commercial fisheries. Catches tend to vary from year to year; the average dollar value of the catch in recent years has been $1.26 million, of which 94% is provided by the Illinois and Mississippi.

Illinois' commercial fishery is but a shadow of what it was at the turn of the century. The abundant mussel beds of the Mississippi and Illinois rivers supplied the turn-of-the-

century pearl button industry, until over-exploitation depleted the resource. In the 1960s, revived populations of mussels supplied a new market as a raw material for Japan's cultured pearl industry. Demand pushed up prices, and the harvest of all mussel species increased dramatically between 1987 and 1990; the value of the catch from the Mississippi and Illinois rivers rose to nearly $3 million by 1990. (Figure 3-1) Harvests of threeridge mussels from the Illinois River more than doubled to more than 900,000 pounds, and 60% more live washboard mussels were hauled in during that time.

Figure 3-1 Commercial Harvest of Miscellaneous Mussel Species in the Illinois and Mississippi Rivers 1920–1943, 1975–1991



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Illinoisans are increasing their demands on their streams.

• Fishing pressure —the number of angling days—on Illinois streams and rivers has increased dramatically in the last 30 years, reflecting a general trend toward more water-based recreation. Page 16

• Four Illinois rivers —the Mississippi, the Illinois, the Kaskaskia, and the Wabash—support significant commercial fisheries. Page 16

POLLUTION

The general quality of the water in Illinois streams has improved over the past 20 years. Measurements of metals, for example, show a trend toward decreasing concentrations, while concentrations of common pesticide compounds showed no significant trends over that time. Research also indicates decreasing trends in chemical oxygen demand, another measure of conventional water pollution. However, a highly significant trend is toward increased concentrations of substances in common agricultural use such as phosphorous and nitrate nitrogen, the latter showing up in the Rock, Illinois, and Kaskaskia river basins.

During the first 60 to 70 years of this century, the discharge of sewage and factory wastes into Illinois streams was the major determinant of their water quality. From 1957 to 1992, the fish species that dominated the polluted, oxygen-poor water of the Illinois River downstream from Chicago's sewage pipes were five species that are more tolerant of pollution than most native species. (The introduced carp and goldfish led the list.) The domination of stream environments by such species is made easier when predators like the largemouth bass, which ordinarily would control their numbers, fail to thrive because of poor quality water.

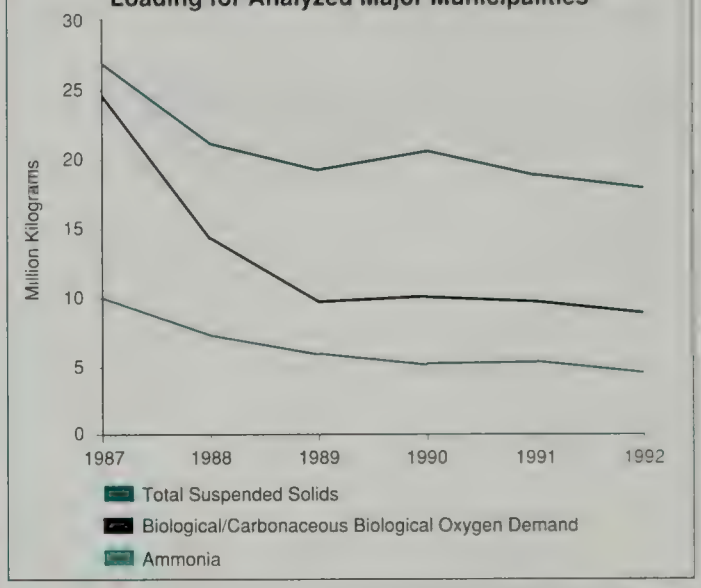
Analysis of discharge monitoring reports filed by major facilities discharging wastes under the federal Clean Water Act of 1972 shows a trend toward reduced effluent loads. Fifty-five major municipal sewage treatment facilities showed reductions of 72% in loadings of biological/carbonaceous oxygen demand from 1987 to 1992. Sixty-one facilities

Urbanization is encroaching on Illinois streams.

• In Champaign County, urban uses along streams increased more than 37% from 1958 to 1988, and much of that occurred within 100 feet of the water.
Page 19–20

reported loadings of ammonia that were 65% lower in 1992 than in 1987. Seventy-one facilities showed a 42% decline in discharges of total suspended solids. Sixty-one facilities reported that from 1987 to 1992 loading of residual chlorine from chlorination had dropped by almost 25%. (Figure 3-2)

Figure 3-2 Estimates of Statewide Pollutant Discharge Loading for Analyzed Major Municipalities



Source: *Sources of Environmental Stress*, ENR Office of Research and Planning, 1994

Trends in loadings of chromium, copper, cyanide, and phenols from major manufacturing and utility facilities also showed declines between 1987 and 1992, with reductions ranging variously from 37% to 53%.

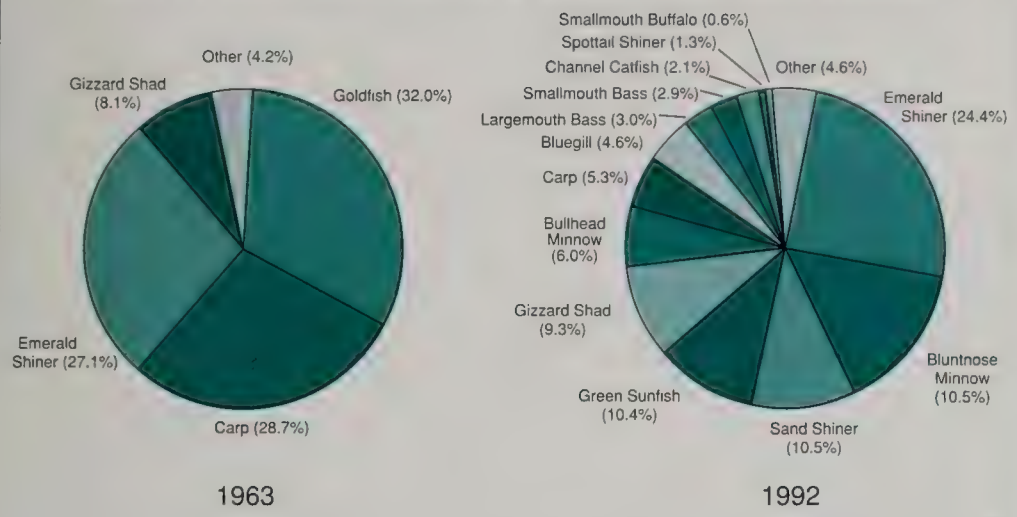
In spite of these improvements, the number of fish kills has increased since 1965. Although numbers fluctuate from year to year, the annual number of fish killed by pollution (rather than by drought or other natural causes) has been rising. The proportion of kills attributable to industrial point sources has declined in the last 30 years and now stands at roughly 10%. Similarly, fish kills attributable to acid runoff from coal-mine waste are becoming rarer as abandoned mine sites are cleaned up. Kills attributable to agriculture, often from unregulated nonpoint sources, have risen steadily.

Analysis of data from 28 permanent fish census stations on the Illinois River for the years 1963 and 1992 reveal what appears to be a general trend toward recovery in terms of certain measures of stream ecosystems. Native species such as minnows and green sunfish have returned to the upper Illinois, relegating carp to seventh place among the more populous fishes. (Figure 3-3) Similar turnabouts have been recorded in other reaches of the river. The bluegill supplanted the carp as most populous species in the middle and lower Illinois. The incidence of external abnormalities in fish (mainly sores and eroded fins) taken from the Illinois River also declined markedly between 1963 and 1992.

Using biological criteria, however, one study found that as of 1988 the proportion of stream-miles in Illinois in fair to very poor condition (based on a sample of approximately 29% of the total) was 66%, while those rated good to excellent comprised 34%. (Figure 3-4)

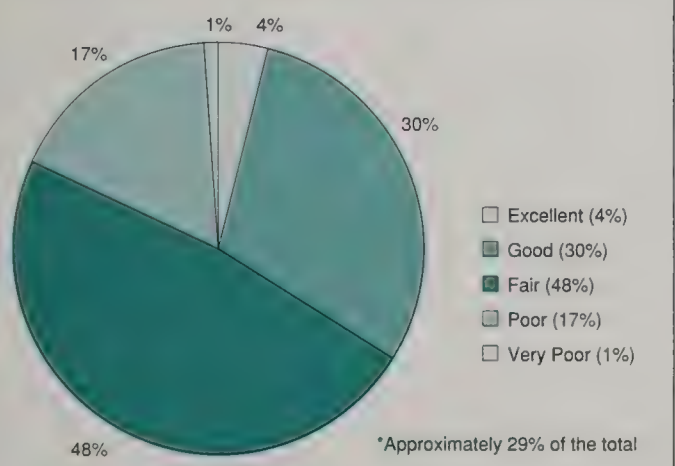
Surveys of Champaign County streams dating back to 1892 showed that the numbers of species sampled dropped by one-fourth from 1928 to 1959, when modern agriculture systems came into wide use and industrial expansion accelerated. Since 1959, however, Champaign County streams have seen revived populations of a few fish species such as the black basses and channel catfish, but poor physical habitat and increased urbanization limit full recovery. (Figure 3-5)

Figure 3-3 Percentages of Catches by Species in Upper Illinois Waterway



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Figure 3-4 Percentage of Illinois Stream Miles Surveyed* Rated by the Biological Stream Characterization



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

As pollution has been reduced in the open water of Illinois streams, attention has shifted to bottom sediments, where metals and other lingering industrial toxics tend to accumulate. The condition of sediments in the Illinois River appears to have improved over the past 30 years, but fish consumption advisories remain in effect for the Illinois River downstream as far as Peoria for bottom-feeding fish such as the freshwater drum and channel catfish. The physical abnormalities that still appear on fish are more common in species such as carp and catfish that feed among the bottom sediments.

PHYSICAL CHANGES

Physical changes remain a perturbing force in Illinois stream ecology. As long ago as the 1940s, researchers suggested that the poor quality of Illinois streams resulted as much from the manipulation of the landscape in their watersheds as from pollution. The remaining riparian forest that acts as an erosion buffer for streams continues to shrink. Along parts of the Little Vermilion, Embarras, and Kaskaskia rivers, forest cover shrank 40% to 80% from 1958 to 1988, as urban uses along Champaign County streams

While water quality in streams is improving in some respects, ecological quality remains low.

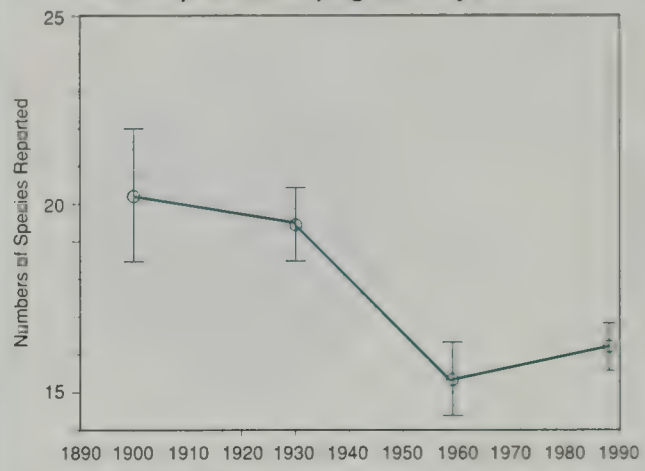
• One study found that, as of 1988, the proportion of stream-miles in Illinois in fair to very poor biological condition was 66%, while those rated good to excellent comprised 34%. Page 18–19

• Of the species present in Illinois at the turn of the century, about one in five fish, one in three amphibians and reptiles, more than half the freshwater mussels, and one in five crayfish have been extirpated or are threatened by extinction. Page 22

Physical damage to Illinois stream systems remains substantial.

• Peoria Lake, the largest and deepest of the bottomland lakes on the Illinois River, lost 68% of its capacity between 1903 and 1985. Page 20

Figure 3-5 Mean Numbers of Indigenous Fish Species Per Sample in Champaign County Streams



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

increased more than 37% during those years, much of that occurring within 100 feet of the water.

In Illinois' larger rivers, physical perturbations to the stream environment also come from within their banks. Propellers churn up bottom sediments, waves erode banks, dredging (to keep channels clear) and spoil-dumping physically reshape river channels and floodplain habitats. Since 1950 freight-carrying barge traffic statewide has increased fivefold (measured in tons), although the rate of increase overall has leveled off since 1980. The exact impact of barge traffic on river ecosystems is not understood but may be assumed to be substantial.

While most soil erosion in Illinois occurs from open fields, most of the estimated 26,000 miles of Illinois streams also experience some enhanced erosion of their banks, especially where banks have been denuded of vegetation. The straightening or channelization of streams also increases their vulnerability to erosion by speeding the flow of water. How much of the sediment load of Illinois streams comes from their own banks varies with local conditions; estimates range from 20% to 80%.

Streams also collect soil particles eroded from elsewhere in their watersheds. The Illinois River basin contains more than 60% of the agricultural acreage in the state. On average, 8.2 million tons of sediment are delivered by tributary streams and deposited in the Illinois valley each year. (This number does not include soil eroded from the river's own banks and from valley bluffs.) Peoria Lake, the largest and deepest of the bottomland lakes on the Illinois River, lost 68% of its capacity between 1903 and 1985. The lake's average depth shrank from 8 feet to 2.6 feet, and if present trends continue it will become a mudflat split by a narrow stream. (Figure 3-6)

In the mid-1970s, an estimated 15.4 million tons of sediments were deposited in the valley each year. The rate at which sediment is being flushed into the Illinois River has been slowing since that time, as acreage planted in row-crops declined from record high levels. But while erosion slowed, the sediments stayed; fish species such as the northern pike and the black buffalo that are dependent on the now-buried shallow backwaters are virtually gone from the lower Illinois.

Changes in the physical shape or morphology of streams profoundly affect their function. Water in channelized streams moves faster—usually at a cost of reduced habitat and increased erosion. More than 25% of the total length of sizeable streams in the Rock, Sangamon, Fox/Des Plaines, and Kankakee/ Vermilion/Mackinaw basins has been straightened. (Figure 3-7) Many of the state's minor streams are wholly artificial, having been built mainly for drainage.

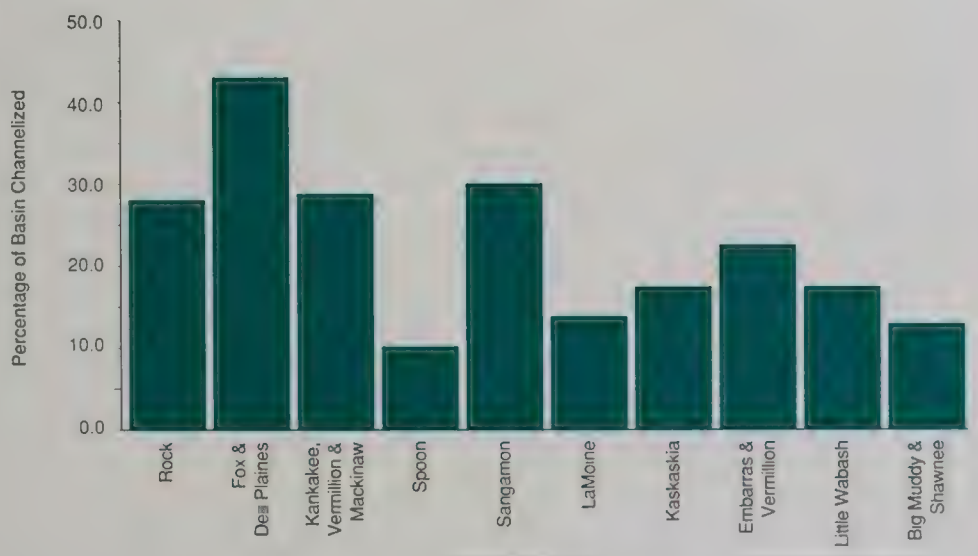
Figure 3-6 Peoria Lake Area Deeper Than Five Feet 1903 and 1985

Source: *Water Resources*, Illinois State Water Survey, 1994

Dams are another major manipulation of stream systems. Almost every sizeable stream in Illinois is dammed in at least one spot, creating a total inventory of nearly 1,200 dams of all sizes. (Figure 3-8) Most dam building occurred in the 1930s, creating small water supply lakes on lesser streams and, on the major rivers, creating a series of deepwater pools to improve navigation. In the 1960s and 1970s, another spate of construction dammed downstate rivers for recreation, flood control, and public water supply. The costs of such benefits have been significant. In large rivers, navigation dams combined with high artificial levees have prevented the

Large watersheds in Illinois show increases in average annual flow for the years 1941–1985, with corresponding increases in peak flows and a doubling of the days in peak flow, all of which correspond to higher rainfall in the watersheds. **Page 16**

Figure 3-7 Percentage of Total Stream Basin Length Altered Through Channelization



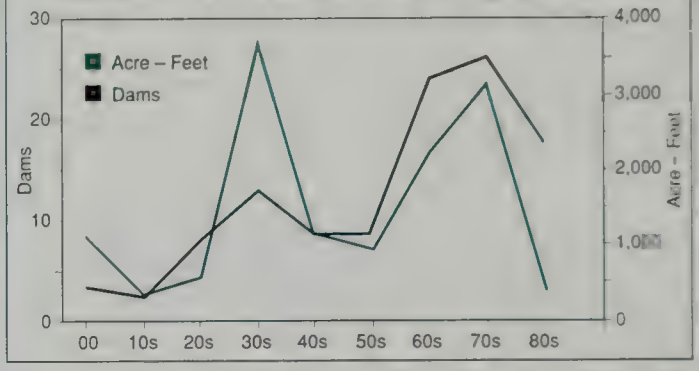
Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Human use has significantly altered natural stream function.

• More than 25% of the total length of sizeable streams in four main river basins has been straightened.
Page 20

• Almost every sizeable Illinois stream is dammed in at least one spot.
Page 21

Figure 3-8 Number of Dams Constructed in Illinois in Each Decade and Mean Normal Storage 1900–1990



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

natural flooding and drying cycle in the floodplains that formerly maintained a highly productive and diverse biota.

Fish and wildlife

Of the larger animal species present in Illinois streams at the turn of the century, about one in five of the fish, one in three of amphibians and reptiles, more than half the freshwater mussels, and one in five of the crayfish have been extirpated or are threatened by extinction. Information is not available to gauge the survival status of insects and aquatic plants.

Forty-four of the 100 species of amphibians and reptiles known in Illinois have a stream-dependent larval stage lasting from several months to a few years, and nearly all of them also deposit their eggs in water. These complex life cycles are especially dependent on high-quality, varied stream habitat. For example, the hellbender salamander requires fast-running clear water and gravelly streambeds of the sort that have been buried by silt throughout much of Illinois; the animal has been seen only once in Illinois since the 1950s.

Sixteen exotic fish species are reproducing in Illinois streams and rivers. Most of them were introduced by accident. Some native species, such as the red shiner, that are tolerant of poor water conditions—wide fluctuations in water pH, low dissolved oxygen, high water temperature—have expanded their ranges.

Plants

Aquatic plants are essential to stream ecosystems, providing food and cover and recycling nutrients. Sedimentation, complicated by pollution, is thought to have caused massive declines in plant life along the Illinois River. Many submerged plants anchor themselves on the stream bottom but need light; sedimentation blocks light, and soft, silty bottoms provide poor root anchorage against currents. Artificially high water levels also leave bottom-rooted plants too far from light. When a two-year drought lowered sediment loads and dropped water levels in the Mississippi River's Pool 26 near Alton, beds of submerged plants reappeared that had not been seen there for years; a return to more typical—if not more natural—water levels caused them to disappear again. ❖

The Illinois River

A thousand years ago a succession of prehistoric peoples found an ideal habitat in the Illinois River valley below Peoria. Five miles wide in places, the valley was the site of a series of town centers scattered up and down its 100 miles. Remnants of this extensive and long-lived occupation are everywhere. By 1980 archaeologists had found evidence in Fulton County alone of roughly 3,000 village and burial sites, representing all the known eras of Native American culture in Illinois.

Later Illinoisans also found the river a rich resource. From 1905 to 1915, more freshwater fish were harvested from the Illinois River than from any other such river in the U.S., except for the Columbia River in Washington state. In 1908 alone, nearly 25 million pounds of fish were harvested. In 1950, flocks of migrating mallards and lesser scaup ducks numbered two million along the Illinois, making it a hunter's paradise. Just after the turn of the present century, the Illinois briefly sustained a fleet of 2,600 boats harvesting mussels for the booming pearl button industry.

Boat traffic—made possible by the deeper channel—generates bank-eroding waves and keeps sediments suspended, clouding the river water.

Today's hunters and commercial fishermen cannot match those historic harvests. The long-term sustainability of the river's biological harvest was hampered by a succession of ecological injuries. They include:

• Drainage of wetlands and the channelization of tributaries that began in the late 1800s. These changes sped up the rate at which water entered the Illinois River, enhancing its ability to carry off topsoil and pollutants from the land into the river.

• Diversion of Chicago sewage and factory pollution into the river beginning in 1900. Extra flows raised water levels, killing less tolerant trees in the floodplain; excessive nutrients degraded water quality.

• Draining wetlands and leveeing of half the floodplain from 1903 to 1926. Undertaken mainly for agriculture, these projects eliminated the most productive habitat and reduced the system's ability to hold and store water.

• Construction and maintenance of a nine-foot minimum navigation channel. Finished in the 1930s, the dam system permanently inundated parts of the floodplain accustomed to seasonal wetting and drying; year-round sedimentation is primarily responsible for the reduction of floodplain lakes to shallow, featureless "deserts" of soft mud.

•More intensive, chemical-reliant farming, especially since the late 1940s. Industrial-style farming increased soil loss and contamination by farm chemicals, especially fertilizers.

There are signs of improvement in the Illinois' chemical water quality, although long-lived pollutants such as heavy metals still linger in bottom sediments. The physical changes, however, are responsible for doing the most enduring damage to the Illinois River's once-fabled abundance. For example, boat traffic—made possible by the deeper channel—generates bank-eroding waves and keeps sediments suspended, clouding river water. Such changes risk sacrificing this once-diverse resource to a single-function stream that serves primarily to transport bulk cargoes by barge. ❖

Chapter 4

Illinoisans are arraying themselves on the land in suburban densities, with effects on air quality and petroleum use disproportionate to the population.

• By 1990, Illinois' urban fringe housed 37% of the state's population—as many people as lived in its central cities. Page 30

• The Northeastern Illinois Planning Commission estimates that between 1970 and 1990 the population of the Chicago region grew by 4% while the amount of urbanized land expanded by 51%—more than 360,000 acres. Page 31

LAND

The land—bedrock and soil—is a vital aspect of all Illinois ecosystems. The type and extent of wetlands in the state, the depth and quality of its agricultural soils, its commercial mineral deposits—all result from geologic and climatic processes. Just as the wealth of the land has shaped Illinois' economy, human competition for that wealth has shaped its politics and social life. (Figure 4-1)

Figure 4-1 Land Use in Illinois

	Agriculture	Residential	Commercial and Industrial	Transport and Other Urban	Reservoir	Surf. Mine*	Landfill*	[illegible]	[illegible]
Percent	82.7	2.7	1.1	0.8	0.9	0.8	0.2	[illegible]	[illegible]
Sq. Mi.	46,000	1,500	700	500	500	400	100	[illegible]	[illegible]

*May also be included in other categories

Source: *Earth Resources*, Illinois State Geological Survey, 1994

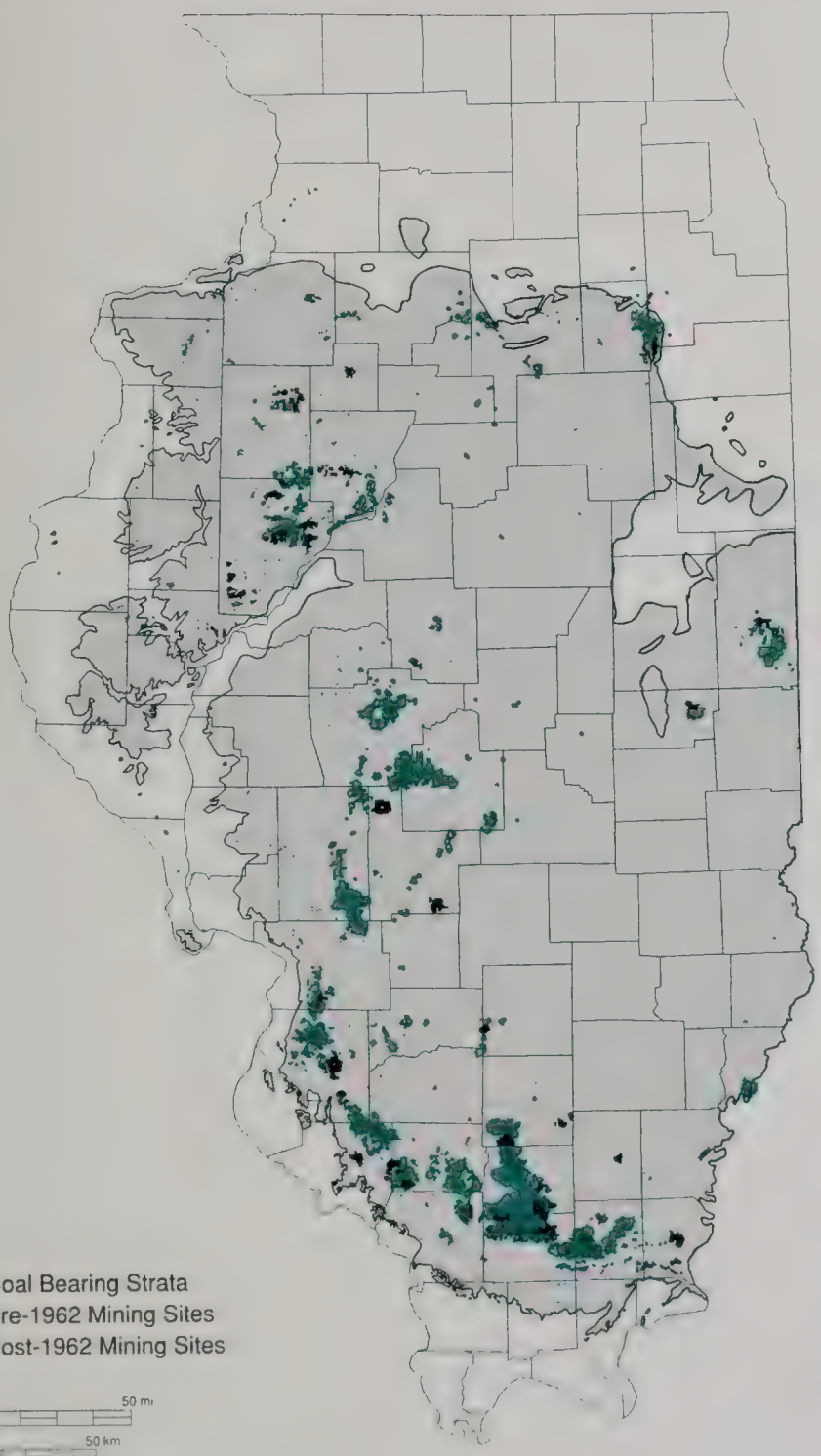
MINING

While Illinois is not generally thought of as a mining state, it ranks fifth in the nation in coal production and first in the production of fluorspar and silica. Illinois also produces large amounts of aggregates (sands and gravels) essential to the building industry.

Coal. Illinois coals are mostly of the "soft" or bituminous type, found in thick, flat-lying, easy-to-mine beds. These coals have a fairly high heat value, and commonly contain sulfur compounds that have made their use problematic since the advent of federal clean-air rules. Deposits with high development potential have been conservatively estimated at 50 billion tons—enough to yield 25-30 billion tons of usable coal, which is enough to last hundreds of years at present consumption levels.

Coal has been mined commercially in Illinois since the early 1800s. (Figure 4-2) Annual production varies with larger trends in the economy, competition from newer fields in other states, changes in industrial and transportation technology (including the use of other fuels), and (most recently) federal regulations. During World War II Illinois mines boomed as they dug a record output of 78 million tons a year; since then production has leveled off at around 60 million tons per year. (Figure 4-3)

Figure 4-2 Coal Mine Locations in Illinois



From ISGS Coal Database, 1993

Source: *Earth Resources*, Illinois State Geological Survey, 1994

Mineral extraction is declining in Illinois.

• Coal output in Illinois during World War II was 78 million tons per year; in 1990 it was 60 million tons. Oil production hit a peak of about 148 million barrels in 1940 and declined to 19 million barrels in 1991.
Pages 24 and 27

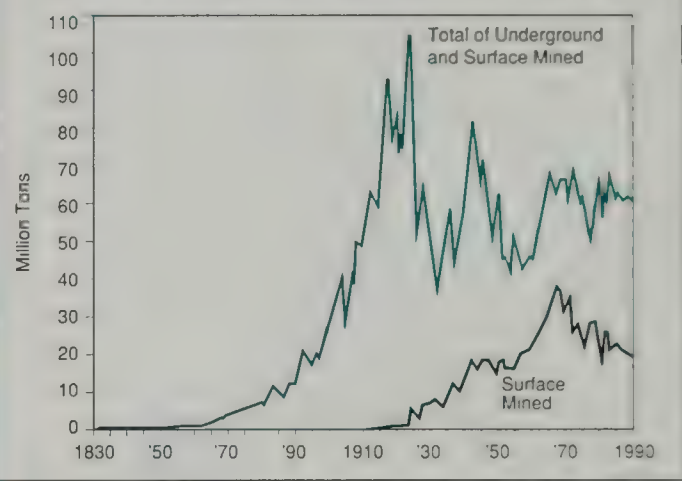
Coal mining is less markedly affecting Illinois land.

• Some 0.8% of Illinois land—about 256,000 acres, most of it farmland—has been affected by the strip mining of coal. Page 26

• Of nearly 153,000 acres of land mined for coal since passage of the Illinois reclamation law in 1962, nearly 108,000 acres had been reclaimed to some productive use. Page 26

The method used to mine coal affects the landscape as does the amount of coal mined. The collapse, or subsidence, of underground mined-out "room and pillar" mines can create hard-to-drain wet spots in farm fields. Since 1983, regulations require that such damage be repaired.

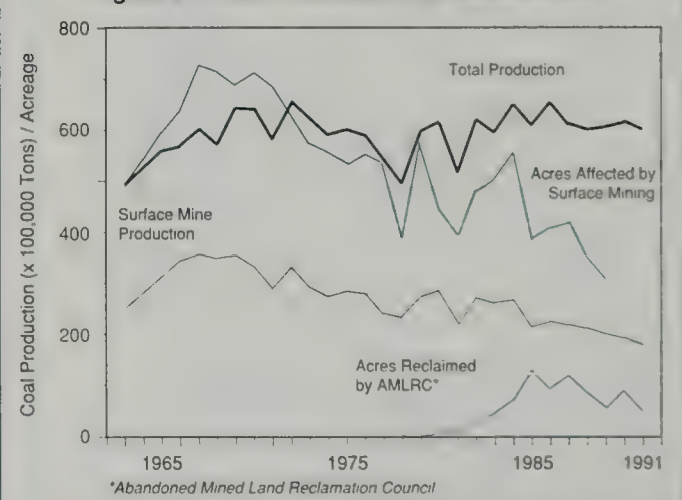
Figure 4-3 Trends in Coal Production in Illinois



Source: *Earth Resources*, Illinois State Geological Survey, 1994

More efficient longwall mining removes all the coal in an underground "panel," after which uniform, controlled subsidence takes place according to an approved plan. This predictability makes it easier to protect surface structures and mitigate damage to land.

Figure 4-4 Coal Production vs. Reclamation



Source: *Earth Resources*, Illinois State Geological Survey, 1994

Some 0.8% of Illinois land—256,000 acres, most of it farmland—has been affected by the strip mining of coal. The state's first, now rather rudimentary, reclamation requirements went into effect in 1962. Of the nearly 153,000 acres of land mined for coal since then, nearly 108,000 acres have been reclaimed to some productive use. In addition, approximately 21,000 acres of land disturbed by mining and abandoned prior to the 1977 federal reclamation laws were covered by mine wastes of various types. Some of these sites are small in size, while others are as large as 300 acres. Some 8,600 abandoned acres have been reclaimed from these so-called "pre-law" sites and another 9,000 acres are considered to need reclamation. (Figure 4-4) Such pre-law land can sometimes be reclaimed for crop production; when feasible, other sites have been reused as vacation home sites, hunting and fishing clubs, and state parks.

Other ore minerals. Illinois land also yields building materials such as sand and gravel; stone used in the manufacture of cement and agricultural lime as well as for ballast and construction aggregates; industrial ores such as silica, clay, and shale; and metallic ores such as lead, zinc, and fluorite, Illinois' official state mineral.

In all, noncoal mining has disturbed about 35,000 acres of land in Illinois. These mines tend to affect only small amounts of land—less than 20 acres over the lifetime of most operations. Some stone quarries leave pits as much as 200 feet deep; some are suitable for lakes, while others must be fenced off for safety reasons, being too large to be filled in. Noncoal mining typically produces fine-grained clays and silts that are slurried into ponds that occupy only about 500 acres statewide; such mining also produces piles of displaced overburden that are typically graded to a gentler slope and planted in grass or trees.

More than half of the sand and gravel produced in Illinois comes from the six northeasternmost counties, where both deposits and demand are large. Nuisance complaints, rather than pollution, are the main problem associated with these sites, many of which have become surrounded by urban development.

Petroleum. Petroleum has been pumped from Illinois wells since the turn of the century. Some 6,700 oil fields draw crude oil from rocks of Pennsylvanian and Mississippian ages and older, mainly in the southern counties. Oil production hit a peak of about 148 million barrels in 1940 and declined to 19 million barrels in 1991.

At present Illinois consumes vastly more oil than it produces, importing 90% from sources outside the state. Most of Illinois' 34,000 wells are small, "stripper wells" that yield as little as two barrels a day. Secondary recovery operations require that water be pumped in large volumes into depleted oil-bearing rocks to force the remaining oil to nearby wells. The process can use as many as 40 gallons of water for every one barrel of oil thus recovered. Most of that water is "produced water" or salt-laden water that has been brought to the surface, separated from the oil, and re-injected, almost always immediately.

POLLUTION

Solid wastes. Recorded land waste sites in Illinois number in the thousands. (Figure 4-5) Illinois first began to regulate the siting and operation of sanitary landfills in 1973. Though far superior to open dumps, even sanitary landfills may pose some risks to nearby land, mainly from leachate, liquids contaminated as they percolate through fill.

Estimates of the solid waste generated per person in Illinois range from 4.7 to 7 pounds per day. Household and municipal waste amounts have risen generally since 1988, peaking in 1991. Illinois is very dependent on landfills for the disposal of the approximately twelve million tons of solid waste generated annually in recent years. The Illinois Solid Waste Management Act of 1986 was intended to reduce that dependence on land disposal.

Over the past 25 years the risk of contamination to Illinois land and groundwater by operating landfills has been steadily reduced, but the risk from both past and present landfills remains. A survey of landfill sites found that nearly 5% of Illinois' public lands (such as parks and nature preserves), 8% of its wetland and deep water habitat, and nearly 5% of its floodable land are within a mile of a known waste site.

Illinois regulations governing landfills are complex. Different standards for construction, operating, and monitoring are required for on-site and off-site landfills depending on which of several categories of wastes they contain. In general, reviews of permit applications require consideration of the effect a proposed landfill might have on adjacent lands, including floodplains and natural areas; they also mandate engineered systems to prevent contamination of groundwater and surface water. (The ability of a leachate to

Net soil movement from erosion remains sizeable.

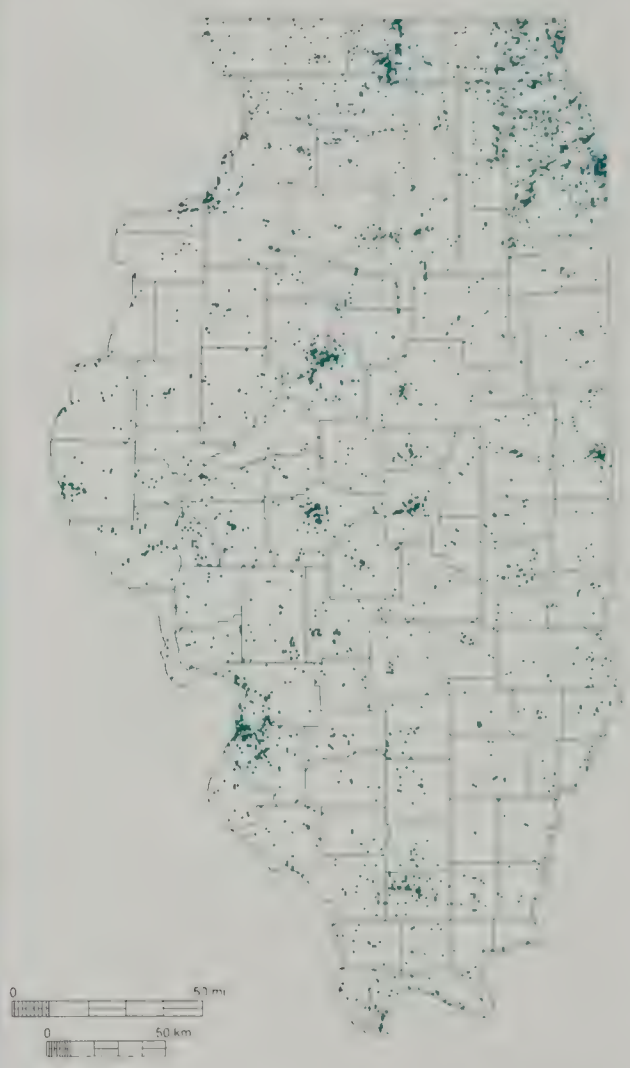
- **An estimated 158 million tons of topsoil erodes from Illinois land each year.** **Page 58**

- **Outside its major river valleys, Illinois has lost an estimated two to nine inches of topsoil since Europeans arrived.** **Page 58**

Net landfill capacity in Illinois has increased since the mid-1980s.

• Though fewer—by 1993 only 64 solid waste landfills were operating in Illinois—Illinois sanitary landfills are getting larger, so that net capacity statewide actually increased since the mid-1980s. Page 28

Figure 4-5 Landfill Locations in Illinois



Landfill locations are represented by a one mile buffered area. This is consistent with USEPA area-of-potential risk estimates and location accuracy studies for landfills in Illinois.

Source: *Waste Generation and Management*, Hazardous Waste Research and Information Center, 1994

migrate off-site varies with the hydrology and geology of a particular landfill and the design of the engineered system.)

By 1992 only 106 solid waste landfills were operating in Illinois, and by 1993 the number had dwindled to 64. The dramatic drop in the number of solid waste landfills in the state is thought to have been induced in part by economies of scale, since only larger landfills generate enough in fees to pay for the pollution controls now required of them. More and more materials are no longer landfilled at all, either because of landfill capacity limits (such as yard wastes) or because the materials are environmentally problematic (such as lead-acid batteries).

Though fewer in number, Illinois sanitary landfills are getting larger, so that net capacity statewide actually increased since the mid-1980s. Transition regulations require the disposal of some wastes by means other than landfilling over the short term, while recycling and waste prevention are expected, over the long term, to cause waste streams to dwindle further. Because of such diversions, the shortages of landfill space predicted to occur in the early 1990s have not occurred.

However, not all wastes are regulated, and not all regulations are as stringent as those that govern the operation of sanitary landfills.

Industrial solid wastes. A portion of the materials now going into Illinois municipal landfills are industrial solid wastes, including officially defined industrial process wastes. Their potential for harm is unknown, although some of these wastes may not prove to be "hazardous"under analysis.

Hazardous wastes. According to federally-mandated reports of releases of common toxic industrial chemicals, a relatively small portion of the toxic chemicals released in Illinois in 1990 (less than 7%) was released onto the land. That still amounted to 15.4 million pounds, most of which was composed of metals such as zinc, manganese, lead, and chromium and their compounds.

Recent regulations require that landfills accepting hazardous wastes be equipped with groundwater monitoring wells, impermeable liners, and leachate collection systems; the new rules are reducing the risk that such fills will adversely affect Illinois groundwater. In any event, officially defined hazardous wastes are landfilled in much smaller volumes than is ordinary garbage or municipal solid waste (MSW). Hazardous wastes landfilled in 1990 amounted to less than 2% of the volume of MSW landfilled; the capacity of hazardous waste landfills is not expected to be stretched to its limit until after the turn of the century, based on current rates of generation and disposal.

As of 1990, the number of old potentially hazardous waste sites that qualified for inclusion on state and federal lists of "remediation" or cleanup sites was nearly 1,500. Not all such sites have been investigated; there are at least 1,500 coal gasification plants that generated tars and other toxic byproducts in the late 19th and early 20th centuries. Cleanup of even known waste-contaminated sites has been slow, dogged by money shortages, legal challenges, and technical problems.

The past pollution of Illinois land has economic as well as health effects. The pollution of former industrial sites poses real barriers to the redevelopment of now-abandoned land in Illinois' older cities, since current owners are now liable under federal law for the cleanup of land polluted by former owners.

Radioactive wastes. Well over half the electricity generated in Illinois is produced by plants fired by nuclear fuel. Highly radioactive waste materials from these reactors are stored on-site, although a federal mandate requires the U.S. Department of Energy to dispose of such high-level waste by 1998. As of 1993, low-level radioactive waste from Illinois nuclear-powered plants was shipped to South Carolina for disposal, but Illinois has entered into an agreement with Kentucky to build a facility in which the two states will dispose of such wastes.

Measured by five-year averages, volumes of low-level radioactive waste shipped from power plants have declined since the mid-1970s by some 17%, presumably because of changes in treatment or production processes at electricity plants. However, the radioactivity of that waste (as measured in curies) increased dramatically from 1974 to 1991, rising by more than 9500% to 41,000 curies.

Liquid wastes. Liquid wastes from industrial processes are often temporarily stored or treated atop the land in tanks or impoundments (sometimes called pits, ponds, or lagoons). This technique allows liquids to be evaporated, or solid wastes to be concentrated, prior to disposal by other means.

An IEPA survey in 1980 counted 7,450 active or abandoned waste impoundments in Illinois. Unlined or improperly lined impoundments are considered by some authorities to be the most significant source of chemical pollution of Illinois groundwater. More than a quarter of the surface impoundments in Illinois are thought to be in places where near-surface geology leaves subsurface soils prone to infiltration; surface soils also may be contaminated when impoundments accidentally overflow.

It is not clear how many waste impoundments are in use today, but tighter regulations are making the practice of storing officially designated hazardous wastes on land less

The cleanup of existing known potentially hazardous waste sites is underway.

• The number of Illinois waste sites that qualify for inclusion on state and federal agencies' lists of priority remediation or cleanup as of 1990 was nearly 1,500, and not all such sites have been investigated. Page 29

• A crude 1980 survey counted 7,450 active or abandoned surface waste pits, ponds, and lagoons of the sort that are thought by some authorities to be probably the most significant source of chemical groundwater pollution. Page 29

Tighter regulations are making the practice of storing officially designated hazardous wastes on land less attractive.

• A 1983 estimate by the Illinois Environmental Protection Agency put the number of hazardous waste impoundments at 150; by 1986 only 27 were still in use. Page 30

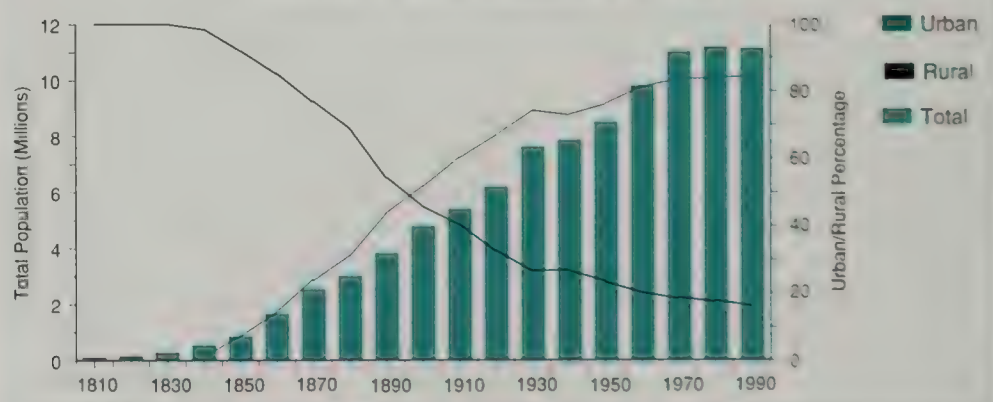
attractive. A 1983 estimate by the Illinois Environmental Protection Agency put the number of on-site storage impoundments at 150; by 1986 only 27 reportedly were still in use.

Mining wastes. At sites where coal was processed at the surface, piles of "gob" or leftovers from the separation of coal from rock and other impurities can occupy large tracts of land. Slurry ponds contain very fine-grained clay and minerals cleaned from coal. Pyrite grains (iron sulfide) that occur in most Illinois coals may react with moisture and air at the surface, creating acid drainage that may contaminate nearby streams. Untended gob piles and dried-out slurry ponds are a source of airborne pollutants, and erosion from unstable piles can clog drainage ditches and flood nearby farm fields.

Miscellaneous. Illinois land is used to dispose of assorted organic matter, mainly agricultural wastes such as crop residues and animal manures. Farm land also is the preferred site for the disposal of sludge from publicly-owned sewage treatment works and certain cannery wastes generated by commercial food processors. Most of the former are small works, located in rural areas with immediate access to large amounts of land.

There also is a trend toward land storage and disposal of nonhazardous sludges. Many Illinois towns and villages, for example, use surface pits to dry sewage sludge before trucking it to landfills. More than 12% of the amount of sludge that was landfilled in 1989 was land-applied in 1991, in part because of state landfill regulations that encourage the latter practice. However, those regulations also strictly limit the amount of toxic metals that may be taken up from the soil and incorporated into food crops; as a result, land disposal is not an option for Illinois' biggest publicly owned treatment works, whose sludge contains residues of factory wastes.

Figure 4-6 Illinois Population 1810–1990

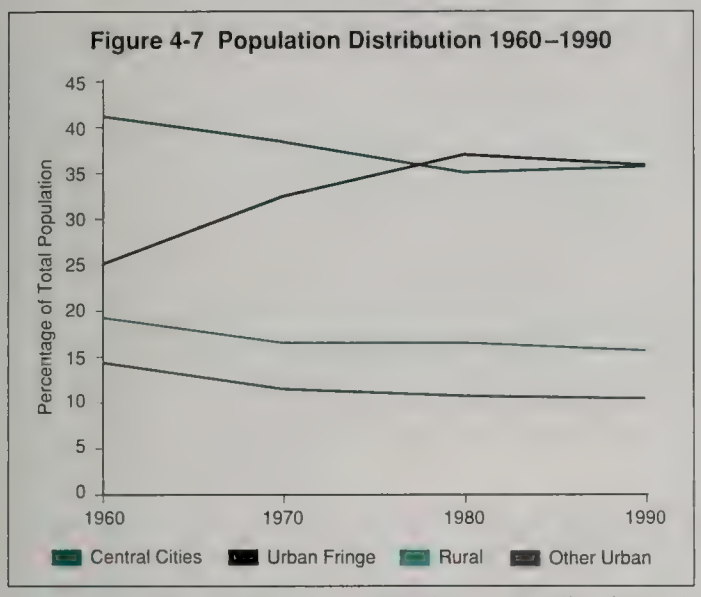


Source: *Sources of Environmental Stress*, ENR Office of Research and Planning, 1994

Urbanization

Urbanization is a well-remarked trend nationwide. In 1860, 86% of Illinoisans lived outside of cities. By the turn of the present century, as many people lived in urban as in rural areas; by 1990, 85% of Illinoisans lived in urban areas. (Figure 4-6)

The automobile and the truck are accelerating the movement of 20th century Illinoisans into what the U.S. Census defines as "urbanized areas" on the fringes of cities. Beginning around 1960, Illinois' urban fringe grew so rapidly that by 1990 it housed



Source: *Sources of Environmental Stress*, ENR Office of Research and Planning, 1994

37% of the state's population—as many people as lived in central cities at that time. (Figure 4-7)

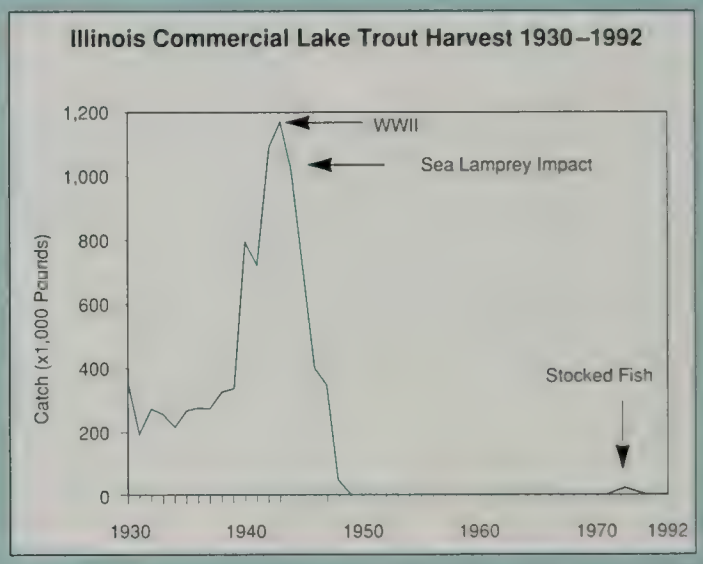
Much of Illinois' recent population growth is centered in the northeast. The Northeastern Illinois Planning Commission estimates that between 1970 and 1990 the population of the city's six Collar Counties grew by 4%, while the amount of urbanized land expanded by 51%—a net land consumption over the two decades of more than 360,000 acres. These are not trends unique to Illinois; indeed, urban sprawl was somewhat later in arriving here than in boom states of the East and the Sunbelt. ❖

Urban sprawl was somewhat later in arriving in Illinois than in the boom states of the East and the Sunbelt. Page 31

Unnatural Selection

At present 17% of the fish species in Lake Michigan are introduced species. Many of them, such as the Pacific salmon (coho and chinook) and brown and rainbow trout, were introduced deliberately, usually for sport. All but one of these species must be sustained by stocking, since they do not reproduce naturally in Illinois' alien waters.

Other exotics were introduced unintentionally. The opening of navigation channels between Lake Michigan and the Atlantic Ocean via the St. Lawrence and Welland canals improved shipping at the cost of the lake's native fish populations. Exotic species such as the alewife and the parasitic sea lamprey migrated into lake waters, where they either competed with natives for food or fed on them. These changes had sometimes catastrophic results; the sea lamprey, for example, is thought to have helped extirpate the lake trout by the mid-1950s.



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Exotic species have assumed the roles of major predators and major forage species in the ecosystem, leading to unstable fish stocks with fluctuating population densities. For example, the decimation of the lake's natural predators by the sea lamprey in the 1950s allowed populations of the introduced alewife to explode, and they in turn decimated native prey fish species such as the emerald shiner, both by outcompeting them for food and by eating their larvae. Emerald shiner were so abundant in the late 1950s that the fish was a nuisance at power stations that drew upon the lake for cooling water, but they had disappeared from the lake proper by the early 1960s.

The most recent of Lake Michigan's problematic non-natives is the zebra mussel, introduced to the Great Lakes in 1986. Astonishingly prolific breeders, these tiny mussels attach themselves to power plant and water system intakes, among other underwater structures. Costs of killing or screening larvae can be quite high. A recent survey of Chicago-area water treatment plants and industrial boilers found costs per facility averaged well over $500,000.

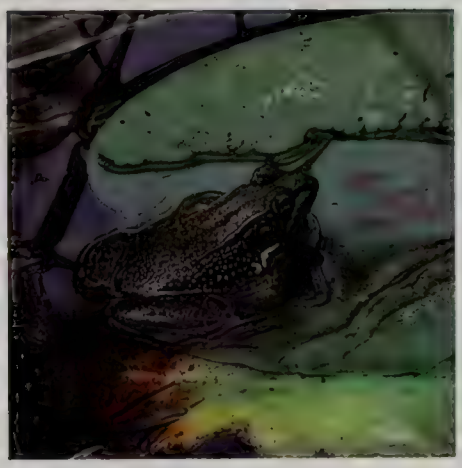
Zebra mussels are filter feeders that take microscopic particles from open water and expel undigested bits as pseudofeces. Their feeding thus speeds the transfer of food from open water to the lake bottom. Some benthic species—amphipods, planaria, chironomid larvae—benefit from what amounts to the manuring of the lake bottom, but the cleaning of lake water also has perverse effects. It rids open water of plankton that is the base of the food chain that ultimately supports sport and commercial fish, and by allowing more light to penetrate at depth it spurs growth of photosynthesizing macrophytes.

Tighter controls (including restrictions on the dumping of ballast water by ocean-going ships entering the Great Lakes) may help reduce the movement of new species into the Lake Michigan ecosystem. But the zebra mussel occurs in densities of several thousand per square meter, and already threatens to totally displace native mussel species in the Mississippi and Illinois rivers. Because of their sheer numbers and unique biological traits, zebra mussels may be able to reshape the whole lake ecology. ❖

Findings II: Ecosystems at Risk

Forests

Prairies



Wetlands

Chapter 5

Total forest area is now increasing statewide.

• The increase in wooded acreage from 1926 to 1985 has been estimated to be 41%, from 3.02 million to 4.26 million acres.
Page 34

FORESTS

Because it sits at the junction of several continental climate regions, Illinois has a rich diversity of wooded lands. In all, Illinois counts 14 subcategories of upland and floodplain forest plus the less common sand and flatwoods forests; Illinois forests include eight major species associations that encompass more than 30 forest types in all.

FOREST FLUCTUATION

In 1820 an estimated 38% of the Prairie State—some 13.8 million acres—was wooded. Within a century only slightly more than 8% of this original forest remained, and today only 11,600 acres, or 0.9%, of the presettlement forest, is left. (Figure 5-1) Large plots of rarer forest types, such as sand forests, have virtually vanished from Illinois. The removal of the Illinois forest rivaled in pace, if not in scale, the cutting of the tropical rainforests today.

The process continues in some places wherever tillable or buildable land bears trees; for example, 17 of 21 counties lost more than 5,000 acres of forest land between 1962 and 1985 in the farming districts of south central Illinois between Shelbyville and the Shawnee Hills. Ancient Illinois trees generally survive on private land that is too hilly or wet for farming or located too inconveniently for housing; Beall Woods, at 329 acres the largest tract of original deciduous forest in Illinois, stands in the Wabash River bottom.

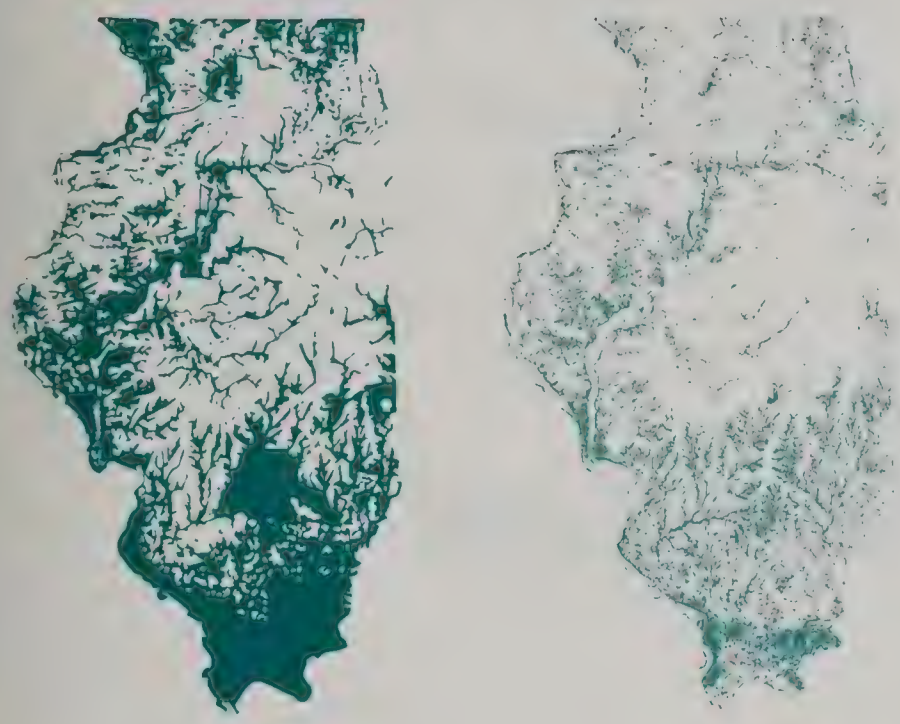
Hundreds of thousands of acres of pastures and forage cropland were converted to row crops or abandoned beginning in the 1940s as Illinois farmers switched from animal husbandry to row-crop production. Woody plants quickly re-established themselves on abandoned pastures. This secondary growth forest is a patchwork, geographically and ecologically. The shift of land back into forest has been uneven, proceeding briskly in the north, while forests continue to dwindle in the south. Overall, the increase has been estimated to be 41% (1.24 million acres) compared to 1926. The current Illinois forest is about 31% as large as the state's original wooded acreage.

Wooded parcels everywhere in Illinois tend to be small. Only 11% of the 214 "Grade A" and "Grade B" forest sites cataloged by the Illinois Natural Areas Inventory are greater than 100 acres in size. Each of the more than 169,000 private forest owners is estimated to hold only 21.5 acres on average. An analysis of 13 counties in south central Illinois found that the vast majority of "forests" in this region were smaller than one acre in size, the equivalent of backyards with trees.

FOREST INDUSTRIES

While the southern Illinois forests still contain commercially attractive populations of oak and hickory suitable for lumber, Illinois imports virtually all of the wood it needs from other states. Nearly two million cords (43% of the annual removal of wood material of recent years) is firewood. Three-fourths of the firewood harvest today is from dead trees, so the harvest poses no particular threat to the resource; it does threaten animal species that depend on snags for breeding and roosting, however, and thus forest biodiversity.

Figure 5-1 Forests in Illinois 1820 and 1980



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

The composition of Illinois forests is changing.

• Illinois forest acreage dominated by maples has increased more than 40-fold since 1962, while oak acreage has decreased by 14% and elm acreage has shrunk by half, the latter a result of disease and bottomland conversion. Page 36

Stands of trees in Illinois are in fairly good health overall, at least compared to those in the southern and eastern U.S. (No direct damage from acid precipitation has been noted in Illinois.) Atmospheric deposition is the primary route of nutrient supply to forest ecosystems over geological time scales. (Illinois' rich loess soils were deposited by wind, for example.) The total amount and proportions of this nutrient chemical "rain" is certainly different today than it was 10,000 years ago, and the impact of this change is as yet unknown, but the potential to affect forest ecosystems exists.

Recent field surveys found a relatively high incidence of crown dieback in white oak and sugar maples—a potential sign of stress for which researchers have no explanation. Mortality rates since 1965 have increased, but the increase is thought not to signal general ill health among forests trees; instead, it reflects catastrophic losses among one species—the American elm—due to Dutch elm disease and the general aging of the forest. (Figure 5-2)

While growth rates overall are slowing, Illinois forests still are growing faster than they are being depleted. "Growing stock" in 1985 amounted to 4.8 billion cubic feet (or 21.6 billion board-feet of lumber), which is 40% more than in 1962. Overall annual growth exceeds timber removals by 40%, so that (barring other changes) the volume of wood in Illinois forests will continue to increase. The historically dominant oak-hickory forest still accounts for half the commercial acreage, but it is giving way to the maple-

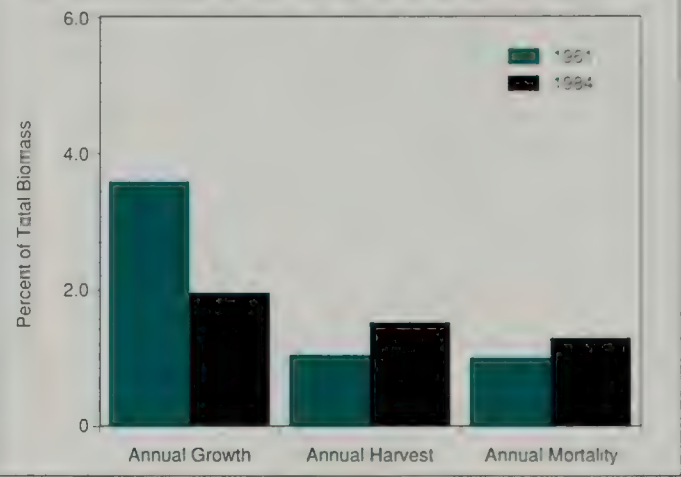
Timber volume is increasing, but net annual growth is slowing.

• Timber volume rose by 40% between 1962 and 1985. Net annual growth was 30% lower in 1962 compared to 1984, reflecting the aging of Illinois' second-ary-growth forests. Page 35

Chemical pollution has had minor quantifiable effects on Illinois forests to date. Page 35

beech (mainly sugar maple) forest that is less biologically diverse and has less value as a timber resource. The acreage dominated by maples has increased 40-fold since 1962, while oak acreage has decreased by 14% and elm acreage has shrunk by half (mainly as a result of disease and bottomland conversion). (Figure 5-3)

Figure 5-2 Forest Growing Characteristics, All Species



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Forest Plants

Notwithstanding the shift in acreage toward the maple-beech forest, the single most numerous tree in Illinois forests is an elm—the slippery or red elm, a smallish (and thus not commercially valuable) tree that thrives in the understory, untouched by Dutch elm disease. Of the 1.93 billion trees estimated to stand in Illinois forests, roughly 18% are slippery elms.

A total of 508 taxa of woody plants (284 of them shrubs) are found in Illinois forests. Nearly half (49%) of the plant species rare to Illinois are found in its woods, from grasses to orchids. Twelve Illinois native forest plant species are thought to be extirpated.

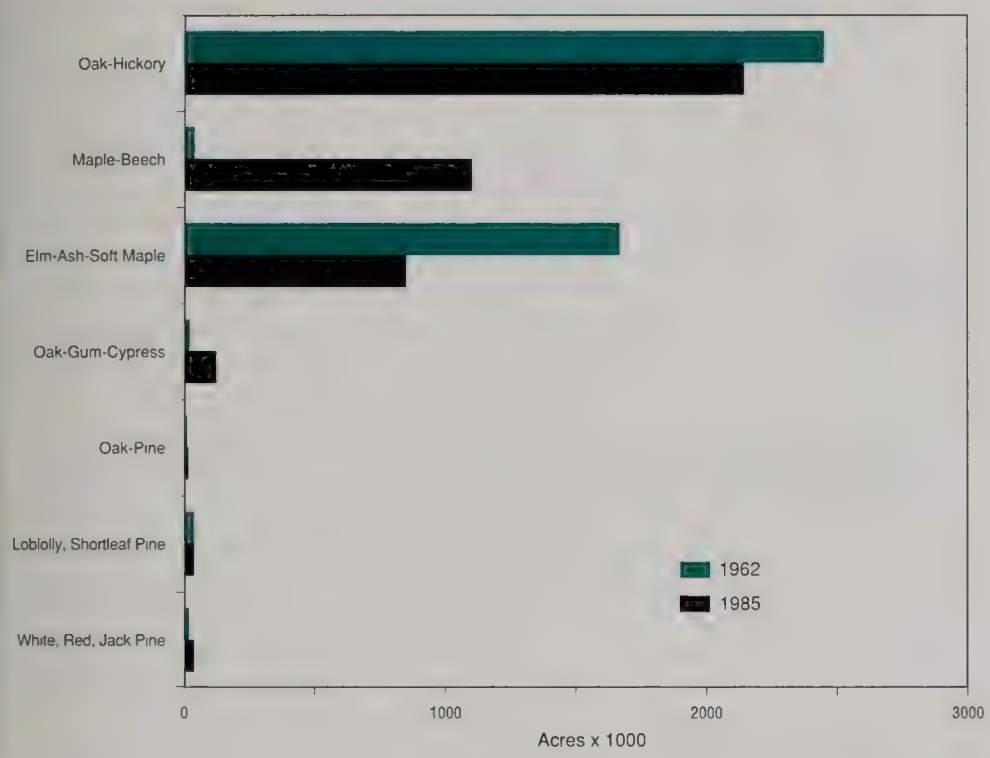
Perturbations, natural or human, often provide growth opportunities for exotic or non-native weedy shrubs. When trees are downed by winds or disease, certain woody vines such as the Japanese honeysuckle quickly exploit the opening and crowd out any trees that would otherwise repopulate the opening. Defoliation (a common disease symptom) increases the amount of sunlight that falls on the forest floor; this benefits sun-loving species (many of which, unfortunately, are aggressive exotics) and thus changes the species composition of that level of the system.

Most of these plants, such as the amur honeysuckle and the autumn olive, were introduced to Illinois as ornamentals or wildlife habitat. Unfortunately, they thrive in environments lacking the pressures from predators and competitors that keep their spread under control in their own native habitats. Common buckthorn is a pest in northern Illinois woods while multiflora rose is a problem everywhere in Illinois; garlic mustard now is recorded in 41 counties, and probably is present in many more. There are even weed trees—the amur maple, white mulberry, golden rain tree, and tree of heaven. In areas where these aliens thrive, the natural succession of forest plants may be altered and the structure of the forests themselves thus drastically changed.

Wildlife

Illinois forests are the state's unofficial wildlife refuge system. As islands amid the ocean of grain, forests comprise more than 75% of Illinois wildlife habitat, according to one index. Four of five mammals and amphibians and three of five birds need forested land

Figure 5-3 Composition of Illinois Commercial Forests 1962 and 1985



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

for at least part of their lifecycles; in all, the woods are home to more than 420 birds and other vertebrates.

The gradual loss of biological diversity observed in Illinois forests in recent decades is reflected in the adaptation to—one could almost say appropriation of—the forest by adaptable, "generalist" plant and animal species such as starlings and brown-headed cowbirds. (Some generalist animals of the forest, such as opossum and raccoon, have made themselves at home in towns and villages, too, as have woodland birds like the blue jay.)

Forest edges are rich habitats for plants and animals like deer able to exploit them, but they leave the forest itself vulnerable to aggressive weeds, non-native animal competitors for nest sites and food, and predators. Hunters surveyed in 1991 reported seeing half as many housecats as raccoons in woods in most regions of the state.

Mammals. Many commercially important furbearers dwell mainly or exclusively in forests, including the red and gray foxes, coyote, and raccoon. A 1991 survey of hunter sightings found that the red fox was more common in the north, the coyote and the badger in the south.

Although small rodents are numerically dominant, squirrels and deer are the most conspicuous among mammals in Illinois woods. Their large numbers are less a matter of these species adapting to the Illinois environment as the Illinois environment having been modified—inadvertently—for them. Fox squirrels prefer mature oak-hickory forests near

Exotic species invasions of Illinois forests are increasing in severity and scope.

- **The gypsy moth, which has already decimated Eastern forests, has been caught in traps in Illinois (mostly around Chicago) since the mid-1970s. Page 39**

- **Common buckthorn is a pest in northern Illinois woods while multiflora rose is a problem everywhere in Illinois; garlic mustard, a herbaceous weed, now is found in at least 41 counties. Page 36**

- **Hunters surveyed in 1991 reported seeing half as many housecats as raccoons in woods in most regions of the state. Page 37**

The biological diversity of Illinois is being carried in large part by its forests.

• Nearly half (49%) of the plant species rare to Illinois are found in its woods, from grasses to orchids. Page 36

• Four of five Illinois mammals and amphibians and three of five of its birds need forested land for at least part of their lifecycles. Pages 36–37

corn and bean fields. Similarly, the white tailed deer, Illinois' largest and most coveted game animal, was so victimized by habitat change and hunting that by 1901 it was considered extirpated in Illinois. The reversion of farm fields to woods, and the recovery of understory in woods where it had been suppressed by grazing livestock, provided deer with a perfect habitat. That change in habitat plus the lack of predators led to a population explosion. The forests of Illinois (including its urban and suburban woods) are now home to more deer than were thought to have been present at settlement; in many parts of the state, deer are a road hazard and garden pest.

Birds. According to a 1991 survey of hunter sightings, turkeys were common where the forests are most dense (mainly in the western counties), while pheasants were common where habitat favors them, mainly farming areas that still have hedgerows.

Some of Illinois' forest songbirds—like warblers and vireos—are neotropical migrants that breed in North America and winter in Central or South America. Surveys of two forests in central Illinois that have been monitored since 1927 and 1949 respectively—one nearly 60 acres in size and the other 1,500 acres—confirm findings from other studies. Larger tracts of woods harbor more different kinds of birds than do small ones, and annual fluctuations in abundance are pronounced. The Illinois data also suggest that while the number of species found in these particular woods is not in decline, the relative abundance of migrants has declined. Neotropical migrants once accounted for more than 75% of breeding birds but as of 1992 make up less than half those numbers on even large wood lots. (Figures 5-4 and 5-5)

Figure 5-4 Numbers of Bird Species Breeding in Trelease Woods

Figure 5-5 Relative Abundances of Migrants in Trelease Woods

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Insects. The number of insects harbored by the virgin forests is unknowable. No counts were done, although

reminiscences of travelers and settlers give the impression that greenhead flies, katydids, grasshoppers, and (especially) mosquitoes made their presence known to nonscientists.

It is known that when mature forest is destroyed and is replaced by second-growth forest, dramatically different insect communities move in. Non-native trees provide habitat for insect species not indigenous to Illinois; for example, pine plantations that were planted as part of soil erosion programs in the 1930s, are now home to such pests as the northern pine weevil, pales weevil, and Nantucket pinetip moth. In 1914 the European pine shoot moth was found in Illinois; in its borer form it stunts and disfigures Austrian, Scotch, and red pines in the northern half of the state. In 1979 pine wilt disease, caused by the pine wilt nematode, was discovered in Illinois. The Caroline pine sawyer (a native beetle) serves as the nematode vector in Illinois. The disease has devastated red and Scotch pine plantations, many of which will probably be eliminated from the state by the late 1990s. The larger pine shoot beetle was found in Illinois in 1992; an exotic, it bores into new pine twigs, killing them.

As noted, many of these infestations are exotic in origin. One of historic Illinois' ecological catastrophes—the decimation, beginning in the 1950s, of the American elm forest—was caused by a fungus borne by the smaller European elm bark beetle. The gypsy moth, which has already decimated the forests in the East, has been caught in traps in Illinois (mostly around Chicago) since the mid-1970s. Entomologists worry that, as Illinois is exposed to more international trade, the unintended importation of exotic insect pests will increase in spite of restrictions on imported plant materials. ❖

Forest fragmentation has reduced the ability of Illinois forests to maintain biological integrity.

• In one Illinois forest, neotropical migrant birds that once accounted for more than 75% of breeding birds now make up less than half those numbers. **Page 38**

"Ancient undisturbed repose"

The first Europeans found woods mainly along streams and rivers. Something of the scale of these woods can be gleaned from accounts of travelers and pioneer settlers. A 17th-century Frenchman enthused that the trees of "prodigious height and girth" were the very finest for shipbuilding, apart from being inconveniently distant from an ocean. Rebecca Burlend, an English immigrant who settled on an 80-acre Pike County farm in the 1830s, later wrote of the woods on her land, "Everything here bears the mark of ancient undisturbed repose." A few years later, Englishman William Oliver described the "lofty dark forest" that was home to the "monarchs of the ages," whose coolness he likened to that of a sepulcher.

A glimpse of the old oak-hickory forest can be seen today in such relicts as Allerton Park in Champaign County, Carpenter Park outside Springfield, and Funks Grove south of Bloomington-Normal. Mature hardwoods can grow so tall that naturalists have to use binoculars to see their leaves. The French moved up and down rivers aboard dugout canoes made from single logs of cottonwood or sycamore up to 40 feet long. A Shumard red oak in Beall Woods is the biggest such tree in the United States, and Illinois hosts hickories that are 400 years old. Some cypress tress in the southern Illinois bottomland forests have been likened to sequoias, being as many as one thousand years old.

Mature hardwoods can grow so tall that naturalists have to use binoculars to see their leaves and some cypress trees in the southern bottomland forests have been likened to sequoias, being as many as one thousand years old.

During most of the human occupation of Illinois, the forests constituted an essential part of the domestic economy. The diversity and quality of forest food is high, although supplies vary more than in other ecosystems. (Trees don't fruit every year, for example.) Wild plums—one of more than a dozen edible fruits found in Illinois woods—grew so profusely that early farmers left most of them for their hogs. Nuts are ubiquitous at Illinois archeological sites (hickory nuts, including pecans, were most prized by native peoples) and the flocks of passenger pigeons that used to fill Illinois woods fed on beechnuts. As late as the 1920s, groves of pecans along Thompson Lake on the Illinois River provided nuts by the wagonload to local families in the fall.

Native American agriculture in most eras was a forest agriculture, but as populations tended to be small, the girdling of trees for plots did not threaten forests. Illinois' first European settlers imitated this early style of forest economy, and French settlers learned from Native Americans how to tap maple trees for sugar-making. Sugar became a staple of the pioneer economy as well as its diet, since the sweet was often used as a medium of exchange.

Sugar-making was not the only early industry in Illinois to exploit trees. Salt also was crucial as a commodity and as currency barter. The center of production was the mineral springs in Saline County. The native population had long evaporated salt from spring water in pans, but the Europeans took a more industrial approach, burning wood in salt "furnaces" to boil off the water.

The dependence of early European immigrants on trees for both energy and building materials led to repeated—if local and temporary—exhaustion of the resource. Profitable mines often were abandoned not because their ores were dug out but because cheap local sources of wood for fires and timbers were exhausted. Lead mining at Galena in the 1830s led to massive deforestation of the surrounding hills; the consequent soil erosion rendered impassable the river that connected the town to the vital shipping traffic on the nearby Mississippi.

Some Native American settlements exploited trees for fires and defensive palisades; archeological evidence suggests that the harvesting of trees in adjacent upland stream courses led to occasionally calamitous soil erosion from suddenly denuded slopes. The result was siltation of downstream reaches so severe that streamside camps were flooded. ❖

Quercus alba

The oak-hickory forest is typical of the Appalachian forest system, of which Illinois is the westernmost fringe, and the oaks are the dominant tree in it. The oak is long-lived and has commercial value as hardwood—two of the reasons why the white oak, or *Quercus alba*, was adopted as Illinois' official state tree.

While the majority of Illinois' oak trees are young and small, roughly two-thirds of Illinois forests dominated by oaks in 1985 were older than 60 years. Oaks are still by far the largest contributor (8.83 billion board feet, or 51.2%) to the volume of Illinois' commercial forest, in spite of the fact they comprise only 12.2% of its trees.

In many places these aging trees are not regenerating naturally. Grazing deer take a toll. Fires no longer clear the forest understory of the oak's competitors. More shade in the forest understory means that oak seedlings, which need sun to grow, are being overwhelmed by shade-tolerant trees like maples. When the overstory is removed (by cutting, windthrow, or disease) the maples are positioned to rapidly exploit the opening. The result is "maple takeover," the process by which the oak-hickory forest is replaced not by younger oak and hickory trees, but by different tree species.

The oak is long-lived and has commercial value—two of the reasons why the white oak, or *Quercus alba*, was adopted as Illinois' official state tree.

Disease and insect infestations also are changing the ecology of the oak-hickory forest. A serious outbreak of gypsy moths in Illinois appears to be inevitable, in spite of state and federal control programs underway since the early 1980s. By the late 1990s the moth is expected to infest Chicago Forest Preserves and then move downstate. ❖

Quercus alba

Chapter 6

Prairie in the Prairie State is disappearing.

- **In 1820 at least 60% of Illinois' land area was grasslands of one type or another. Page 42**
- **The Illinois Natural Areas Inventory found that only 1/100 of 1% (2,352 acres) of high quality original prairie survives. Page 42**
- **Of the 253 prairie sites identified by the Illinois Natural Areas Inventory, four out of five are not protected as dedicated nature preserves. Page 42**

PRAIRIES

What wasn't forest or open water in presettlement Illinois was prairie. The exact extent of these grasslands is disputed, but it is safe to say that in 1820 at least 60% of Illinois' land area was grasslands of one type or another.

Modern scientists recognize six main subclasses of prairie in Illinois. These are distinguishable mainly by differences in soils and topography; further subdivisions based on soil moisture produce a total of 23 distinct prairie types in the Prairie State.

Flat terrain and deep loess soils made most Illinois prairies ideal for agriculture. The breaking of the Illinois prairies began in earnest with the invention in 1837 of a self-scouring steel plow both strong enough to slice through the dense mat of prairie plant roots and slick enough to slip through sticky loam soils. Vast stretches of prairie were destroyed between about 1840 and 1900. According to one account, the 60-square-mile Fox Prairie in Richland County was reduced from more than 38,000 acres to 160 acres of prairie between 1871 and 1883. McLean County once had 669,800 acres of prairie; today it has five of high quality. Champaign County once had 592,300 acres of prairie; today it has one of high quality. (Figure 6-1) Prairie remnants in such counties probably have escaped natural areas surveyors (especially along railroad rights-of-way) but including them would still leave Illinois with only a very small number of acres of surviving prairie.

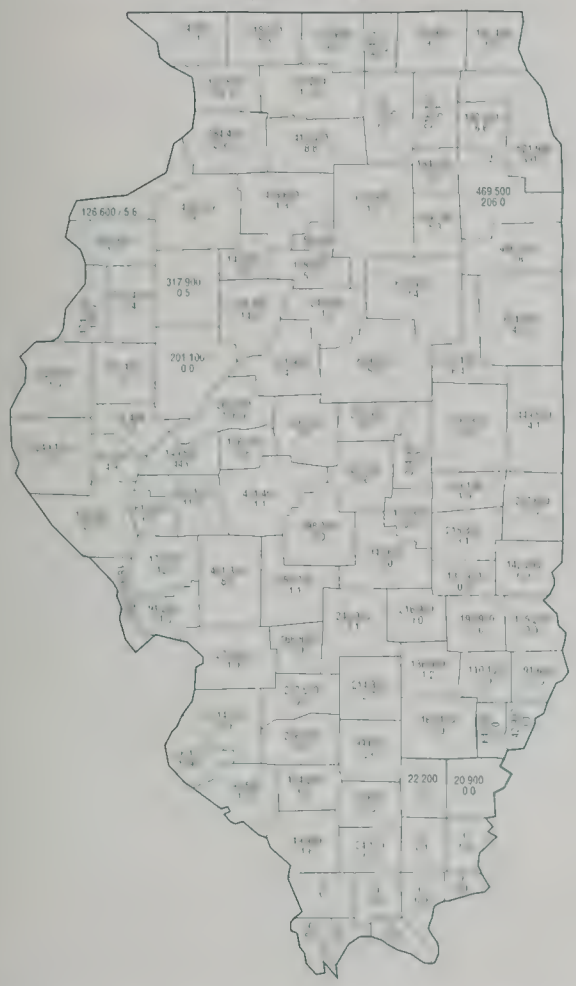
The Illinois Natural Areas Inventory completed in 1978 found that only 1/100 of 1% (2,352 acres) of high-quality original prairie survives. Most sites of relict prairie occur on hilly land along the northern and western edges of the state and other places where plows and bulldozers can't reach, such as wetlands, cemeteries, and railroad rights-of-way. Four out of five of the state's prairie remnants are smaller than ten acres and one in three is smaller than one acre. Of the 253 prairie sites identified by the inventory, four out of five are not protected as dedicated nature preserves.

Illinois prairie remnants are often less than one acre in size, and the entire local population of some plant and animal species may be only a few individuals. The smaller such local populations are, the more vulnerable they are. Extremely isolated populations of plants and animals can develop so-called inbreeding depression, or an inability to reproduce, especially if they are not wind-pollinated species whose widely dispersed seed gives them ample opportunities for cross-breeding with distant populations.

To date Illinois has few examples of inbreeding depression in its prairie preserves, although that may also reflect the lack of appropriate studies looking for it. Many prairie plants are long-lived, producing only a few generations per century, and thus are unlikely to quickly show the effects of inbreeding.

Because they tend to be inaccessible to the plow, hill prairies are among the last "living windows" into the presettlement Illinois ecology. Illinois hill prairies hold only half the acreage they did 50 years ago. Without periodic fires to check their growth, woody species invade hill prairies from adjacent lands. Comparing aerial photos from 1940 to

Figure 6-1 Changes in Illinois Prairie Acreage by County*



*The top figure is the number of acres of prairie in 1820; the bottom figure is the number of acres of high-quality prairie remaining in 1976

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

the present shows that Revis Hill Prairie has decreased in size from 39.2 acres in 1939 to 17.4 acres in 1988.

The tallgrass prairie (where it survives) is a nitrogen-limited system, meaning that the exuberant growth of grasses and other plants consume most of the nitrogenous nutrients in the soil. This chronic nitrogen shortage helps prevent plant species not adapted to it from invading the grasslands. However, supplemental nutrients can enter prairie ecosystems in various ways and in various forms and are likely to alter their species composition. Nitrate and ammonium compounds are delivered from the air by both wet and dry deposition. Total nitrogen deposition on Illinois soils through most of the 1980s ranged from 17 kilograms per hectare per year to less than ten in the Chicago area; nitrogen pollution from runoff and groundflow is locally even more concentrated than that from the air. Prairie plants have been shown to vary in their ability to capitalize on atmospheric carbon dioxide, another nutrient, which some experts expect to double during the next century.

Illinois' remaining prairies are being fragmented.

• Four out of five of the state's 253 prairie remnants are smaller than ten acres and one in three is smaller than one acre—too small to function as self-sustaining ecosystems.
Page 42

PLANTS

The number of "prairie species"—those plants capable of living at least part of their life cycle in that habitat—is quite large. The Illinois Plant Information Network counts 851 species of plant native to Illinois prairies. However, by no means do all of these occur in any one site. More than 100 species are seldom found in any one prairie, although (as is true of forest land) the larger patches are host not only to more plants, but to more kinds of plants.

Of the 497 plant and animal species considered endangered or threatened in Illinois as of 1993, 117 occur in prairies. Because nearly all species found in prairie occur in other

Prairie ecosytems face extirpation in Illinois, although few prairie plants do.

• While 117 of the 497 plant species considered endangered or threatened in Illinois as of 1993 occur in prairies, only one occurs solely in prairies.
Pages 43–44

states, or in habitats other than prairies, there are few species endemic to the Illinois prairie ecosystem.

Because of the peculiar conditions under which many Illinois prairie remnants survive, they are vulnerable to peculiar threats. Plants native to blacksoil prairies of the sort that flourish atop undisturbed country graveyards are being overtaken by non-native species planted by mourners as landscape ornamentals. Many exotic plants are little more than nuisances when they root in prairie patches, but species such as white sweet clover and giant teasel are very aggressive. Some can be eliminated by such approved management techniques as periodic burning.

Wildlife

The conversion of prairie to "secondary grasslands" in the form of hay fields and pastures actually enhanced Illinois' habitat for certain birds such as the dickcissel and the prairie chicken. But more recent changes in agricultural practice led to the decline of even these surrogate prairies. Three species of birds once common on the prairies have been extirpated in Illinois (the sandhill crane, once thought extirpated, recently reappeared in Illinois) and another thirteen species were endangered or threatened in the state as of 1993.

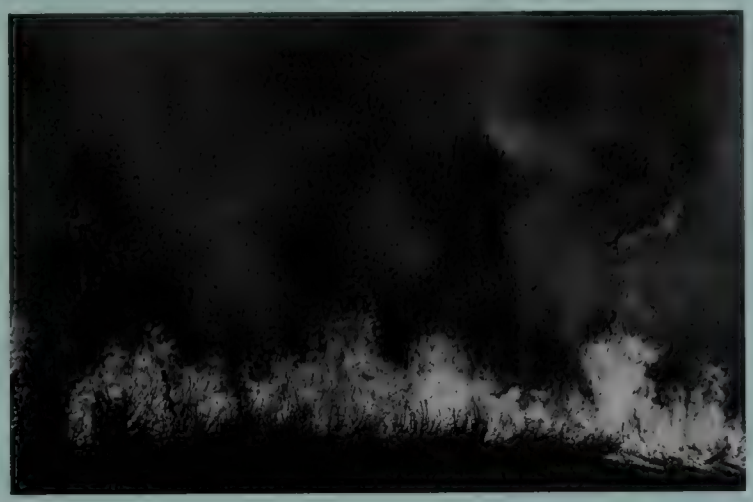
Insects have proven more adaptable, although some species may be struggling in Illinois. Typical is the Karner blue butterfly. A native of the Great Lakes and Northeast, the caterpillar of the Karner blue is uniquely adapted to feeding on the leaves of the wild lupine once common in northern Illinois savannas. Nationwide, populations of the Karner blue have declined by 99%, and in 1992 the U.S. Fish and Wildlife Service added it to the list of endangered species. The insect had not been seen for a century in Illinois until the summer of 1992, when five (perhaps a windblown "tourist" and its progeny) were spotted in Lake County.

The distribution of 255 of 640 prairie insect species surveyed since 1982 is restricted to prairie/savanna remnants. Perhaps one-fifth of these are found in only a very few, usually small, sites and must be considered imperiled. Among these is the loosestrife rootborer, which today is found at fewer than six sites; a handful of other species, such as the Dakota skipper, have not relocated to nonprairie habitat and are assumed to be extirpated in Illinois. Separate surveys of the protected prairie at Illinois Beach State Park have found that two butterfly, one moth, and a dozen leafhopper species that once inhabited it have not been seen there for many years. ❖

"The appropriation of habitat by habit"

Grasslands are found in Illinois where climate and soils produce trees in others parts of the world. The difference is fire.

Fires occur spontaneously in nature, but archeological evidence confirms that the early humans of Illinois also deliberately burned their range. Fire rendered the landscape more hospitable—by driving game to slaughter, by clearing brush from fields, and by killing off woody plants that competed with the (mainly) annual plants that supplied the seeds and tubers upon which advanced hunter-gatherers relied. Many of the plants that were nurtured by gatherers and later by the first farmers are quick to exploit disturbed areas. Burning was an easy way to see that the landscape stayed disturbed, to the benefit of both annual plants and plant-gatherers.



Some researchers have speculated that, were it not for the fires set by Native Americans, forest would have covered as much as 20% more of the Illinois landscape at the time the French explorers arrived.

Some researchers have speculated that, were it not for the fires set by Native Americans, forest would have covered as much as 20% more of the Illinois landscape at the time the French explorers arrived. According to this interpretation, prairies are cultural as much as natural features. The mixed-grassland-forest of presettlement Illinois was a result of what geographer Carl Sauer called "the appropriation of habitat by habit."

What human hands did to help create the prairies, they can also undo. For instance, by putting away their plows and putting out fires, humans virtually ensure that trees will take over an abandoned farm field. Hot, dry climates favor grasses over trees. There was a resurgence of hot summers in the 1980s, but even an extended warming trend favoring them would not necessarily cause grasslands to increase in Illinois without periodic cultivation or fires to suppress competing trees—although a warming trend might at least slow the advance of woody plants into extant prairies. In the absence of periodic cultivation or fires to suppress them, trees, rather than prairie, will take over an abandoned farm field.

As a result, hardwood forests have spontaneously, if modestly, increased their extent in Illinois in recent years. From 1820 to 1980 an estimated 2.64% of Illinois land (mainly abandoned farm fields) reverted to forest. With burning stopped, only the plow has retarded the natural reforestation of Illinois. ❖

Chapter 7

Illinois wetlands are disappearing.

• At the time of settlement at least eight million acres in Illinois were wetlands of one kind or another. Some 918,000 acres of natural wetlands survive statewide—less than a tenth of their original extent. Only about 6,000 acres of the state's remaining wetlands are of high quality and undisturbed. Pages 46 and 48

WETLANDS

Illinois land was once famed for its wetness as much as its richness. It is conservatively estimated that at the time of European settlement more than eight million acres in Illinois (roughly one acre in five of its total area) were wetlands of one kind or another. Other estimates suggest that this figure is low. (Figure 7-1)

A VALUABLE ECOSYSTEM

"Wetlands" describes land where the water table is at or near the surface and the soils are hydric (wet and low in oxygen) and occupied by hydrophytes (plant species adapted to life in water or in saturated soils.) That definition encompasses bogs, marshes, sedge meadows, wet prairies, fens, swamps, bottomland forest, ponds, sloughs, mudflats, and areas having frequent river overflows. Wetlands in Illinois may be fed by runoff, rainfall, seepage from groundwater, or a combination of all of these sources.

The value of wetlands to the environment has only recently been widely recognized. For example, wetlands filter and purify water that flows through them. They also store water during flood events and trap sediments that otherwise would enter streams. Wetlands are thought to provide natural flood control by slowing the movement of rainfall and snowmelt into streams and by storing excess water that streams cannot accommodate during high flows. They are also thought to contribute to increased low flows in streams, in part because they help recharge shallow aquifers that feed streams during low-rainfall periods. Wetlands provide habitat to an impressive diversity of plants and animals.

Wetlands of all types have been substantially reduced in extent, mainly because of agriculture. A study using the Illinois Wetlands Inventory found some 918,000 acres of "natural" wetlands (that is, not diked, impounded, or excavated) remained statewide in the 1980s—less than a tenth of their original extent. (Illinois is one of the ten states that have lost more than 70% of their original wetland acreage.) Remaining natural wetlands cover only about 2.6% of the state's land area. (Figure 7-2) These are concentrated in the northeast (along major rivers such as the Fox, Illinois, Des Plaines, and Kankakee) and in southern Illinois. Of the surviving wetlands, only about 6,000 acres are high in ecological quality and undisturbed.

In 1992 Illinois had some 330,000 acres of wetlands modified or created by dikes, impoundments, or excavations (e.g., farm ponds and municipal reservoirs). Under federal rules, the destruction of wetlands in certain cases such as dredging or filling must now be mitigated by the construction of a like amount of wetlands elsewhere. In the first half of 1993, the U.S. Army Corps of Engineers approved the filling of 91 acres of wetlands, and mitigation was completed for 93 acres. However, created or restored wetlands have not generally been able to function at the levels of biological and hydrologic complexity of their natural models.

PLANTS

Wetlands are ecologically complex, and plants living in them have made complex adaptations. Of the 172 families of vascular plants that occur in Illinois, 108 contain species

Figure 7-1 Presettlement Wetlands

Approximation of the types and distribution of presettlement wetlands in Illinois based principally on maps of soil associations with supportive data from maps of drainage and levee districts, maps of forests, and historical wetland information. Havera 1985.

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

As wetlands disappear, those that survive are increasingly important as a reservoir of biological diversity.

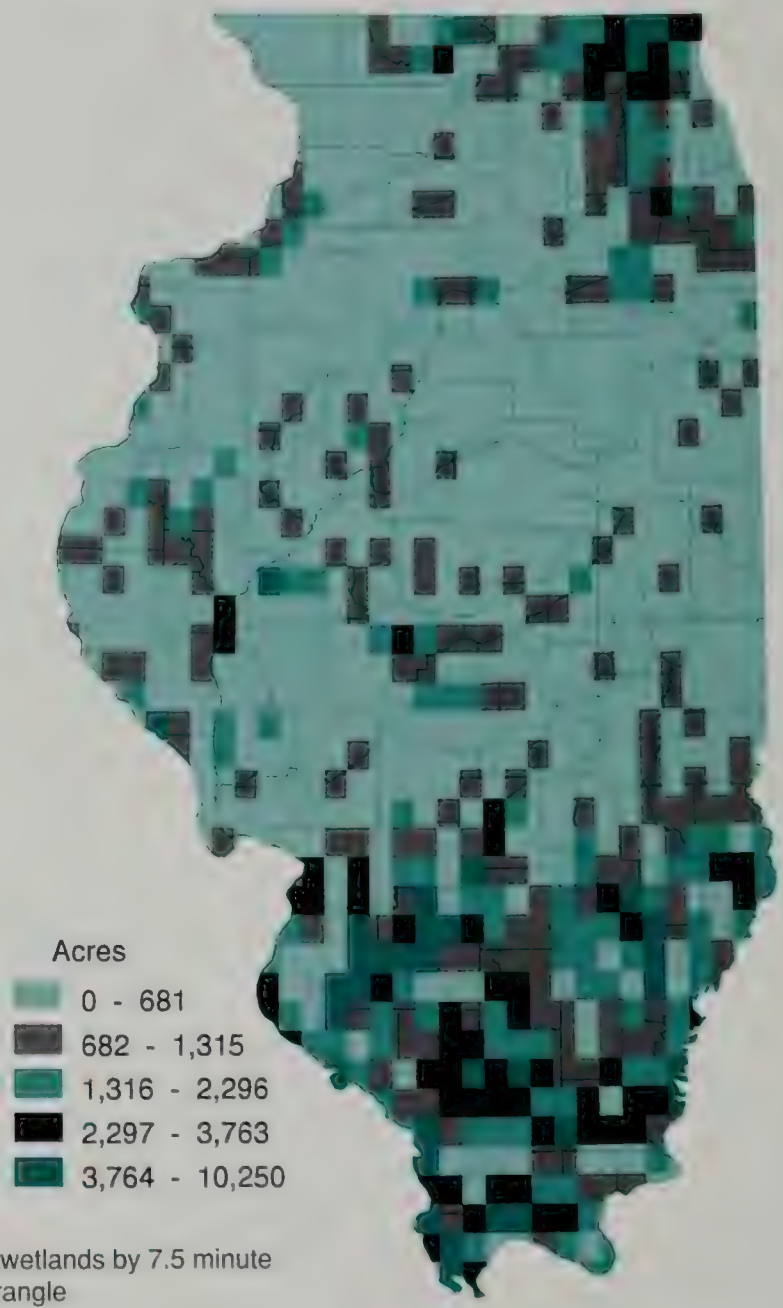
- **Only 350 undisturbed acres each of bogs and fens are thought to survive in Illinois, but they are home to 34 rare plant species. Page 49**

- **As of 1993, eight of the ten mammal species considered endangered or threatened in Illinois use wetlands to some extent. Of the 43 bird species then listed, 30 are strongly associated with wetlands, especially during the breeding season. All three of the amphibians and seven of the nine reptile species (three turtles and four snakes) listed depend on wetlands. Twelve of the 29 fish species listed either occur in wetlands or breed in them. Page 50**

The value of wetlands is being officially recognized.

• Under federal rules, the loss of wetlands in some instances must be mitigated by the construction of a like amount of wetlands elsewhere. In the first half of 1993, the U.S. Army Corps of Engineers approved the filling of 91 acres of wetlands, while mitigation was completed for 93 acres. Most created or restored wetlands, however, have not been able to recreate the biological and hydrologic complexity of their natural models.
Page 48

Figure 7-2 Distributions of Wetlands in Illinois 1980–1987



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

that thrive in aquatic or moist-soil environments. The sedges are the most species-rich of these families, followed by grasses, sunflowers, orchids, and mints. According to a conservative definition of wetland plants, a total of 952 species are found in Illinois wetlands and these constitute about 42% of the state's native flora.

Those wetland plant species considered endangered or threatened in Illinois as of 1993 and known from extant populations were most numerous in Lake (with 66 species), Cook (with 38 species), and McHenry (with 41 species) counties. Cook leads all counties in the number of species listed as threatened or endangered that were believed to be extirpated from the county, with 36; Cook was followed by Kankakee (17 species), McHenry and Peoria (16 each), Kane (15), and Lake and Winnebago (14 each). Approximately 35 wetland species are thought to have become extirpated from the state overall. *Thismia americana*, which is known to have appeared only in Illinois (near Chicago's Lake Calumet), was last seen here about 75 years ago and may be extinct, although efforts to locate *Thismia* continue.

The rarest types of wetland habitats tend to support the greatest number of rare plants. Illinois bogs and fens are a minor part of the Illinois wetland inventory in terms of acreage (only 350 undisturbed acres of each are thought to survive), but those peatlands support some three dozen endangered and threatened plant species.

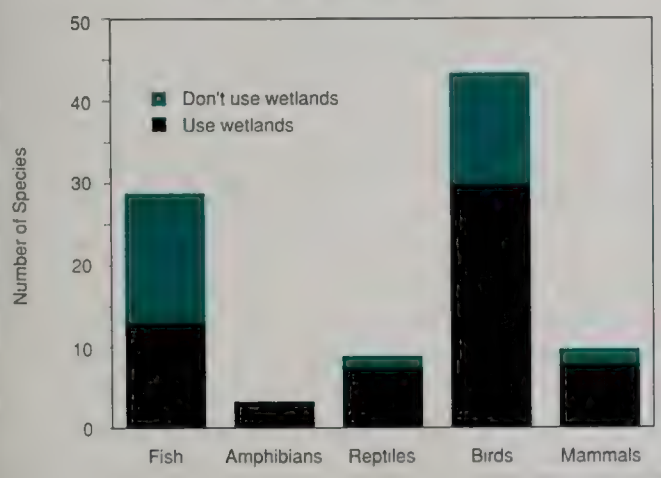
Less than 10% of the plant species now found in Illinois wetlands are not native to the state. Though few in number, the non-native wetland species are aggressive. Glossy buckthorn infests sedge meadows, bogs, fens, and floodplain forests, especially in northeast Illinois, where it quickly overtops native species; seeds of its fruits are widely dispersed by birds.

Purple loosestrife, a northern European native that arrived in North America nearly 200 years ago and reached Illinois sometime before 1940, was found in at least 25 Illinois counties by 1985, mostly in the northeast. Sale of purple loosestrife is now illegal in Illinois but it reproduces abundantly from roots, stems, or its copious seeds.

WILDLIFE

Because they are rich habitats for animals, wetlands are the venue for a disproportionate amount of Illinois' animal-based recreation, from fishing to waterfowl hunting. Wetlands also harbor disproportionate numbers of rare animals; 64% (61 of 95) of the endangered and threatened animal species listed in Illinois as of 1993 use wetlands in some way. (Figure 7-3)

Figure 7-3 Wetland Use by Endangered and Threatened Vertebrate Species



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Birds. In all, 274 bird species commonly observed in Illinois can use wetlands opportunistically for nesting, foraging, and resting, but 105 typically depend on or are strongly associated with these highly specialized habitats for nesting and foraging. Their populations have become imperiled as these habitats shrink in size. King rails, for example, are much less commonly sighted than they once were.

Habitat change has placed many wetlands species under stress.

- **King rails are less commonly sighted than they once were. Page 49**
- **The eastern newt, once thought to occur across Illinois, is no longer found in the state's central counties due to the draining of prairie marshes. Page 50**
- **The draining of wetlands is thought to have contributed to declines in populations of Blanding's turtle and the massasauga snake. Page 51**
- **The blacknose shiner had been recorded throughout the northern two-thirds of Illinois prior to 1905, but has been found only in Lake County since 1980. Page 50**

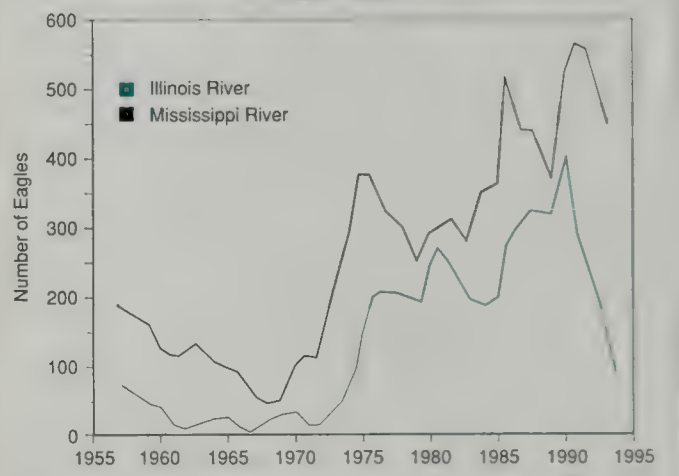
Some wetland bird species appear to be increasing in number.

• Combined populations of migrating double-crested cormorants in the Illinois and Mississippi valleys rose from fewer than 100 birds around 1970 to nearly 6,000 in 1992. Page 50

Many nesting birds such as egrets, herons, and double-crested cormorants build colonies in wetlands (mainly floodplain forests). The total numbers of some birds, such as great egrets, increased during the 1980s, while those of the night heron declined. Fluctuations in colony size and species composition are common among such birds; however, the apparent increased number of colonies may be partly the result of more diligent field surveys.

Of the 43 bird species listed as endangered or threatened in Illinois as of 1993, 30 are strongly associated with wetlands, especially during the breeding season. Some species are dependent on more than one type of wetland; the great egret, for example, typically nests in floodplain forests but prefers to forage in shallow-water wetlands.

Figure 7-4 Bald Eagles Along Major Illinois Waterways 1958–1993*



*Three-year moving averages, aerially inventoried during fall

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

As recently as the 1880s, many bald eagles nested in Illinois, mainly along the Illinois and Mississippi rivers. However, poisoning by the insecticide DDT, hunting, and habitat destruction throughout its range caused a decline in eagle populations, and from 1978 to 1987 only two to four such nests were recorded in Illinois. While numbers of nesting bald eagles seem to be increasing in recent years—17 nests were recorded in 1992—Illinois remains mainly a wintering ground. A total of 1,211 bald eagles were counted along the Illinois and Mississippi rivers in 1990. (Figure 7-4)

The double-crested cormorant is another bird that seems to be rebounding from a mid-century decline. Combined populations documented during the fall migrations through the Illinois and Mississippi river valleys rose from fewer than 100 birds around 1970 to nearly 6,000 in 1992.

Mammals. Although few mammals are adapted specifically to wetlands, eight of the ten mammal species considered endangered or threatened in Illinois as of 1993 use wetlands to some extent. The swamp rabbit (whose populations are in decline in Illinois), and the marsh rice rat are among them. Such commercially valuable furbearers as the raccoon, mink, muskrat, and beaver also inhabit wetlands.

Reptiles and amphibians. Not surprisingly, 37 of Illinois' 41 amphibian species—salamanders, frogs, tree frogs and toads—use wetlands at least part of each year. Because of their permeable skin and because they are exposed to both terrestrial and wetland environments, amphibians are especially susceptible to environmental stresses. Their highly specific adaptations also leave some species vulnerable to habitat changes; the only natural Illinois population of the silvery salamander occurs in Vermilion County, where

the animals breed in a single vernal pool. The eastern newt, once thought to occur across Illinois, is no longer found in the state's central counties due to the draining of prairie marshes.

Reptiles as a group are less dependent on water than are amphibians, but at least 47 of the 60 Illinois reptiles use wetlands to some extent. Seven of the nine species listed as endangered or threatened in Illinois as of 1993 (three turtles and four snakes) use wetlands. The draining of wetlands in heavily farmed parts of the state is thought to have contributed to declines in Blanding's turtle and the massasauga snake significant enough to put both species on the state's watch list.

Fish. Twelve of the 29 fish species listed as threatened or endangered in Illinois as of 1993 either occur in wetlands (mainly swamps, oxbow lakes, and sluggish backwaters) or breed in them. The widespread drainage of such habitats reduced the range for seven Illinois wetland species that were subsequently listed as threatened or endangered. The blacknose shiner, for example, had been recorded throughout the northern two-thirds of Illinois prior to 1905, but was seen in only eight counties in the 1950s and 1960s and has been found only in Lake County since 1980.

Invertebrates. Wetlands are rich grounds for invertebrates, from protozoa to clams and snails. A significant number of insects are adapted for life in water; they include water beetles, mayflies, dragonflies, and water scorpions. Several faunal studies have examined species groups, mainly pest insects such as mosquitoes, deer flies, and horse flies. But as is true of most other wetland-dwelling species, data that might demonstrate population trends for these macroinvertebrates in Illinois wetlands are largely lacking.

Relatively few (four of 51) of the invertebrates endangered or threatened in Illinois as of 1993 are wetland species. One of these, Hine's emerald dragonfly, demonstrates how complex are the survival needs of many species. Known in Illinois only since 1983, this dragonfly is limited to specific habitats in the Des Plaines River watershed. It requires clean water during its immature stage, which lasts three years, and is restricted to marsh communities where calcareous water seeps from between overlying glacial till and limestone bedrock.

POLLUTION

Because they are low-lying, wetlands function like sinks that collect polluted runoff or sediments from adjacent lands. Wetlands have long been favored as places to dump wastes because they were considered "waste" land. (A prime example is Chicago's Lake Calumet area, which functions improbably as a combination landfill and nature area.) Many of the more than 3,000 Illinois sites known to have been used for land disposal of wastes are located in wetlands. A 1988 survey found that 8% of Illinois' surviving wetlands and deep water acreage—more than 100,000 acres in all—are located within one mile of a known landfill or open dump site and thus potentially are at risk from contamination. ❖

Wetlands have long been favored as places to dump wastes.

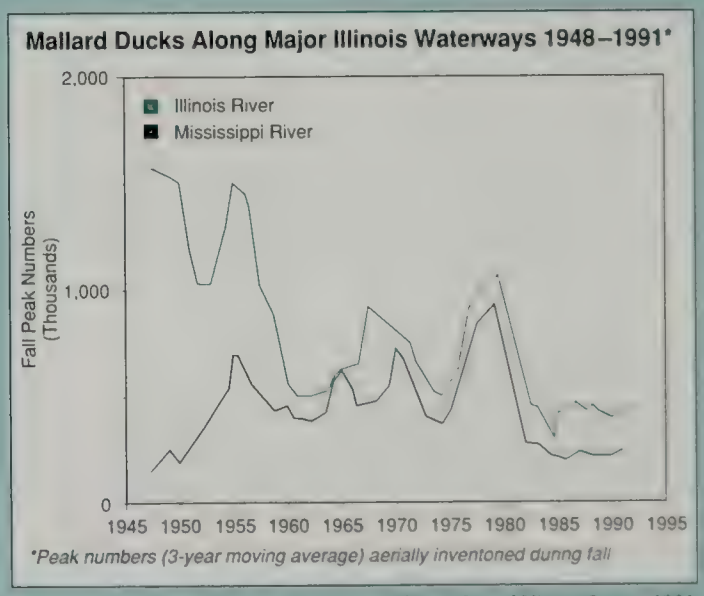
• Many of the more than 3,000 Illinois sites known to have been used for land disposal of wastes are located in wetlands. Page 51

Disappearing Ducks

Historically the Illinois River's backwater lakes have been among the most important migration areas for several species of ducks, including mallards. Since 1948, however, significantly fewer migrating mallards have alighted in the Illinois valley each fall. The trend is thought to reflect the general decline in mallard numbers across North America, but there is evidence that local conditions also have deteriorated.

> Since 1948 significantly fewer migrating mallards have alighted in the Illinois valley each fall.

The Illinois River's complex system of wetlands has long attracted more mallards than that of the Mississippi River. (In the late 1940s, mallards along the Illinois outnumbered those sojourning on the larger river nine to one.) The post-1948 decline in mallard counts along the Illinois has been relatively steeper than that recorded on the Mississippi, where sedimentation has not caused such drastic reductions in the amount and variety of natural plant foods available to migrating flocks. In addition, tillage of increased acreage of harvested corn fields in central Illinois during fall sharply decreased the waste grain available to the field-feeding mallards.



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Two other duck species—the lesser scaup and the canvasback—have suffered more drastic population crashes on the Illinois River. Lesser scaups were abundant in the Illinois valley before the 1950s, especially on Upper Peoria Lake. More than 585,000 ducks were counted on one stretch of the river in 1954; three years later the number was around 10,000. Similar trends were recorded in populations of canvasbacks. During the 1952 migration more than 105,000 birds were counted along the Illinois River north of Peoria; in 1971, only 120 were seen.

The cause of the decline in numbers of lesser scaup and canvasback ducks in the Illinois River valley is a scarcity of food. The rafts of aquatic vegetation that used to sustain the canvasback flocks on the Upper Peoria Lake have disappeared as a result of sedimentation (which causes turbid water and flocculent lakebeds) and changes in seasonal water level cycles. Also the benthic macroinvertebrate community—the small clams and other bottom dwelling creatures especially crucial to diving ducks like the lesser scaup—was likely affected by sedimentation and pollution from various domestic, industrial, and agricultural sources. ❖

Findings III: Human Hands on the Land

Agricultural Lands

Lakes and Reservoirs

Groundwater

Chapter 8

Farmland acreage in Illinois is declining.

• Farmland acreage in 1990 amounted to slightly more than 28 million acres; in 1950 the figure was nearly 32 million acres. However, some 80% of the state is still farmed—two-thirds of it planted in crops such as corn and soybeans.
Page 54

AGRICULTURAL LANDS

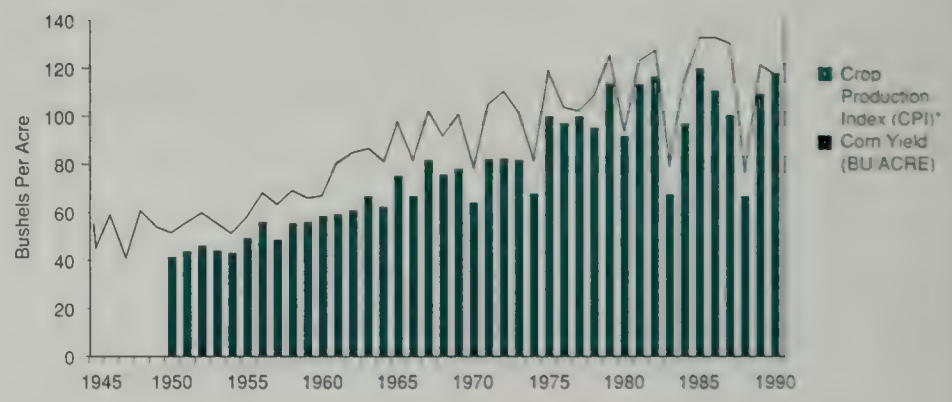
Nothing affects more land in Illinois than agriculture. Some 80% of the the state is farmed—two-thirds of it planted in crops such as corn and soybeans, the rest in pasture, forage crops, orchards, and woodlots. Making farming possible on this scale required by far the most significant of the changes humans have wrought on the state's ecosystems.

THE EVOLUTION OF FARMING

The traditional 19th-century Illinois farmstead was a diverse and productive landscape, in many respects a simplified version of the mixed woodland-grassland ecology it replaced. Beginning in the 1880s and continuing into the 1930s, a succession of innovations came into wide enough use to transform this bucolic Illinois farmscape. These included the following:

Higher yields. Commercial fertilizers and hybrid varieties of corn made possible such higher yields that, beginning about 1940, profits from grain sales rivaled those earned by animal husbandry. The average Illinois cornfield that yielded about 50 bushels per acre in 1945 yielded nearly 120 bushels per acre in 1990. (Figure 8-1)

Figure 8-1 Corn Yield 1945–1990



*Crop Production Index is the total output, in bushels, of farm crop commodities

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Different crops. In 1990 total acreage of small-grain crops (like wheat and oats) and of forage crops (such as hay) was only 44% that of 1945. In their place, farmers have planted grain, especially soybeans, acreage of which has more than doubled since 1945. By 1990 there were more acres planted in beans than were planted in corn in 1945. (Figure 8-2)

Fewer kinds of major crops. Illinois once sustained a locally significant production of orchard fruits and vegetables for the canning industry. The 1980s saw significant declines in the acreage devoted to the latter, and production of apples and peaches (the main orchard crops) also dropped somewhat.

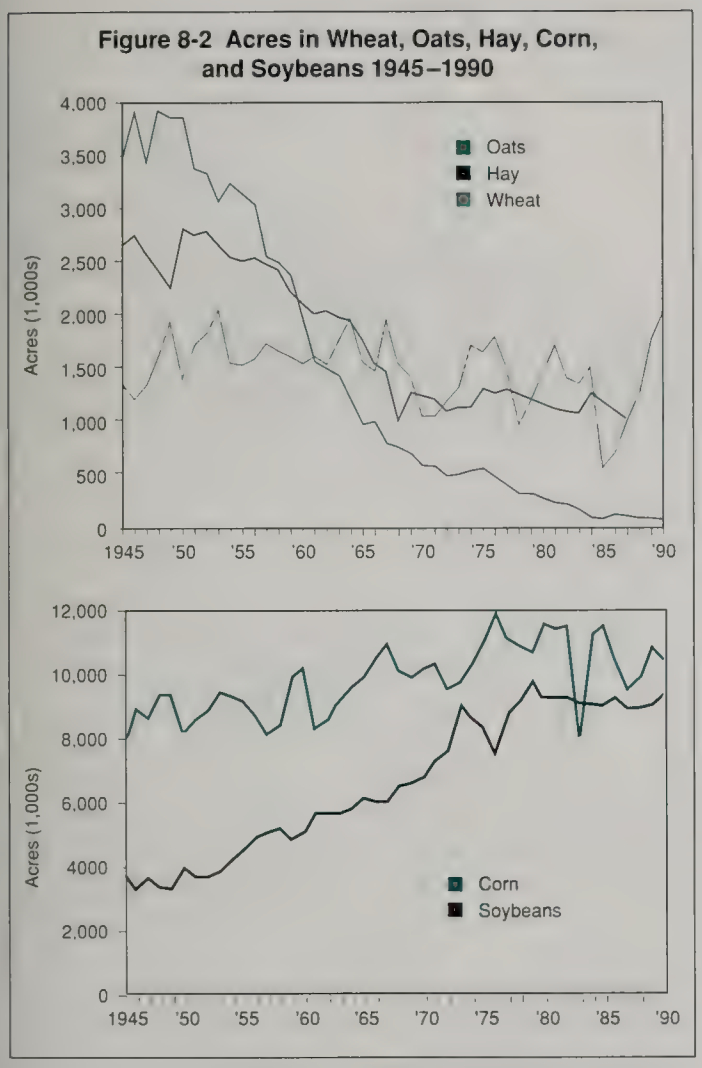


Figure 8-2 Acres in Wheat, Oats, Hay, Corn, and Soybeans 1945–1990

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Fewer animals. Livestock (especially hogs) are produced more and more in large scale facilities. Livestock remains a significant income-producer mainly on land less favored for cash-crop agriculture, such as the hilly districts of west and northwest Illinois.

More use of chemicals. Low-cost commercial nitrogen has made it possible to plant twice the once-standard number of plants of corn per acre. Since World War II, herbicides have made labor-intensive field cultivation unnecessary. Illinois farmers have used substantially more herbicide since 1964; by the early 1990s more than 96% of all cropland in Illinois was treated for weeds at least once each year. (Figure 8-3)

Larger farms. Illinois terrain and soils are especially suited to large-scale farm operations. Since 1950 the size of the typical Illinois farm has expanded more than twofold—from 150 acres in 1950 to 350 acres in 1990. (Figure 8-4)

Illinois farmers are growing different crops.

• In 1990 total acreage of small grain crops (like wheat and oats) and of forage crops (such as hay) was only 44% that of 1945. Soybean acreage has more than doubled since 1945, and by 1990 there were more acres planted in beans than were planted in corn in 1945. Page 54

WEATHER

Illinois' long growing season is a crucial factor in its agricultural productivity. There is a trend detectable over recent decades toward longer growing seasons in Illinois, in spite of a cooling trend overall. Speculation that global warming may alter that seasonal cycle cannot yet be confirmed.

Illinois enjoyed generally moderate summers during crop-growing seasons of the 1960s and 1970s. Virtually all the technological advances that define today's agriculture were tested and adopted during this interval of relatively benign weather, which also was the era in which virtually all Illinois farmers now working learned their craft.

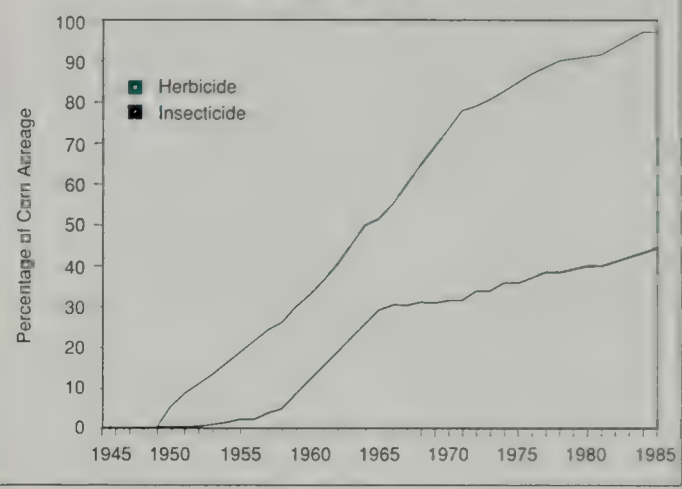
A summer dry spell of several weeks that coincides with a crucial growing period can devastate farm crops even if it does not dry up streams or deplete surface reservoirs used as public water supplies. Illinois suffered persistent and extreme drought in the 1930s,

Use of herbicides is up and use of insecticides has leveled off.

• Herbicide use by Illinois farmers is substantially higher since 1964, with more than 96% of all cropland being treated for weeds at least once each year. Page 55

• In the late 1960s 70% of Illinois corn acreage was treated with soil insecticide to control root worm; by the 1990s that figure had shrunk to less than 30%. Page 56

Figure 8-3 Herbicide and Insecticide Application by Illinois Farmers



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

and the 1980s saw a return to hotter, drier weather. (The severity of the 1988 summer drought was equalled only twice in the years since 1900.) As insurance against such calamitous shortfalls of rain, Illinois farmers have been expanding irrigated acreage statewide, from 40,000 acres in 1970 to about 240,000 in 1987.

Pollution

Agricultural pollution takes two forms in Illinois—pollution by farms and pollution of farms. The former is probably less severe than it was twenty or thirty years ago, although it remains significant if only because farming affects so much Illinois land. The following factors affect the land:

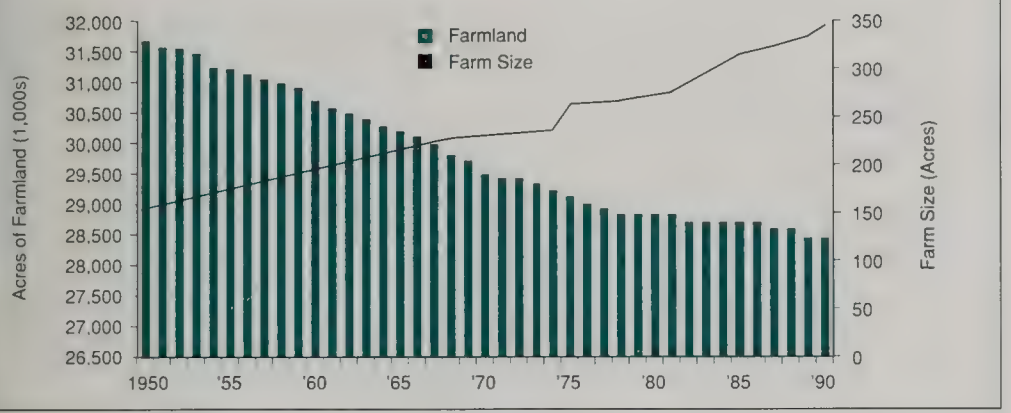
Farm chemicals. Farm chemicals can move off the farm in dust, dissolved in rainwater, attached (or adsorbed) to eroded soil particles, or as volatilized gases. These migratory chemicals are a principal source of nonpoint pollution in Illinois. For example, inorganic forms of nitrogen fertilizer dissolve easily in water and thus are easily washed off fields into streams by rain; in some areas, shallow groundwater may also be affected. (Case studies have documented elevated nitrate levels in rural shallow wells; the problem is still under study.) Possible spills of agricultural chemicals at the more than 1,200 ag chemical distribution sites in Illinois could pose some risk of soil and water contamination; however, recent regulations for these sites should reduce their risks.

Errant nitrogen and other farm nutrients also can cause the eutrophication or artificial nourishment of surface waters, especially lakes, which thus produce water-clouding crops of microscopic water plants such as algae. It is impossible to say with certainty whether eutrophication is getting worse or better; most water impoundments were built in the 1950s and 1960s, after the acceleration of chemical-intensive agriculture was already well underway.

Compared with fertilizers, farm pesticides have been introduced to the larger Illinois environment in relatively small amounts since the 1950s. Unfortunately, early compounds such as DDT and other chlorinated hydrocarbons were persistent and indiscriminate in their effects. Unknown amounts of these chemicals are still present in bottom sediments of many lakes and streams, where they are thought to cause physical deformities among bottom-feeding fish.

Newer insecticide formulations are toxic to nontarget organisms for only a few days. Also, various data suggest that Illinois farmers have been applying them in declining amounts. In the late 1960s, 70% of Illinois corn acreage was treated with soil insecticide to control corn rootworm, a common insect threat; by the 1990s that figure had shrunk to less than 30%. In addition, the amounts being applied per acre were generally smaller.

Figure 8-4 Farmland and Farm Size in Illinois 1950–1990



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

Better monitoring of infestations makes possible more timely (and lower cost) applications, and because newer compounds are more pest specific, they are effective at lower doses.

Pollution of Illinois agricultural lands by nonfarm activities is only a minor threat to the resource. These activities include:

Mining. Since about 1885, strip mining of coal has disturbed 256,000 acres of land, which is less than 1% of Illinois' surface area. Mining regulations passed by the Illinois General Assembly in 1962 and by Congress in 1977 sought to improve reclamation so as to make surface mining a temporary use of the land by returning it to productive use. Three-fourths of the land affected by these laws has been reclaimed as pasture and 14% as row-crop acreage.

Oil production. Oil brought to the surface brings with it copious amounts of water containing dissolved salts. If allowed to spill, high concentrations of these brine wastes can be toxic to some plants at high concentrations. Incomplete surveys in 1980 and 1985 suggest that in those years 38,000 acres of Illinois land had 50% or more of its vegetation destroyed by leaks or spills of this "produced" water. Regulations now require that such water be disposed of in deep underground rock formations.

Air pollution. Illinois agricultural systems have been shown to be relatively insensitive to current levels of acidic precipitation ("acid rain"), in part because of the acid-buffering limestone added to soils by farmers. Ozone has been proven to diminish the quality and harvest of cash crops in several parts of the U.S. but limited data suggest that problematic concentrations of ozone decreased (if modestly) during the 1980s across most of the state. The impact on crops of the dry deposition of common pollutants via airborne particles and gases is less studied, as is the impact of more exotic toxic compounds deposited via both dry deposition and precipitation.

In the 1980s, research suggested that increased concentrations of carbon dioxide (CO_2), the commonest of the greenhouse gases, might induce warming of the Earth's climate. The long-term effects of global warming, if any, on Illinois agriculture cannot now be predicted. Such climatic change might cause shifts in rainfall patterns or growing season deleterious to Illinois' staple crops; because CO_2 is an essential building block in green plants, an increase in atmospheric CO_2 might actually boost farm productivity.

The switch to intensive cultivation of field crops has had significant and growing impacts on adjacent ecosystems.

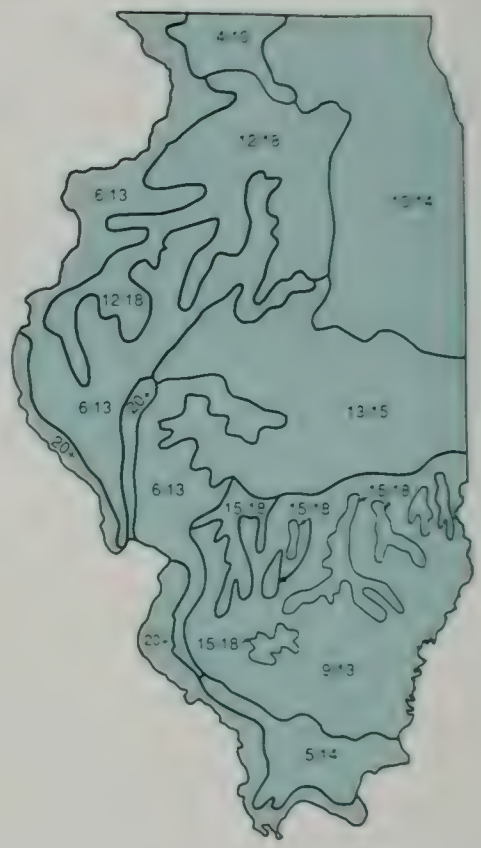
• It is estimated that 90% of all the soil erosion in the state—158 million tons per year in recent years—occurs on its farm fields, and sedimentation is Illinois' most serious water quality problem.
Page 59

Urbanization increasingly competes with agriculture for Illinois land.

• One estimate found that 17 of Illinois' top 20 farming counties are located in or adjacent to urbanized areas, as defined by the U.S. Census Bureau. Page 60

Figure 8-5 Average Thickness of Topsoils in Illinois

1) First number is thickness of present or remaining surface soils, average inches.
2) Second number is thickness of original surface soil without erosion, average inches.
3) Thicknesses are averages of dominant soils within Soil Associations.
4) Areas along the Illinois and Mississippi Rivers, indicated by 20+, are areas of deposition.



Source: *Water Resources*, Illinois State Water Survey, 1994

Wildlife

The diverse farm landscape dominant in Illinois until the 1960s contained abundant wildlife. Even now some species thrive, as human manipulation of the land enhances wildlife habitat for certain species. The expansion of row-crop production onto marginal lands in the 1970s meant sizeable habitat losses for Illinois' upland game species such as quail, pheasant, and rabbit. The resulting population declines are matched by declines since 1956 in the numbers of quail and rabbit killed by Illinois hunters (although pheasant numbers held fairly steady).

Animals killed by hunters also declined in proportion to the "recreation days" invested by hunters. The reduced reward for hunting effort may be one of the factors causing the recent decline in the number of days spent hunting in Illinois, which are fewer (by more than half) than in 1956.

Erosion

Illinois' principal mineral resource is its soils. Waterborne gravels, clays, and rock were overlaid across much of the state with fine windblown particles known as loess. Rich in lime and other minerals, loess is the basis of Illinois' richest soils. That richness is due

in part to their youth. Surface soils have been acted upon by weather for only about 12,000 years in most of Illinois, which is not long enough for leaching and exposure to seriously drain their fertile store of minerals; in far southern Illinois, surface soils have lain exposed for 60,000 years, during which time they have lost much of their original wealth of chemical nutrients.

An estimated 90% of all the soil erosion in the state—158 million tons annually in recent years—occurs on its farm fields. Not all of this soil is lost to the farmer. Soil erosion, or rather soil movement, is a natural process. Soil movement (mainly via water) occurs on even a "flat" farm field. Much of it is simply moved from one part of a field to another, or from one field to another on the same farm.

While soil loss is severe on some farms in some parts of Illinois, overall losses are approximately 0.03 inches per year. Local topsoil losses vary across the state with terrain; surface deposits around Galesburg, for instance, are older and more incised than around Champaign, and soil losses in the former area since settlement are thought to total six to seven inches. (Figure 8-5) Parts of unglaciated southern Illinois (whose topsoils were thinner to begin with) have lost even more than seven inches; the federal government, using Depression-era farm relief programs, bought up much of the ruined acreage and planted it in soil-saving trees, thus forming the nucleus of the Shawnee National Forest.

According to traditional definitions of soil depth, Illinois soil is several feet thick in places. However, the thinner "A-horizon" or topsoil could be eroded away in a matter of decades rather than centuries. In Bond County, for example, the lifetime of the resource, using the surface-to-bedrock definition, is calculated to be 1,300 years; using the A-horizon or topsoil definition, it is 75 years.

Soil loss in general rises and falls depending on the choices farmers make about which crops to plant, as well as where and how. Those choices in turn are affected by grain prices and government erosion-control programs. Erosion rates probably peaked in the 1970s, when high world grain prices encouraged Illinois farmers to bring even marginal land into production. Dire warnings in the mid-1970s that erosion would soon leave Illinois farms bare were not borne out; a crash in grain prices, higher input costs, and soil-conservation awareness led farmers to do less plowing on hilly land, as did government erosion-control programs.

Competition From Nonfarm Land Uses

The amount of farmland in Illinois has declined by 10% since 1950, as farms have been displaced by houses and roads, reservoirs and other manmade lakes, landfills, and mines.

Reservoirs and landfills. Large flood control and water supply reservoirs occupy roughly 0.9% of the Illinois land surface, usually in rural areas. While most industrial and other solid waste is still disposed of on land, these operations occupy only 0.2% of the Illinois surface. Future waste disposal is not expected to be a significant competitor for agricultural land.

Coal mining. Only about 0.8% of Illinois land is, or has been, affected by the strip mining of coal. Since the 1960s the acreage affected by strip mining each year has never exceeded roughly 7,000 acres, and that figure is declining. Newer methods of underground coal mining allow for the planned, controlled subsidence of the surface; under Illinois surface mining reclamation laws, damage suffered by farmers now must be mitigated by coal companies.

Illinois farms are getting bigger.

• Since 1950 the size of the typical Illinois farm has more than doubled, from 150 to 350 acres. Page 55

Expanded production and urbanization has resulted in sizeable habitat losses for many Illinois wildlife species since the 1960s.

• Population declines for upland game species such as quail and rabbit are reflected in declines in the numbers of animals killed by Illinois hunters. Page 58

Illinois enjoyed generally moderate summers during crop-growing seasons of the 1960s and 1970s.

• Virtually all the technological advances that define today's agriculture were tested and adopted during this interval of relatively benign weather, which also was the era in which virtually all Illinois farmers now working learned their craft. **Page 55**

Urbanization. No nonfarm land use is more permanently destructive of the agricultural potential of Illinois land than urbanization. Farming often becomes untenable even on land that is not yet built upon. Increased traffic on narrow rural roads makes it harder to move machines and material to fields; field drainage can be disrupted by construction on adjacent land; vandalism and complaints from nearby residents about farm noise, dust, and smells are common.

It has been estimated that 17 of Illinois' top 20 farming counties are located in or adjacent to urbanized areas, as defined by the U.S. Census Bureau. The phenomenon is most dramatically evident in Chicago's hinterland. The Northeastern Illinois Planning Commission estimates that between 1970 and 1990 the population of the six Chicago-area counties grew by 4%, while the amount of urbanized land expanded by 51%—a net land consumption over the two decades of more than 360,000 acres.

The trend toward the conversion of farmland to residential use varies with the robustness of the economy and underlying social forces such as changes in household size. Given the enormous size of Illinois' farmland resource, urbanization would seem to be a minor intrusion on the state's agricultural estate in the short run. (At present, cities occupy only one-seventeenth the land that agriculture does.) However, Illinois' agricultural resources are not infinite, and their continued transformation to urban uses worries many farm leaders concerned about the state's long-term ability to meet demands for food. ❖

Fertile Inventions

As Native Americans had done before them, early European farmers opened patches of forest by killing trees and planting corn or wheat amidst the stumps. Early travelers reported back to Europe and the eastern U.S. with scarcely believable tales of corn harvests on virgin soils of 100 bushels per acre. (Varying accounts put the harvests as high as 120 bushels and as low as 50–80 bushels).

The natural fertility of such fields was exhausted after a few years and the exhausted fields usually were abandoned. This cycle has been widely denigrated as "slash-and-burn agriculture," but Native Americans rested their plots, allowed woody growth to overtake them, and then burned it off. The result was, some researchers argue, a sophisticated crop rotation system in which nutrients were first drawn to the surface by plants from deep soils and then converted into fertilizer by fire.

As native populations had learned, the soil's riches were easily spent, even on the prairies. The prairies were what scientists would later describe as nitrogen-constrained ecosystems. The big grasses are heavy feeders of nitrogen, and left little of it free in the soil. By the 1870s yields on even good prairie land had slipped to 30 bushels. Soil nitrogen has to be listed among Illinois' natural resources that were exploited to the point of depletion in the past century.

Presettlement horticulture was in many ways as complex, accomplished, and productive as that of today. Native American techniques of planting beans, squash, and corn in the same field and using seed "hills" that required little tilling, left the ground covered and protected against erosion, and yielded crops that could be harvested through the season.

The arrival of numbers of experienced European farmers in the 1820s and 1830s began what some see as the golden age of Illinois agriculture. Over the next century farming moved out of the woods onto the prairie. Because animals figured as prominently in farm economics as grain crops, much of the land was kept in grass-like hay and pasture, which provided soil cover. The animals provided, in turn, a regular source of manure. In the view of agricultural historian Carl Sauer, this conservative plow-and-animal husbandry was a self-sustaining ecological system that differed from earlier systems insofar as no stage of it exploited soil fertility to the point of exhaustion.

Illinois soils remain among the richest in the world in terms of their ability to retain moisture, their store of trace minerals, and their benign pH. Best of all, they are watered and warmed by a climate particularly clement for agriculture.

Like the early hill agriculture had done, the mixed grain-and-livestock farms of Illinois left little land exposed to weather. Anecdotal accounts describe Illinois streams as running clear most seasons of the year well into the 20th century, in spite of the fact that much of their watersheds had been intensively farmed for decades. It was not farming but a particular kind of farming—exclusive row-crop cultivation—that resulted in soil erosion so ubiquitous as to turn most Illinois streams the color of cafe' au lait all year around.

Illinois soils remain among the richest in the world in terms of their ability to retain moisture, their store of trace minerals, and their benign pH. Best of all, they are watered and warmed by a climate particularly clement for agriculture. Nevertheless, while Illinois soil is often described as "most fertile," perhaps it would be more accurate to describe it as "most productive." Soil organic matter has been extensively depleted, its decomposition accelerated by annual cropping. This has lowered the capacity of most soils to recycle, accumulate, and store nutrients. To meet the high demand for nitrogen by crops such as corn, Illinois farmers apply inorganic fertilizers at one of the highest rates in the Midwest. ❖

Chapter 9

Fish species composition in Lake Michigan has significantly changed.

- **In the last century one in seven native fish species in Lake Michigan was either extirpated or suffered severe population crashes. Page 63**

- **Exotics have assumed the roles of major predators and major forage species. Page 63**

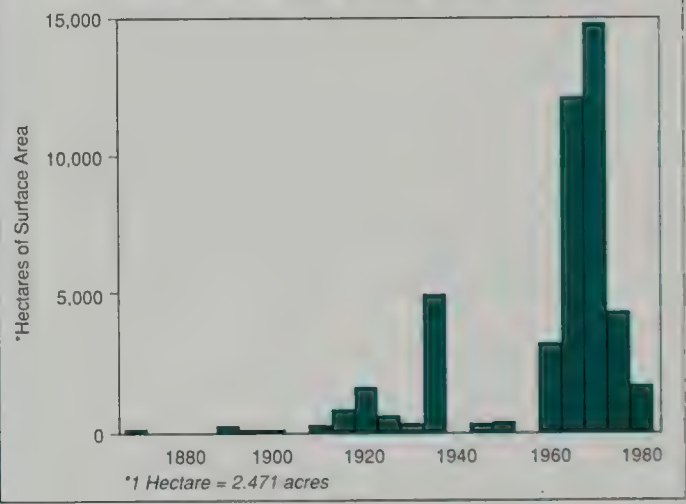
LAKES AND RESERVOIRS

The uses of Illinois lakes are varied, from water supply and recreation to flood control and cooling water, with most large reservoirs providing at least three of the four.

WATER SUPPLY

In the recent geologic past, Illinois was a land of lakes. Today, the largest survivor of that era is Lake Michigan, the sixth largest lake in the world. Most of Illinois' few other true lakes have glacial origins, being depressions or "kettles" formed in the northeast part of the state when blocks of ice buried in glacial till melted. A handful of other natural lakes remain in the few natural floodplains of major rivers that created them. Most Illinois lakes, however, are manmade. They range in scale from huge flood control reservoirs like Lake Shelbyville to worked-out stone quarries, gravel pits, and farm ponds.

Figure 9-1 Amount of Lake Surface Area Impounded During 5-Year Time Periods Since 1880



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

In 1991, 70% of the water withdrawn by Illinois public water supplies (PWSs) came from lakes. Together, the City of Chicago and a number of its suburbs withdraw 1.1 billion gallons each year from Lake Michigan—more than half of all the water used by PWSs in the state and 75% of all the water drawn from surface sources.

Where it is available, groundwater is usually preferred over surface water as a source of public drinking water in Illinois because it needs less treatment and because construction of expensive aboveground storage reservoirs is unnecessary. But where groundwater is scant, as in the parts of southern and central Illinois, surface water is the more viable alternative. Eight percent of the state's current supply comes from these smaller manmade lakes.

In general, demand on Illinois' drinking water reservoirs has flattened in recent years after rising steeply since about 1930. Drought is more likely to stress Illinois' manmade lakes than is demand. Towns dependent on smaller manmade lakes (mainly in southern Illinois) are delicately poised between demand and supply. Recent estimates suggest that 25% of the state's PWSs would be inadequate in a 50-year drought without considerable water conservation—the result in many cases not only of increased demand but also the loss of storage capacity to siltation.

Building reservoirs has been a traditional response to drought in Illinois. Construction peaked in the early 1930s and again in the 1960s. (Figure 9-1) The most significant increase in reservoir acreage occurred in the late 1960s and early 1970s. Most of this acreage came in the form of large flood control reservoirs such as Lake Shelbyville and Carlyle Lake, although the Rend Lake Intercities Water System, established in 1972, also eased the threat of water shortages in a part of the state prone to them. However, lack of suitable dam sites, shortages of federal funding, and controversies over flooding of farmland and wildlife habitat have narrowed prospects for construction of major new manmade lakes. This is true even in communities like Bloomington-Normal that are threatened by drinking water shortages, although current studies seem likely to reveal additional groundwater resources in that area.

Changes in agricultural practice are affecting many Illinois lakes.

• Recent estimates suggest that 25% of the state's public water supplies would be inadequate in a 50-year drought without considerable water conservation, in part because of increased demand and capacity losses to siltation. **Page 62**

Fish and wildlife

Building a lake usually creates new habitat for some fish and wildlife (often in the form of shallows at the points where feeder streams enter lake basins proper.) Fish populations of Illinois lakes have proven sufficient to sustain catches by recreational and a few commercial fishermen. But sluggish backwater lakes are usually less rich habitats than the free flowing streams they replace. Manmade lakes permanently flood stream valleys whose forests and associated wetlands are usually adapted to seasonal wet and dry cycles.

Manipulation (inadvertent and otherwise) of the biological component of lakes also can upset natural systems. On Lake Michigan, overfishing and the introduction of exotic species have combined to unsettle that ecosystem for prey and predator species. The lake's stocks of commercially desirable chub, lake trout, and whitefish began to decline as early as the mid-1800s; a century later, one in seven native fish species in Lake Michigan was either extirpated or had suffered severe population crashes.

Pollution

Lakes tend to collect not only sediment but most of the pollutants that are washed into them, and thus they function, in part, as environmental sinks. Eroded soil that both muddies water and fills in lake bottoms has significantly degraded lake ecosystems across Illinois. Lake Michigan is an exception. (Whereas siltation from farmed land is the major pollution source in other Illinois lakes, none of the Illinois portion of the Lake Michigan watershed is farmed.) Another factor degrading lakes is excessive algal and macrophyte growth caused by plant nutrients washed into them from farm fields and septic fields. Oxygen levels in some lakes are so chronically low that the composition of fish and other aquatic populations has shifted toward species more tolerant of such conditions.

The impact on lakes of atmospheric deposition of acids, as well as of toxic pollutants and nutrients, has not been well documented in Illinois. While the surface water in most parts of Illinois has a very high buffering capacity, this is not true in extreme southern Illinois. Given the amounts of such substances known to be at large in the atmosphere—total sulfur deposition downstate through the 1980s amounted to nearly 20 kilograms per hectare—significant negative impacts are probable in that part of the state.

As noted, many of Illinois' manmade lakes were built in the 1960s. Three decades may be too brief a time for all meaningful trends to emerge, even if data were systematically gathered, which they are not. Data collected at 659 lake water quality stations were analyzed for the years 1971 to 1991. Data that might reveal the presence in lake water

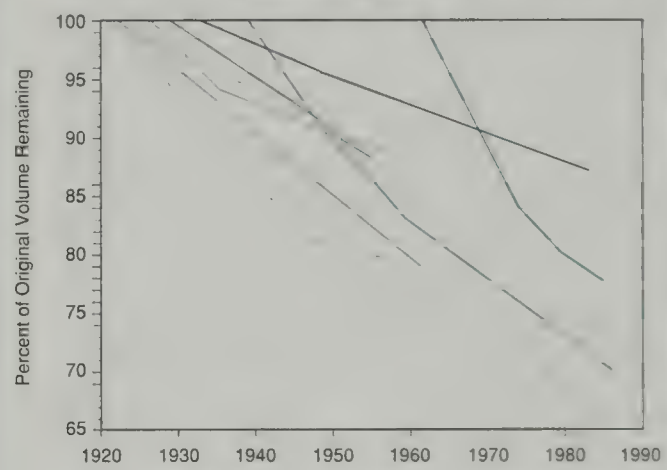
Lakes remain Illinois' most important drinking water resource.

• Together the City of Chicago and a number of its suburbs withdraw 1.1 billion gallons each year from Lake Michigan—half of all the water used by public water systems in the state and 75% of all the water drawn from surface sources. Page 62

• Manmade surface reservoirs provide 8% of Illinois' current water supply, most of it in the southern part of the state. Page 62

of phenolics and the pesticides chlordane, dieldrin, and DDT were too sparse to be analyzed. The data show no significant trends for the common industrial metals such as cadmium, chromium, and lead; fecal coliform bacteria; pH; phosphorous; and two common compounds of nitrogen. Some lakes showed some deviations from that profile (mainly increased nitrogen and decreased heavy metals); that may reflect recent relative declines in industrial activity in otherwise agricultural watersheds.

Figure 9-2 Storage Capacity Loss for Eight Illinois Reservoir Lakes



Lake Name	County	Original Capacity (acre-feet)
Lake Pittsfield	Pike	3,580
Lake Springfield	Sangamon	59,900
Lake Carlinville	Macoupin	2,350
Lake Bloomington	McLean	6,650
Frankfurt Reservoir	Franklin	1,700
Lake Bracken	Knox	2,881
Arctic Lake	Macoupin	176
Lake Decatur	Macon	27,900

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

The Illinois portion of Lake Michigan's drainage is not large, but it contains Illinois' heaviest concentrations of industry. Prior to 1890 the lake was used as a sink in which to dump sewage and factory wastes, and it has been classed the second most degraded of the Great Lakes. Levels of sulfate, cadmium, magnesium, sodium, potassium and chloride increased in the lake waters since the 1800s, although new protocols adopted in 1978 banned the discharge into the lake of some chemicals and reduced the discharge of others.

Unfortunately, many of the toxics already dumped there, such as PCBs, are long-lived. Large predator fish, such as the lake trout, feed at the top of the lake food chain and so accumulate in their fatty tissues organic chemical poisons originally ingested by their prey from bottom sediments; as a result, people are advised to limit the amount they eat of these otherwise commercially desirable fish. Lake Michigan water also carries heavy loads of phosphorous and nitrogen compounds as a result of runoff and fertilizer use in the watershed; these nutrients have led to increases in phytoplankton populations.

Tighter regulation has reduced direct discharges of industrial wastes into Lake Michigan, as have reductions in industrial activity. (Much of the more than 15% decline in manufacturing in Cook County between 1969 and 1989 occurred within the Lake Michigan drainage, and total cargo shipments in and out of Chicago deep-draft ports dropped 74% between 1974 and 1988.) Changes in indirect discharges of pollutants into the lake are harder to calculate. The extent of acid deposition over Lake Michigan from distant, inland sources via either wet or dry processes can be estimated but seldom has been measured on the lake surface itself; nor has the impact of atmospheric deposition of toxic pollutants and nutrients to lakes been documented.

Erosion

Agriculture is the biggest threat to Illinois lakes. Many chemicals in common agricultural use have a strong affinity for fine soil particles. When the latter erode, these chemicals are carried with them into surface waters. The soil itself is a problem when it accumulates in quantity in lakes. Lake Pittsfield lost nearly a quarter of its volume to sedimentation in only 24 years. (Figure 9-2)

While methods to remove silt and rejuvenate lakes have been successful in some places, replacing lost water storage capacity is expensive. To recover the 13% of capacity lost since the mid-1930s, the City of Springfield removed sediments from a small arm of Lake Springfield in 1988 at a cost of $10 million. Less obviously, sedimentation buries once-varied underwater topography under a blanket of mud, degrading it as a feeding and fish-spawning site. ❖

Demand on Illinois' drinking water reservoirs has flattened in recent years after rising steeply since about 1930. Page 62

Chapter 10

Heavy withdrawals made by Chicago suburbs beginning about 1950 caused water levels in some local wells to drop more than 1,000 feet. In the 1980s many Chicago suburbs switched to Lake Michigan water, reducing groundwater withdrawals to levels closer to natural recharge rates. Pages 66 and 68

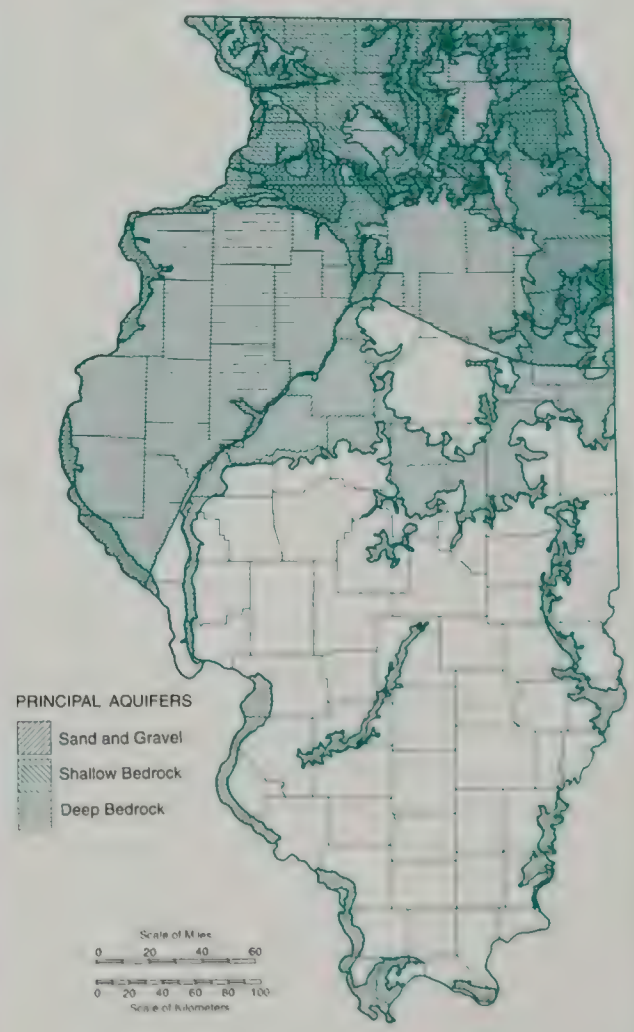
GROUNDWATER

Enough water to supply a single home can still be found by drilling a well most places in Illinois. Today, groundwater is used for industry, irrigation, and cooling water as well as drinking supplies. In all, more than one billion gallons of groundwater per day are displaced and/or consumed in Illinois for one human use or another.

SUPPLY

In most parts of Illinois, groundwater is not a separate water resource, but merely one of the forms taken by stored water as it moves from the atmosphere into the ground and back again. The water table—the zone of total saturation near the surface—does not supply shallow wells alone. It also acts as a reservoir that slowly feeds confined aquifers beneath it. Where local geology allows it, groundwater often even flows into surface streams, providing most of the flow during periods of slack rainfall.

Figure 10-1 Principal Aquifers in Illinois



Source: *Water Resources*, Illinois State Water Survey, 1994

While no underground rivers churn beneath Illinois, subterranean water can be made to move slowly from one region to another. Heavy withdrawals made by Chicago suburbs from that region's Ironton-Galesville sandstone aquifer, beginning about 1950, eventually caused water levels in some local wells to drop more than 1,000 feet, with lesser declines recorded as far away as Wisconsin. Court action by that state led Illinois authorities to

agree to a long-range plan to reduce pumpage from that aquifer system.

An aquifer is a water-bearing stratum of permeable sand, gravel, or rock. Aquifers sufficient to supply municipal or industrial uses are somewhat patchily located around Illinois (Figure 10-1), ranging in depth and differing in quantity and quality. Aquifer units may occur in alluvium along major rivers (shallow), in buried glacial alluvium deposits and buried valleys (shallow and deep), and in shallow and deep bedrock. The nature of the formation largely determines whether and to what extent water withdrawals may be economic. Units of fine-grained, low-permeability bedrock are poor water producers, while coarse-grained and/or well fractured bedrock units are generally good producers. Transmissivity is a measure of an aquifer's permeability or hydrologic conductivity; transmissivity of Illinois aquifers ranges from as much as 300,000 gallons per day per foot to as little as a few thousand gallons.

In no part of the state does it appear that groundwater is being withdrawn faster than it can be replaced in the long term.

• To date, groundwater mining has occurred only in northeast Illinois. As Chicago's western suburbs switch to Lake Michigan water or augment wells with river or lake water, water levels in the Elmhurst area may rise by as much as 650 feet by 2010. Page 67

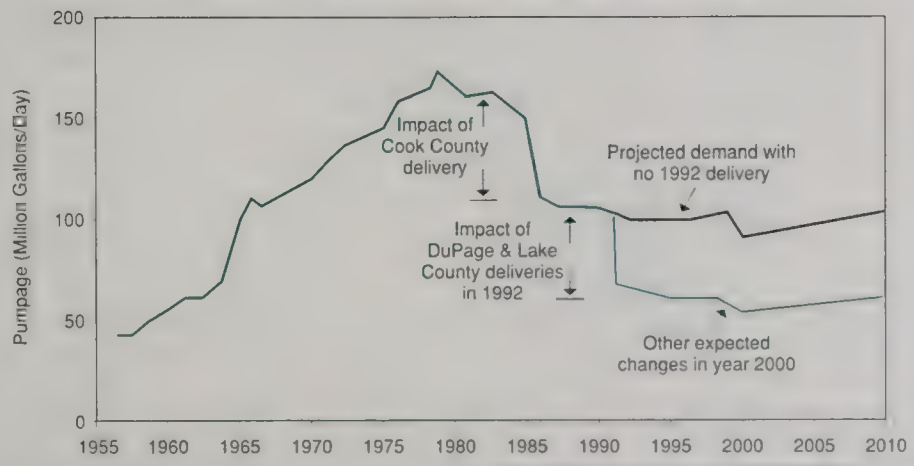
DEMAND

Overall, Illinois is relying less on groundwater for its public water supply. In 1991 Illinois' larger public water systems pumped slightly more than 340 million gallons of water per day; in 1980 daily pumpage by facilities of this size was roughly 410 million gallons. Most of the reduction in groundwater use occurred in the Chicago area. (Figure 10-2)

Water may not be withdrawn from a given aquifer faster than its hypothetical average annual recharge rate without depleting it. This average annual recharge rate depends on rainfall, especially in the spring. An analysis of 21 shallow wells during the drought of 1988-89 found six new low-water level records had been set in five regions of the state, and near-records were recorded at nine other sites.

Groundwater that is withdrawn faster than it can be recharged is said to be "mined." To date, groundwater mining has occurred only in northeast Illinois, where a trend of steadily increased pumpage from some aquifers persisted for roughly a century. In the 1980s many Chicago suburbs switched to Lake Michigan water, as did DuPage County in 1992. This reversed the trend and reduced groundwater withdrawals to levels closer to natural recharge rates. Other northeast Illinois communities have or are planning to

Figure 10-2 Groundwater Use in the Chicago Area



Source: *Water Resources*, Illinois State Water Survey, 1994

Illinois farmers have been expanding land irrigated by groundwater.

• Irrigated acreage increased from 40,000 acres in 1970 to about 240,000 in 1987, some 65% of which is located in only five counties. Most (96%) of this irrigation water is groundwater. Page 68

• Increased withdrawals by farmers, while locally significant, are not thought to pose a long-term threat. Page 68

augment their municipal wells with river or lake water. If this most recent trend continues, water levels at Elmhurst may rise by as much as 650 feet by 2010, and the region's Cambrian-Ordovician aquifer system may be restored to its natural balance for the first time since the 1950s.

As insurance against drought, Illinois farmers have been expanding their irrigated land, from 40,000 acres in 1970 to about 240,000 in 1987. Some 65% of this acreage is located in five counties, all but one of which are in the northern half of the state. Most of this irrigation water (96%) is groundwater, usually added to high-value specialty crops that make the costs of pumping and equipment worthwhile. Increased withdrawals by farmers, while locally significant, are not thought to pose a long-term threat to regional resources.

Pollution

Groundwater quality seldom varies under natural conditions, so significant changes often indicate degradation due to human action. Chloride, nitrate, and sulfates occur in groundwater naturally. However, high sulfate concentrations may betray the presence of acid wastes from (for example) metal pickling operations. Concentrated chlorides may be a clue that road salt or oil field brine has entered an aquifer. High nitrate levels are usually associated with farm fertilizer applications, feedlot runoff, or septic tanks.

Shallow aquifers are more vulnerable to contamination than deep ones, and aquifers in industrialized areas are more vulnerable to contamination than ones in rural areas. (Figure 10-3) Unlined or improperly lined impoundments pose obvious risks of chemical pollution of groundwater. More than a quarter of the surface impoundments in Illinois are thought to be in places whose near-surface geology leaves subsurface soils prone to infiltration; surface soils also may be contaminated when impoundments accidentally overflow. However, various studies confirm that contamination from human activity tends to be local in both cause—a broken storm sewer pipe, a leaky retention pond—and effect.

Landfills. A recent survey concluded that approximately 25% of public water wells in Illinois are located within one mile of a known landfill or open dump site, as are approximately 10% of the known private drinking water wells. (Figure 10-4) Mere proximity is no certain measure of the risk of contamination, as the geology and the engineered systems of each site determine whether leachate flows toward or away from local wells.

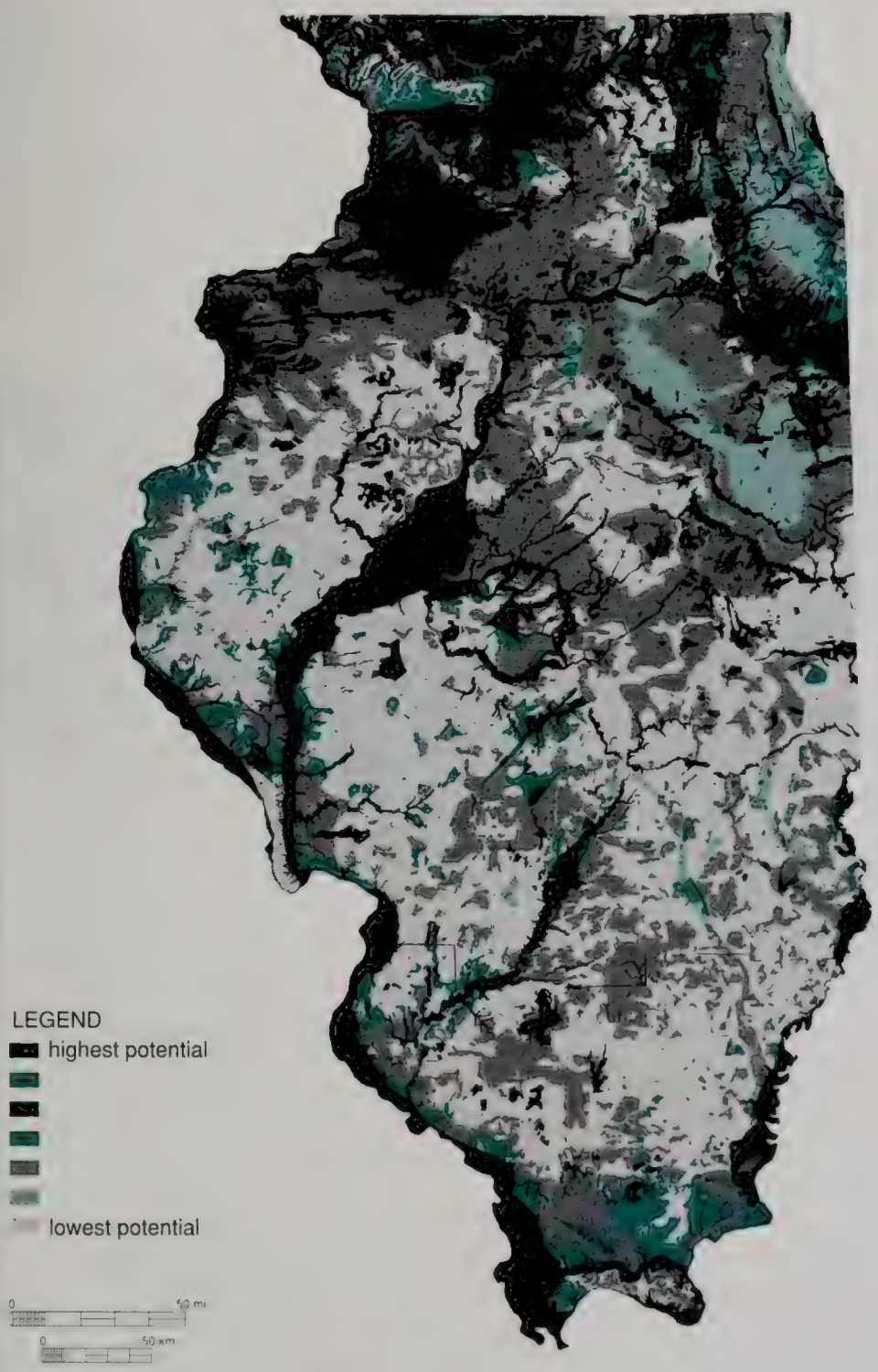
Underground injection. Since 1965 several classes of injection wells have been used in Illinois to dispose of a variety of wastes, from factory residues to stormwater runoff, sewage, and heat pump effluent. For example:

• Five deep "Class I" wells each year dispose of more than 300 million gallons of certain industrial wastes in Illinois, mainly dilute (70-95% water by volume) acids. The number of waste injection wells in Illinois has been on the decline since the 1980s as new regulations began to make land disposal of various liquid hazardous wastes illegal or more costly.

• In 1990 there were some 13,000 wells in Illinois used to inject mainly brine from oil and gas recovery into depleted oil fields lying below Underground Sources of Drinking Water (USDW). Few instances of saltwater contamination of aquifers from injection wells have been documented in Illinois (although historical contamination of groundwater associated with near-surface storage of such wastes has been documented).

• Another nearly 1,800 wells in Illinois dispose of more general wastes from sources

Figure 10-3 Contamination Potential for Aquifers in Illinois



Modified from Berg & Kempton, 1984.

Source: *Waste Generation and Management*, Hazardous Waste Research and Information Center, 1994

Overall, Illinois is relying less on groundwater for its public water supply.

• In 1991 Illinois' larger public water supply facilities pumped slightly more than 340 million gallons of groundwater per day; in 1980 daily pumpage by facilities of this size was roughly 410 million gallons. Page 67

Contamination of groundwater does not appear to be occurring on a regional scale, but is a local problem with local effects.

• Approximately 10% of the known private drinking water wells in Illinois are located within one mile of a known landfill, as are approximately 25% of public water wells. Page 68

• As of 1992, 364 wells statewide had been closed or restricted in use because of contamination by heavy metals and organic compounds. Page 70

Figure 10-4 Private Water Well Locations

From ISGS Wells Database, 1993

Source: *Waste Generation and Management*, Hazardous Waste Research and Information Center, 1994

ranging from auto shops to household toilets. (In Illinois, most such "wells" are septic tanks.) Illinois regulations permit injection of these wastes into underground formations both above and below USDW, as long as groundwater quality standards are maintained.

Tanks. Buried storage tanks containing petroleum or hazardous chemicals have been recognized as probably the most important (if not the most widespread) source of groundwater contamination in the U.S. For example, as of 1987, the number of underground storage tanks in Illinois was estimated at 60,000. Many of these tanks are leaking. A cleanup fund established in 1986 has spurred the ongoing removal of leaking tanks and clean up of dirty sites. Installation of new tanks are subject to stricter standards than heretofore.

Industrial pollution. There are nearly 1,400 listed or potential Superfund sites in Illinois, many of which are suspected by the IEPA of contributing to groundwater pollution. As of 1992, 364 wells statewide had been closed or restricted in use because of contamination by heavy metals and organic compounds like chloroform or vinyl chloride.

A sizeable database of 50,000 records of private and public drinking water wells give information on trends in groundwater supplies that might suggest pollution's cumulative effect on this resource. A recent analysis of these water quality records from 1900 to 1992 focused on six dissolved chemicals indicative of groundwater quality—iron, total dissolved solids, sulfate, nitrate, chloride, and "hardness." Data showed some variability, but overall there were no statewide trends for this time period, which suggests that Illinois groundwater quality is at least not declining. ❖

Trends in Trends

Chapter 11

Trends in Trends

Several "trends in trends" are generic to all Illinois ecosystems. Findings suggest that, overall, pollution is down, in many cases dramatically. Rates of wetland loss have slowed, forests are coming back, and active citizen groups are at work restoring prairies and helping protect surviving natural areas.

Habitat fragmentation and other physical changes have surpassed conventional pollution as threats to ecosystem function. Page 72

Illinois is moving from complex natural systems toward simpler ones, from stable systems toward unstable ones, from native species toward non-native ones, from integrated systems toward fragmented ones, from self-sustaining systems toward managed ones. Page 72

The Changing Illinois Environment

Habitat fragmentation and other physical changes have surpassed conventional pollution as threats to ecosystem functioning. Even though pollution is being reduced in Illinois, most of the state's natural systems have not responded with anything like their former vitality, and the burdening of the atmosphere with carbon dioxide since industrialization may affect the climate for decades to come.

Illinois may be said to be moving away from complex natural systems toward less diverse ones, from stable systems toward unstable ones, from native species toward non-native ones, from integrated systems toward fragmented ones, from self-sustaining systems toward managed ones, and from preserved systems to restored or created ones.

Illinois is also moving away from systems constrained by ecological forces toward ones constrained by social forces (such as regulation). These social forces are evolving too, moving from private decision-making about resources toward shared private-public decision-making, and from an ethic of resource consumption toward one that emphasizes efficiency, reuse, and pollution prevention.

The Trend From Dirty Toward Clean

Illinois' industrial century ended roughly with the 1960s. Since then, Illinois streams have become chemically cleaner and the air in its cities more breathable. Old mines and factory sites are being cleaned up, if slowly; new ones operate under regulations meant to make future cleanups unnecessary. Illinois factories use fewer environmentally problematic materials, or use less of them, or dispose of them more responsibly.

Pollution has changed since it was first recognized as a public issue in the last century. In Illinois' industrial era, pollution tended to be local in its extent and concentrated in form; since the 1960s pollution is increasingly dispersed and dilute ("downstream" now refers to the atmosphere as well as streams), and it poses uncertain risks to human health and ecosystem function. Trends in the newer, chemically more exotic pollutants are harder to measure, in part because they have only recently been recognized as pollutants. (PCBs and CFCs once were thought to be environmentally safe.) So while Illinois is getting indisputably cleaner in some ways, it may also be getting dirty in new and unrecognized ways.

The Trend Toward Simpler Natural Systems

While the environmental history of Illinois is popularly understood as the degradation of unsullied systems into polluted ones, the larger trend has been the replacement of a complex natural environment with an ever-simpler one. Dams, levees, and channelized

streambeds simplify the complex seasonal ebbs and flows of surface waters. Fish censuses show populations skewed toward the few tolerant species (native and exotic) and away from the several species valued for sport or essential to ecosystem function. Rural row-crop lands have been called a "grain desert" because of their paucity of wildlife and plant habitats.

Illinoisans used to be dependent on complex local ecosystems for sustenance, using fairly simple systems of gathering; now they rely on fairly simple ecosystems—plant monocultures of various kinds and factory-style animal production—gathered by very complex economic systems. The farms of the Midwest, for example, are a drastically simplified version of the grassland ecosystem they replaced, as prairies that grew as many as one hundred species of plants were replaced by fields growing a half dozen.

Illinois still boasts an impressive range of habitat types. But complexity lingers mainly in habitats only marginally of use to humans, such as river bottomlands, swamps, hillsides, and bogs. As is noted elsewhere in this report, high-quality wetlands, forests, and prairies in Illinois tend to be very small and thus vulnerable to changes in their immediate environment.

As niche environments disappear, niche species dependent on them disappear as well. The result is a trend toward a generic Illinois environment populated mainly by "generalist" species able to exploit simplified ecosystems. These species include deer, certain weeds, carp, starlings, and—one of the most successful—*Homo sapiens*.

Figure 11-1 Percentage of Alien Species in Illinois (Spontaneous Vascular Plant Flora) 1846–1992

Flora Author	Year of Publication	% Alien Species
S.B. Mead	1846	10.2
I.A. Lapham	1857	6.6
H.N. Patterson	1876	7.5
W.C. Flagg and T.J. Burrill	1878	10.5
G.N. Jones	1945	15.9
G.N. Jones	1950	15.9
G.N. Jones and G.D. Fuller	1955	25.0
G.S. Winterringer and R.A. Evers	1960	26.0
G.N. Jones	1963	24.7
R.M. Myers	1972	25.4
R.H. Mohlenbrock	1975	27.9
R.H. Mohlenbrock and D.M. Ladd	1978	28.7
ILPIN	1992	28.0

From Henry and Scott, 1980

Source: *Ecological Resources*, Illinois Natural History Survey, 1994

THE TREND TOWARD NON-NATIVE SPECIES

The very complexity of undisturbed natural systems tends to protect them against interlopers. But disturbed ecosystems are often vulnerable to exotic species against which native competitors have evolved no defense and whose spread is not constrained by natural predators.

According to a 1991 estimate, some 28% of the vascular plants growing in Illinois are not native but were introduced from Europe, other parts of North America, and eastern Asia. (Figure 11-1) At present, 17% of the fish species in Lake Michigan are not native to that body. (Figure 11-2) Many of Illinois' most agriculturally damaging insect pests migrated to the state over the last 30 years, including exotic pests and pathogens that threaten Illinois populations of such key tree species as pines and oaks. Some 25 species of exotic weeds are found in Illinois woods; the non-native plants known as velvetleaf, foxtail, and cocklebur are the three most expensive weed pests in Illinois farm fields, as measured in money spent to control them. The ring-necked pheasant, a game bird from Asia, has helped reduce populations of Illinois' native prairie chicken to

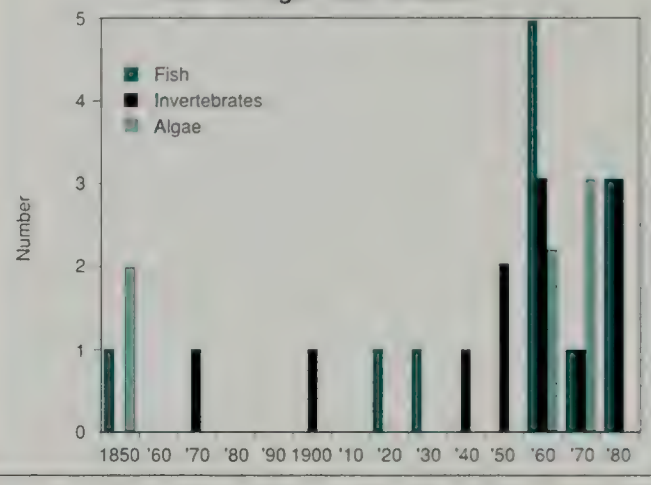
Illinois is moving away from systems constrained by ecological forces toward ones constrained by social forces (such as regulation). Page 72

Illinois peoples used to be dependent on complex local ecosystems for sustenance, using fairly simple systems of gathering; now they rely on fairly simple systems—plant monocultures of various kinds and factory-style animal production—gathered by very complex economic systems. Page 73

Illinois still boasts an impressive range of habitat types. But complexity lingers mainly in habitats of only marginal use to humans, such as river bottomlands, swamps, hillsides, and bogs. Page 73

There is evolving a trend toward a generic Illinois environment populated mainly by "generalist" species able to exploit simplified ecosystems. Page 73

Figure 11-2 Number of Species Introduced Into Lake Michigan Each Decade



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

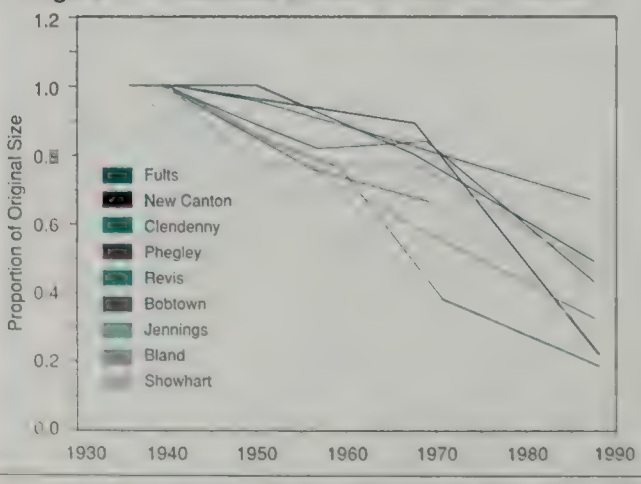
some 100 birds; the zebra mussel, introduced to the Great Lakes in 1986, threatens to do the same to Illinois' native mussels.

Even before humans arrived in Illinois, species mix changed repeatedly as the result of climate change, the natural spread of seed by birds and wind, and animal migrations. Problems occur when exotics reproduce exaggeratedly or otherwise out-compete native species. Many weedy exotics were introduced by state and local agencies to provide forage for wildlife or to control erosion or were widely sold in the landscape trade as ornamental plants. The Illinois DOC banned the growing of problematic exotics such as the autumn olive at its own nurseries in 1983, and now cultivates only native species of trees and shrubs that it supplies for reforestation and wildlife habitat in Illinois.

The Trend Toward Fragmented Natural Systems

Many plants and animals are thought to need large blocks of uninterrupted habitat. Illinois surveys have found that the number of plant species found in a prairie shrinks with its size, and certain birds native to the forest interior are thought to need at least 600 acres of forest to thrive. But, as has been noted elsewhere in this report, most of Illinois' intact natural systems are quite small. Wooded parcels larger than 600 acres are as common as one per township in only a quarter of the state. All but the largest remnant prairies in Illinois—Goose Lake Prairie State Park and Illinois Beach State Park—cannot fully function as ecosystems.

Figure 11-3 Decrease in Size of Nine Hill Prairies



Source: *Ecological Resources*, Illinois Natural History Survey, 1994

The configuration of a natural forest or prairie as well as its overall area determines its viability as habitat. A study of trends in nine extant hill prairies in Illinois found that the ratio of perimeter to area increased from 1940 to 1988, leaving them more exposed to invasion by

woody plants. (Figure 11-3) Illinois' secondary-growth forest is almost all edge—small plots with very high edge-to-center ratios or riparian forests that have in effect no center at all, making them more vulnerable to invasion by weedy exotics.

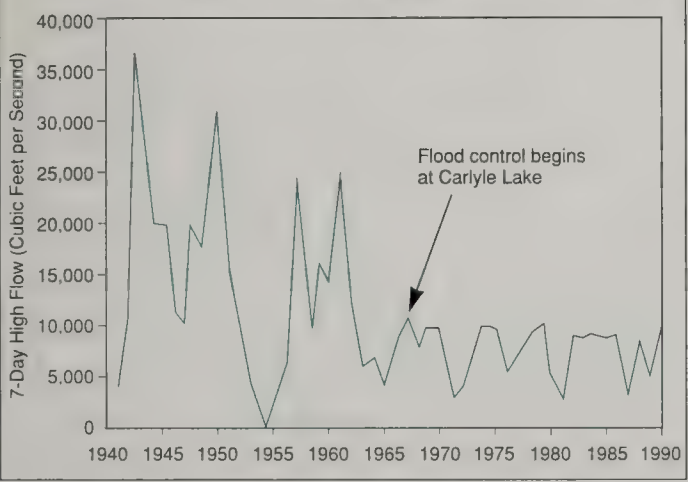
Most of Illinois' intact natural systems of all kinds are quite small. Page 73

The Trend Toward Unstable Systems

Habitat fragmentation and competition from exotic species have combined to render once-stable ecosystems less so. Lake Michigan is just one example. The decimation of the lake's natural predators by the sea lamprey in the 1950s allowed populations of their common prey, the tiny alewife, to explode. The alewife then decimated native prey fish such as the emerald shiner. The alewife in turn so proliferated that it outpaced its food supply and suffered beach-clogging die-offs in the 1960s; the die-off, in turn, starved the introduced salmonid sportfish that, having been introduced to control the alewife, had come to depend on it.

Habitat fragmentation and competition from exotic species have combined to render once-stable ecosystems less so. Page 74

Figure 11-4 Annual 7-Day High Flow Series of the Kaskaskia River at Carlyle



Source: *Water Resources*, Illinois State Water Survey, 1994

The Trend Toward Managed Ecosystems

Management by humans in many cases is the only alternative to habitat and species loss in ecosystems unable to sustain themselves, and seems likely to become a trend. Managed ecosystems are hardly new to Illinois. Native Americans burned prairies to trap game, among other purposes. Indeed, one could describe the human history of the state as a centuries-long unplanned experiment in ecosystem management.

However, human management of complex ecosystems can have unnatural "downstream" effects in both literal and figurative senses. A seasonal "flood pulse," thought essential to organisms adapted to Illinois' major streams, is reduced when flood control reservoirs are built on such streams. Annual seven-day high flows recorded on the Kaskaskia River at Carlyle, for example, shrank by two-thirds after a flood control dam was built there in 1967. (Figure 11-4) Governments must now achieve by complex regulations what used to occur naturally. Current law requires that reservoirs funded by or licensed by federal agencies provide for minimum flow releases to protect the ecological integrity of downstream reaches of parent streams.

Natural boundaries seldom coincide with human ones. Managing on an ecosystem basis means that resource decision-making must transcend property lines or the government jurisdictions that demark responsibility in Illinois' system of essentially local resource control. For example, agencies attempting to protect instream water flows in Illinois must do so in the face of the absence of clear regulatory authority, disputes over

Managing on an ecosystem basis means that resource decision-making must transcend property lines or government jurisdictions that demark responsibility in Illinois' system of essentially local resource control.
Page 75

Most experts agree that ecosystem creation is a viable alternative to the destruction of extant natural systems, but it has yet to prove itself as a more desirable alternative to their preservation.
Page 76

what water levels are appropriate, unwillingness by private users to pay for studies needed to determine such levels, and conflicts over who will monitor and enforce mandated withdrawals.

The Trend Toward Created Ecosystems

The ultimate managed ecosystem is one that is created by humans. Illinois has much experience with artificial ecosystems, although much of it was acquired inadvertently. The Illinois Department of Conservation has been building wetlands for wildlife since the 1940s. Various government farm and game programs provide incentives for private landowners to restore wetlands (mainly for waterfowl) or to improve water quality; still others have been built for stormwater storage. In all, Illinois in 1992 had some 330,000 acres of created wetlands. (That figure includes farm ponds and other manmade lakes.)

Illinois boasts several examples of restored tallgrass prairies, products of a labor-intensive process that includes growing seeds in greenhouses, hand-planting of sprouts, and the careful control of non-native invaders. Attempting to create a wetland from scratch is no less difficult. Few native species are near enough to most Illinois sites to colonize new sites naturally, and because wetland plants often have very specific requirements in soil pH and hydrology, only about 40% of the species planted in a created wetland can be expected to grow even under intense management. Research underway at the Des Plaines River Wetlands Demonstration Project—450 acres of abandoned farm fields and gravel pits developed as a site of controlled experiments—may eventually improve the design and management of wetlands. Most experts agree that ecosystem creation, while a desirable alternative to the destruction of extant natural systems, has yet to prove itself as a substitute for the preservation of such systems.

The Trend Toward Social Rather Than Ecological Control

In some respects humans already have become so ecologically dominant in Illinois that it is impossible to draw clear lines separating natural systems from the social, economic, technological, and political systems that influence them. Rates of soil erosion, for example, appear to vary with how much land is planted in which crops, which in turn is determined by grain prices and U.S. government crop set-aside programs.

As natural systems are more and more affected by human activity, unnatural systems—economic and technological systems, environmental laws, government incentive programs—will become more and more important. Since World War II, social trends (such as suburbanization), economic trends (such as the shift from a manufacturing to a services economy), and political trends (such as the spread of "green" politics) have had a profound environmental impact in Illinois. Understanding the long-term trends in the Illinois environment thus means understanding more than just ecological trends.

One unambiguous trend over the past 20 years is the increasing number of public programs to moderate the human impact on the environment. (Figure 11-5) Twenty-two state and federal laws affect wetlands in Illinois, among them requirements that new wetlands be created in certain cases as mitigation for natural wetlands destroyed by development. The Illinois Forestry Development Act offers incentives for land owners to convert certain farm fields to forest; these incentives are expected to have as marked an impact on the rate of reforestation as climate change did in the past.

Environmental laws serve two broad ends—pollution control regulations and natural resource preservation and management. To achieve them, a wide range of means have been

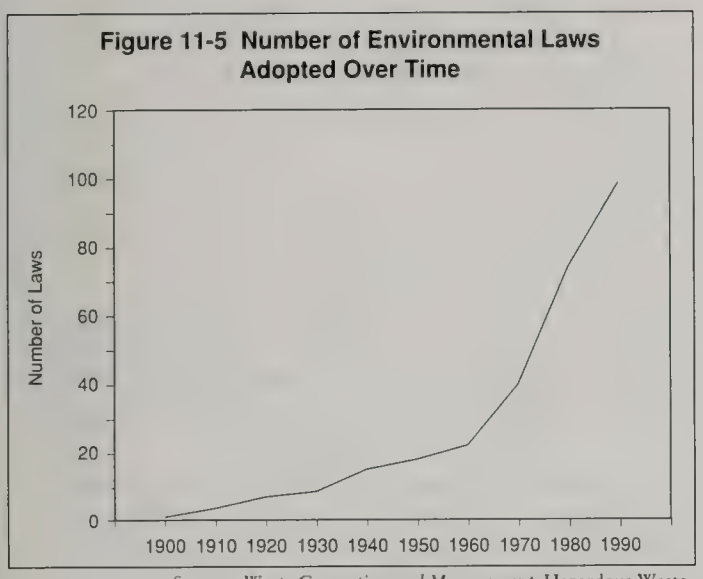


Figure 11-5 Number of Environmental Laws Adopted Over Time

Source: *Waste Generation and Management*, Hazardous Waste Research and Information Center, 1994

adopted, from "command and control" regulations to financial incentives and voluntary programs.

Regulations. The European occupation of Illinois began more than 300 years ago, but the significant body of law affecting landfills, mining, industrial wastes, groundwater protection, exotic species control, forest conversion, and so on date from the last 30 years.

During this period, resource regulation has had some dramatic successes in Illinois. Trends toward improved visibility at weather stations at Chicago's O'Hare Airport—improvements that run counter to trends in some downstate cities—may be due to more stringent pollution controls on industry in that part of the state. Fewer than 100 doublecrested cormorants were observed in the Illinois and central Mississippi river valleys between 1966 and 1973; in the fall of 1992, 5,195 birds were counted along the Illinois River alone, part of a continental population recently enlarged in part because of federal bans on the insecticide DDT and the phase-out of leaded gasoline.

In general, the constraints on the exploitation of Illinois' natural resources have been economic rather than regulatory. But the economics of resource use increasingly are complicated by regulation, and vice versa. The federally-mandated Toxic Release Inventory compelled Illinois companies to catalog how many environmentally problematic (and expensive) materials were being thrown away; the information induced many firms to reduce emissions in their own economic interests. Industries whose waste streams are not tightly regulated have not reduced waste volumes as much as industries subject to stricter regulation.

Natural resource laws. Until recently, government policy at all levels in the U.S. addressed the consequences of environmental change mainly by encouraging it. The draining of wetlands via state levee-building and drainage laws in the 1870s and 1880s is perhaps the most conspicuous example; under terms of the federal Swamp Land Acts of the mid-1800s, the State of Illinois gave wetlands to counties for the latter to sell, proceeds being used to fund local drainage projects.

Laws to protect natural resources began to be passed in Illinois in the 1960s. The Illinois Nature Preserves Act (later amended with the Illinois Natural Areas Preservation Act) was adopted in 1963. The state's Endangered Species Protection Act took effect in 1972. In 1987 the state enacted the Groundwater Protection Act, a prevention-based approach aimed to protect groundwater as both a public and private resource. In 1989 Illinois enacted the Interagency Wetland Policy Act, which set a goal of no overall net

Human management will become increasingly the response to habitat instability. Page 76

In some respects humans already have become so ecologically dominant in Illinois that it is impossible to draw clear lines separating natural systems from the social, economic, technological, and political systems that influence them. Page 76

A trend is evident among firms and individuals toward more effective use of resources through pollution prevention, reuse, and various efficiency improvements that should reduce environmental stress in the future.
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loss of existing wetlands, and further directed state agencies to not only preserve and enhance existing wetlands but to create new ones where feasible.

In a state with a *laissez faire* tradition, however, public authorities are empowered to aggressively manage only those few lands owned by government. Public programs tend to affect land management indirectly (if substantially, in the case of federal agricultural policies). State of Illinois programs are generally limited to the provision of technical and financial management assistance to land owners.

Private hands will continue to fashion Illinois' *de facto* natural resource policy for the foreseeable future. Some 90% of Illinois forests and nearly all of its farmland is privately owned, as are its mineral deposits. On average, only 15% of the banks of Illinois' major streams (unlike most levees) are publicly owned; that ratio varies across the state, from a high of nearly 40% in the Fox/Des Plaines basin—due mainly to that area's forest preserve system—to only about 6% in the far southern Little Wabash drainage.

Economics. Future pollution control efforts will likely rely less on command-and-control regulations and more on economic incentives. This trend is dictated as much by the high cost of applying the former to large numbers of sources (such as automobiles) as by the high costs of complying with them.

There is already evident an alternative trend among firms and individuals toward more effective use of resources through pollution prevention, reuse, and various efficiency improvements. Municipalities and individuals have also reduced their waste streams. Recycling is growing (Figure 11-6) and significant parts of the reductions in consumption of fossil fuels in Illinois are owed to efficiency improvements. Reduced waste streams generally mean reduced stress on the environment, although the magnitude of these reductions is hard to measure.

Technology. Arguably technology is a more profound influence on Illinois environmental trends than even law. Since the 1920s, for example, new farm technologies in the form of labor-saving equipment, hybrid plant varieties (especially of corn), artificial nitrogen, and chemical pesticides have transformed agriculture, and with it 80% of Illinois' surface. New methods compensated for the inability of Illinois soils to sustain themselves in the face of soil compaction, erosion, and the depletion of soil nutrients and organic matter.

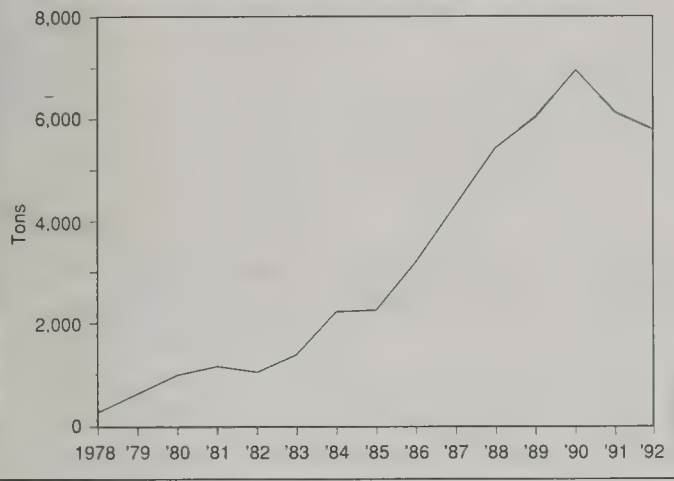
In the future, the genetic manipulation of plants or nitrogen-fixing bacteria might lead to dramatically lower use of nitrogen fertilizers. High-protein grasses capable of fattening cattle in pasture might spur a switch of land out of row-crop cultivation. Computer-sensed irrigation monitors promise new economies in groundwater use.

Trends in technology off the farm will be crucial as well, mainly in the areas of energy use, water efficiency, and pollution prevention and control. More efficient internal combustion engines have already allowed Illinoisans to enormously increase their vehicle miles traveled in the 1980s without proportionate increases in emissions.

Technology seems less likely to effect significant changes in land use, which in some ways has surpassed conventional pollution as the major process affecting ecosystem integrity in Illinois. New communications technology may enable more people to work from physically disparate sites and so reduce some of the transportation costs of sprawl, for example, but by eliminating distance as an aspect of job choice it is just as likely to add to the pressure to convert now-remote farmland to urban use.

Public opinion. Public opinion is a crucial factor in democratic societies that ultimately make their own environmental laws. Consensus on environmental values will probably

Figure 11-6 Recyclable Materials Collected and Marketed from the Champaign Area 1978–1992



Source: *Waste Generation and Management*, Hazardous Waste Research and Information Center, 1994

always be elusive in a state as socially diverse as Illinois. Whether a stream is "clean" or "dirty" depends on whether one is drinking from it, fishing in it, boating on it, or flushing away factory wastes with it. Private resource owners may or may not share the priorities of public resource agencies, or indeed each other. A survey in the 1980s found that owners of large tracts of forest in Illinois were most interested in income from timber sales, but that private owners of the more typical small tracts managed their holdings for aesthetic value or as wildlife habitat.

Problems also arise when the culture's deep-rooted customs clash with more recent environmental consciousness. For example, the postindustrial sprawl of people across the Illinois countryside is an important trend with implications for air quality, energy consumption, and farmland preservation. This is why it is nearly universally decried by environmentalists and land use planners. However, many Illinoisans still only a generation or two from the small town want to recreate that environment in a new urbanized context in spite of its collective environmental cost. Zoning laws have not slowed conversion, whether via "urban villages" (self-contained developments unconnected to existing towns), the conversion of large farms into "farmettes," or one-house "subdivisions" platted to evade zoning restrictions in agricultural areas.

Public perceptions of the environment eventually inform public policy. Those perceptions vary from person to person, however, so that consensus becomes difficult to achieve. The condition of a woods will be judged differently by a bird watcher, a logger, a hunter, a nearby homeowner, a local tax official, and a resource manager, yet each judgment in its context can be valid. A commuter driving home may find immensely satisfying the view of a forest fragment that an ecologist perceives as a degraded forest. The standards of the commuter—that a forest be green and that it be visible from the highway—are radically different from those of the scientists who measure it in terms of species diversity, mortality rates, and so on.

As in much of the U.S., public support for environmental regulation in Illinois may be broader than it is deep. The environment that most Illinoisans know is increasingly artificial and—compared to presettlement Illinois—less and less "Illinoisan." Increasingly sedentary lifestyles and air conditioning mean not merely that people stay indoors but that they seal off their houses from the outside world. This isolation from the experience of the natural means that people live in one Illinois (one that is manicured and largely exotic in origin) and venture into a second Illinois (one that survives in remote nature preserves or state parks) as they might visit a museum or zoo. ❖

Technology should improve energy and water efficiency and pollution prevention and control in Illinois, but it seems less likely to effect significant changes in land use, which is likely to replace conventional pollution as the major process affecting ecosystem integrity in Illinois. Page 78

AFTERWORD

As was noted in the Foreword to this report, environmental data in Illinois has typically been collected for regulatory and management purposes. That effort has been essential in achieving many pollution control successes since the 1960s. But baseline data to monitor broader ecological conditions has not generally been systematically collected on a statewide basis.

THE PRESENT

CTAP's analysis found that data on environmental pollution in Illinois is collected by different agencies acting under different laws, often using different standards. Data collection also changes with changes in the laws mandating it. Data of several kinds have not been gathered long enough to allow scientists to speculate reliably about trends. Data-gathering also tends to have a narrow focus; apart from pioneer ecological work on Illinois streams done earlier in this century, most data-gathering has limited ambitions—to test the drinkability of well water, or a company's compliance with antipollution regulations, or to count the potential harvest of a few animal species desired for sport or commerce.

Here are some specific examples drawn from CTAP reports:

Agriculture. The precise amount of fertilizers and pesticides being applied either to Illinois croplands or to urban areas is not known. Per-acre applications have changed with changing farm practice, but farm chemical use traditionally has been measured by the number of acres sprayed, not the amount of chemicals sprayed per acre.

Regarding erosion, the Sediment Benchmark Network was set up in 1981 with some 120 instream sediment data stations; by 1990 the network had shrunk to 40 stations, the majority of which have data for only one to three years. Some stations on the sediment network take readings daily, some weekly, which makes calculations of sediment loads and "budgets" unreliable.

Air. Firms obligated to report releases of toxic materials to the atmosphere are not required to report every chemical released. Also the reporting requirements have varied from year to year, and much of the data must be estimated.

Some air pollutants, including some considered toxic, have not been measured routinely in Illinois for reasons that usually involve the cost of analysis and/or the technical ability to detect their extremely low concentrations in the atmosphere.

Streams and Rivers. Even though records of flows in the Mississippi River go back 113 years and several other flow records go back 77 years, the length of even these stream-gauging records is generally not sufficient to identify fluctuations that recur less frequently than every few decades.

Not all water quality parameters are recorded at all of the more than 200 monitoring stations on Illinois waters. This makes possible more efficient use of scarce funds to monitor compliance with discharge permits, but more comprehensive data would be useful in charting ecological trends over space and time.

Current law requires that reservoirs funded by or licensed by federal agencies provide for minimum flow releases to protect the ecological integrity of downstream reaches of parent streams. Specifying an appropriate minimum flow requires knowledge of the minimum water levels suitable to various fish species, taking into account the geometries of riffles and pools, fluctuations in flow, and short- and long-term rainfall trends. Setting streamwater quality standards that are appropriate to various uses is equally difficult. There are few streams about which scientists know enough to attempt either calculation with confidence.

Groundwater. Damage from the operation of waste injection wells is known to have occurred in Illinois, but no inventory of such contamination has been made.

Most drinking well records in Illinois date from after 1970 and focus on only a few water quality criteria.

More recent samples have tested for compliance with more comprehensive drinking water regulations, and so also were analyzed for organic compounds such as pesticides or industrial solvents.

Private well records draw from more locations across the state, but tests on municipal wells tend to span more time; neither is sufficient to track long-term changes statewide.

Land. Detailed geologic mapping needed to detect earthquake hazards, chart new groundwater sources, etc. remains to be done; only 4% of the state's surface has been mapped to a scale of 1 inch : 2,000 feet.

The federal Resource Conservation and Recovery Act sets forth rules to deal with certain hazardous wastes destined for disposal on land, but the definitions under the law do not cover many of the wastes that are potentially threatening to human health and the larger environment. The staff of the Illinois Hazardous Waste Research and Information Center have concluded that it was not until 1986 that data on hazardous waste generation were reliable and sophisticated enough to warrant year-to-year comparisons.

Wetlands. Long-term interdisciplinary study is needed to learn the quality and distribution of the state's surviving wetlands; the function and values of wetlands (including their sediment, nutrient, and pollution-trapping abilities) need to be measured. Not enough is known about wetland fauna, including long-term population trends in game animals and the relationship between wetlands and bird populations. Standards for the construction and monitoring of created wetlands need to be devised and tested, as do methods for managing sediment inflows and changes in hydrology.

Even ample facts about the Illinois environment do not always lead to a proportionate increase in knowledge. Illinois scientists often are obliged to use whatever data on environmental trends are available, which often means data gathered for some purpose other than scientific inquiry. Compliance data regarding industrial and other wastes are the most numerous, but often they are not very useful in measuring pollution prevention or evaluating the risks to human health and the environment on an ecosystem basis. Likewise, researchers are hampered in their attempts to describe the spatial contours of air pollutant concentrations statewide because the limited number of sampling sites are concentrated in Chicago and Metro-East. These sites are appropriate for the purposes the monitoring was set up to achieve; if one is testing industrial pollution, one is wise to set up monitors where industry is. But the data thus collected will give only partial answers to broader questions of ecological function. ❖

Sources

This summary report is an integrated synopsis of the seven-volume technical report prepared for the Critical Trends Assessment Project. CTAP investigators drew heavily upon the work of many different agencies, chief among them the Illinois Environmental Protection Agency. To save space, data and documents drawn from outside sources were credited in this synopsis to the ENR divisions that authored the respective volumes of the CTAP technical report; original sources are credited in full in the volumes listed below.

From *Volume 1: Air Resources*, Illinois State Water Survey, 1994

Climate Trends in Illinois
Air Quality Trends in Illinois
Atmospheric Deposition Trends in Illinois

From *Volume 2: Water Resources*, Illinois State Water Survey, 1994

Chemical Surface Water Quality
Statewide Ground-Water Quality
Erosion and Sedimentation
Ground-Water Mining
Drought Impacts on Water Resources
Water Supply and Use
Streamflow Conditions, Flooding, and Low Flows
Instream Flow Uses, Needs, and Protection

From *Volume 3: Ecological Resources*, Illinois Natural History Survey, 1994

Prairies
Forests
Agricultural Lands
Wetlands
Lakes and Impoundments
Flowing Waters

From *Volume 4: Earth Resources*, Illinois State Geological Survey, 1994

A Geologic Perspective on Ecosystems, Earth Resources, and Land Use
Trends in Energy Consumption in Illinois
Quantity and Quality of Coal Consumption
Trends in Coal Production
Trends in Oil Production and Consumption
CO_2 Injection for Improved Oil Recovery
Trends in Natural Gas Production and Consumption
Underground Storage of Natural Gas
Stone, Sand and Gravel Industry
Other Minerals Produced in Illinois
Reclamation of Abandoned Mined Land

From *Volume 5: Waste Generation and Management*, Hazardous Waste Research and Information Center, 1994

Part I. Introduction and Trends
Introduction
Overview of Waste Management Issues and Trends

Part II. Waste Generation
- Waste Generation Introduction
- Municipal Solid Waste
- Hazardous Waste
- Industrial Waste
- Medical Waste
- Low Level Radioactive Waste
- Mineral Extraction Waste
- Toxic Release Inventory

Part III. Waste Management Methods
- Introduction to Waste Management Issues
- Landfills
- Recycling
- Surface Impoundments
- Land Application of Municipal Sewage Sludge
- Underground Injection Wells
- Treatment, Storage and Recycling of Hazardous and Industrial Wastes
- Pollution Prevention
- Remediation

From *Volume 6: Sources of Environmental Stress*, Office of Research and Planning, Department of Energy and Natural Resources, 1994
- Manufacturing
- Transportation
- Electricity Generation
- Urban Dynamics
- Indoor Radon Exposure
- Wastewater Discharges
- Accidental Releases
- Greenhouse Gas Emissions
- Human Exposure to Air Pollutants
- Human Exposure to Water Pollutants

Volume 7: Bibliography is an extensive listing of journal articles, abstracts, conference proceedings, government documents, and other material such as references to relevant methodologies and modeling (including their application to the analysis of environmental conditions in Illinois) and references to similar reports by municipalities, other U.S. states, and foreign governments. Volume 7 also lists reports on public perception of and participation in environmental policies.

Volumes of the CTAP technical reports are available to the interested public, as are many of the databases developed during the project.
See "About the Critical Trends Assessment Project," page ii.

GLOSSARY

WORDS SET IN SMALL CAPS ARE DEFINED ELSEWHERE IN THE GLOSSARY

-A-

ACID RAIN. More accurately, acid precipitation that is created when airborne SULFATES and NITRATES react with water in the atmosphere to form dilute sulfuric and nitric acids that return to the surface, mainly in rain and snow.

ACRE. Area measuring 4,840 square yards. An American football field covers one and one-third acres.

ADSORB. To attach, as gases or dissolved substances such as pesticides and fertilizers attach themselves to the surface of soil particles.

AGGREGATE. *See* CONSTRUCTION AGGREGATE.

AGRICULTURAL LIME. Ground limestone, applied to buffer or neutralize excess acidity in farm soils.

ALGAE. A group of green plants without roots, stems, or leaves; algae are found in water and damp places and include seaweeds, pond scum, etc.

AMMONIA. Water-soluble compound of nitrogen and hydrogen in common use as a fertilizer; also a pollutant formed when nitrogenous organic matter decays.

AMPHIPODS. Large group of crustaceans comprising beach fleas and related forms.

ANGLING DAY. A measure of recreational pressure on fishable waters equivalent to one day spent by one fisherman trying to catch a fish.

AQUIFER. Water-bearing stratum of permeable sand, gravel, or rock.

ATMOSPHERIC DEPOSITION. The movement of gases and dust in various forms from the air to the surface. Wet deposition delivers pollutants to the surface by precipitation; dry deposition occurs as airborne pollutants settle onto the surface, are blown onto it by winds, are intercepted by fogs, and so on.

-B-

BALLAST. Broken stone laid in railroad track beds. Also, anything heavy carried in a ship to give it stability. Zebra mussels are presumed to have reached North America in ballast waters from Europe.

BARREL. Basic measure of petroleum production equivalent to 42 gallons.

BEDROCK. General term for the rock that underlies the surface soil or other unconsolidated surface material. In some parts of Illinois bedrock lies at the surface.

BENTHIC. Relating to all the plants and animals living on or closely associated with the bottom of a body of water.

BIODIVERSITY. *See* BIOLOGICAL DIVERSITY.

BIOLOGICAL OXYGEN DEMAND (BOD). Measurement of the amount of organic pollution in water, reported as the amount of oxygen that can be taken up by a given volume of water. A low BOD indicates little pollution.

BIOLOGICAL DIVERSITY. The world's living organisms along with their associated HABITATS and ecological systems.

BIOTA. The animal and plant life of a region.

BUFFERING CAPACITY. The ability to neutralize acids and bases in solution.

-C-

CADMIUM. Metallic element found in a variety of chemical forms; can affect human kidneys and liver. Most humans are exposed to cadmium via food or cigarette smoke; direct air and water exposure accounts for less than 10% of the total exposures.

CALCAREOUS WATER. Water rich in CALCIUM carbonate.

CALCIUM. Soft metallic element, very common in combination in certain minerals and rocks. An essential constituent of plant and animal cells.

CAMBRIAN. The first geological period in the Paleozoic Era, beginning 550 million years ago and lasting roughly 70 million years.

CARBON DIOXIDE (CO_2). Heavy colorless gas produced by the decomposition (including via combustion) of organic matter. Essential to plant photosynthesis.

CARBON MONOXIDE (CO). Colorless, odorless gas that reduces the blood's ability to carry oxygen. Formed during the incomplete combustion of virtually all fuels; most of it comes from motor vehicles.

CARBONACEOUS OXYGEN DEMAND (COD). The weight of oxygen taken up by the organic matter in a sample of water. A test used to assess the strength of sewage. Similar to BOD.

CHANNELIZATION. Artificial straightening of a stream channel to increase the rate of land drainage.

CHIRONOMID. Member of a family of tiny two-winged flies.

CHLORDANE. An organochlorine insecticide much used from the 1950s to the mid-1970s for control of soil insects, especially termites. Its use was greatly restricted in the 1970s.

CHLORIDE. A compound of chlorine combined with another element.

CHLORINE RESIDUAL. Total amount of chlorine (combined and free available chlorine) remaining in wastewater at the end of a specified contact period following its chlorination.

CHLOROFORM. A colorless, volatile, heavy toxic liquid used chiefly as a solvent.

CHLOROFLUOROCARBONS (CFCs). Stable gaseous compounds used as working fluids in refrigeration systems, solvents, and aerosol propellants, and

as "blowing agents" in the manufacture of insulation and packaging foams. In the upper atmosphere the chlorine molecules in CFCs act as catalysts to break apart OZONE molecules.

CHLORINATED HYDROCARBONS. Organic chemicals widely used as pesticides. *See* HYDROCARBONS.

CLAY PAN. Compacted layer of soil that hampers root penetration.

CLEAR-CUTTING. Method of harvesting forest trees in which all trees are cut down rather than just selected trees.

COMMERCIAL FOREST. Any FOREST that may be harvested and that is capable of producing more than 20 cubic feet of wood per ACRE when managed.

CONSTRUCTION AGGREGATE. Rock of various size mixed with cement to form concrete.

CORD. Quantity of wood equal to a stack of logs that measures 4 feet x 4 feet x 8 feet, or 128 cubic feet.

CRITERIA POLLUTANTS. Pollutants for which national or state air quality standards have been set. *See* CARBON MONOXIDE; NITROGEN DIOXIDE; OZONE; SULFUR DIOXIDE.

CROWN DIEBACK. The death of some of the upper branches on a tree; caused by a variety of diseases and other stress factors.

CURIE. Unit of radioactivity equal to 3.7×10^{10} disintegrations per second.

-D-

DDT. PERSISTENT organochlorine compound used widely as a pesticide from the mid-1940s to the 1960s.

DEFOLIATION. Loss of many or most of the leaves on a plant. May be caused by leaf-feeding insects, chemical treatments, or the effects of weather.

DIEBACK. *See* CROWN DIEBACK.

DIELDRIN. PERSISTENT organochlorine used widely as a pesticide from the 1950s to the 1960s.

DRIFT. Rock material transported by a glacier.

DRY DEPOSITION. *See* ATMOSPHERIC DEPOSITION.

-E-

ECOLOGY. The branch of biology that deals with the interrelations among living organisms and their environment.

ECOSYSTEM. A relatively self-contained and interconnected system of living plants and animals along with certain essential features of their HABITAT (e.g., water, oxygen, mineral nutrients).

EDGE. Margin between different kinds of HABITAT, such as between FOREST and cultivated fields.

EFFLUENT. Discharged liquid waste.

ENDANGERED. As applied to any species that is in danger of extinction throughout all or a significant portion of its geographical range. *See* EXTINCT; THREATENED.

ENTOMOLOGIST. A scientist who specializes in insects.

EUTROPHICATION. As applied to bodies of water, the process of becoming rich in dissolved nutrients, often leading to seasonal oxygen deficiencies. Often caused in Illinois by runoff into LAKES and ponds from fertilized farm fields or septic systems.

EXOTIC. *See* NON-NATIVE.

EXTINCT. As applied to any SPECIES that has died out and no longer exists.

EXTIRPATED. No longer living in the state. Many species that are extirpated in Illinois are not EXTINCT, as they may thrive elsewhere.

-F-

FAUNAL STUDIES. Investigations of the animals of a specified region or time.

FECAL COLIFORM BACTERIA. Any of a group of colon bacteria typified by *Escherichia coli*. Their presence is a standard indicator of the pollution of water by fecal matter.

FISH KILL. Visible, mass die-off of fish, usually but not always caused by human activity.

FLATWOODS FOREST. Forest type usually occurring on poorly drained level uplands and stream terraces. In Illinois, commonly dominated by post oak and having a closed SAVANNA-like structure.

FLOCCULENT. Consisting of loosely aggregated particles; soft.

FLOODPLAIN. Land formed by an adjacent river and periodically flooded by it.

FLOOD PULSE. Natural, seasonal rise and fall of river level that inundates the river's plain.

FLOW. Quantity of water that moves through a stream under specified conditions.

FORAGE CROPLAND. Cropland used to raise oats, hay, and similar crops fed to livestock.

FORAGE SPECIES. As applied to lakes and streams, those SPECIES of animal preferred by PREDATOR species.

FOREST. Generally, land with trees on it. Foresters define as forestland any land stocked with trees of any size that cover 16.7% of the land area.

FUGITIVE EMISSIONS. Emissions that could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

-G-

GLACIAL TILL. *See* TILL.

GOB PILE. Waste coal, rock pyrites, slate, and other material of relatively large size that is separated from coal and other mined materials in the cleaning process.

GREENHOUSE GASES. Common air pollutants thought to contribute to global warming, including CARBON DIOXIDE (CO_2), METHANE, NITROUS OXIDE (N_2O), NITROGEN OXIDES (NO_x), and CARBON MONOXIDE (CO).

GROUNDWATER. Water found underground in porous rock strata and soils. *See* AQUIFER; WATER TABLE.

GROWING STOCK. In forestry, the net volume in cubic feet of sound wood in the central stem of live timber trees from one foot off the ground to a stem diameter a minimum of four inches in size.

-H-

HABITAT. The kind of locality in which a plant or animal naturally grows or lives, such as forest, prairie, or wetland, and which provides a particular set of environmental and ecological conditions.

HALONS. Chemicals used in fire-fighting equipment; halons are present in much smaller amounts than CFCs but they have a much higher OZONE-depleting potential per molecule.

HARDNESS. Degree to which water contains certain dissolved calcium and magnesium salts that react with soap to form an insoluble precipitate or scum.

HERBACEOUS. Plants that are nonwoody and die back to the ground each year.

HIGH FLOW. *See* FLOW.

HYDRIC. As applied to soils, wet and low in oxygen.

HYDROCARBONS. Strictly, chemical compounds composed only of hydrogen and carbon; more loosely, many carbon-based compounds that also contain other elements.

HYDROPHYTES. Plant SPECIES adapted to life in water or in saturated soils.

HYDROLOGY. Science dealing with the properties, distribution, and circulation of water.

-I-

IMPOUNDMENT. A manmade pond or lagoon used to store, process, or dispose of wastes. Also any manmade pond or lake. *See* SLURRY POND.

INBREEDING DEPRESSION. A reduction in vigor of plants or animals caused by inbreeding (i.e., matings between related individuals).

INDIGENOUS. Native, or natural to a particular land, region, or environment.

INTRODUCED. In ecological terms, any plant or animal not native to a region and thought to have been brought in by humans.

INVERTEBRATES. Animals without backbones. Includes insects, worms, mussels, crayfish, and many other groups.

-K-

KETTLE. Bowl-shaped depression without surface drainage. Kettles formed in northeastern Illinois when blocks of ice buried in glacial drift melted.

KILOGRAM. Metric measure of weight equivalent to 2.205 pounds.

-L-

LAKE. Inland body of water lacking an appreciable directional water current. *See* KETTLE; MANMADE LAKE; RESERVOIR.

LANDFILL. Facility at which wastes are buried.

LEACHATE. In environmental terms, a liquid or some other polluted medium that has percolated through a landfill.

LOAM. Humus-rich topsoil consisting of clay, silt, and sand.

LOESS. Widespread, homogenous, usually unstratified and unconsolidated fine-grained dust usually considered to be composed of material transported by the wind during and after the most recent glacial period. The mineral basis of most Illinois soils.

LOW FLOW. *See* FLOW.

-M-

MACROPHYTE. Large aquatic plants, as distinct from PHYTOPLANKTON and other small ALGAE.

MANMADE LAKE. Any surface impoundment created by damming a watercourse, from flood control reservoirs to farm ponds. *See* LAKE.

METHANE. Explosive gaseous hydrocarbon produced by the decomposition of organic matter. Methane is the principal constituent of natural gas and a major "greenhouse gas."

MISSISSIPPIAN. Subperiod of the Carboniferous geological period, during which coal formations were laid down in Illinois, beginning some 305 million years ago.

MITIGATE. As used in environmental statutes, to repair or compensate for losses or degradation of farmland, wetlands, etc.

MORTALITY RATES. Proportion or percentage of deaths in a POPULATION during a specified period of time.

-N-

NATURAL SUCCESSION. Sequence of ecological changes in which one dominant group of plant or animal SPECIES is replaced by another over time. This sequence is consistent and predictable for any given physical environment.

NEMATODE. Any of a class of (usually microscopic) elongated worms.

NITRATES. Any of the highly soluble, negatively charged compounds consisting of one atom of nitrogen and three of oxygen. Very important contributor to rapid growth in green plants. Associated with farm fertilizer applications, feedlot runoff, or leaking septic tanks.

NITRATE NITROGEN. *See* NITRATE.

NITROGEN DIOXIDE (NO_2). A pungent, brownish-red gas. Can combine with water to produce nitric acid, which is harmful to plants and animals.

NITROGEN OXIDE (NOx). Any of several compounds of nitrogen produced when fossil fuels are burned. Two of them, nitric oxide and NITROGEN DIOXIDE, are quite reactive and are precursors of OZONE.

NON-NATIVE. Any SPECIES that does not occur naturally in a geographical region, but was INTRODUCED either deliberately or accidentally, by the actions of humans.

NONPOINT SOURCES. As defined in environmental protection laws, indirect sources of pollution. A farm field is a nonpoint water polluter; automobiles are nonpoint air polluters. *See* POINT SOURCES.

NONTARGET ORGANISMS. Those plants or animals not meant to be killed by applications of pesticides.

-O-

Ordovician. Geological period beginning roughly 480 million years ago and lasting for 85 million years.

Organic compounds. Any chemical compound containing carbon. In nature, most organic compounds can only be produced by living organisms.

Overstory. Layer of foliage in a forest canopy.

Ozone. A corrosive gas created when atmospheric nitrogen oxides are bombarded by ultraviolet light energy from the sun. A principal component of smog in the lower atmosphere; in the upper atmosphere, ozone absorbs harmful ultraviolet radiation from the sun.

-P-

Particulate matter. Very small bits of airborne metal, fibers, stone dust, ash, and soot. Because it can be a health hazard, state and national air quality regulations set standards for total suspended particulate matter and for very small particulate matter.

PCBs. Polychlorinated biphenyls, widely used until the 1970s as insulating fluids, among other things; suspected of causing human birth defects and cancer. Production was banned in the U.S. in 1976.

Peak flow. *See* flow.

Pennsylvanian. Subperiod of the Carboniferous geological period, during which coal formations were laid down in Illinois, beginning some 305 million years ago.

Permeability. *See* transmissivity.

Persistent. Long-lasting. Applied to pesticides, the term refers to a compound's ability to be lethal for more than a few weeks.

pH. Measure of how acidic or alkaline a substance is, according to the concentration of hydrogen ions in a solution.

Phenols. An aromatic hydrocarbon widely used in manufacturing.

Phosphorous. Widely occurring element and one of three primary ingredients of commercial agricultural fertilizers.

Photosynthesis. Chemical process by which water and carbon are transformed in the presence of light into carbohydrates by chlorophyll cells in plants.

Phytoplankton. Plankton consisting of plant life.

Planaria. Small freshwater flatworms.

Plankton. Minute plant and animal life of open waters.

Point sources. Facilities (municipal or industrial) that discharge wastes directly into the air or surface waters. A sewer pipe is a point source, as is a factory smokestack. *See* nonpoint sources.

Population. All the individuals of a particular species living in a given area.

POTW. Publicly-owned treatment works, or municipal sewage treatment plants.

Prairie. Biological community occurring in central North America where the landscape is flat to rolling and is largely devoid of trees, and where most plants are herbaceous, with an abundance of grasses.

Precursor. A substance from which another substance is formed. Nitrogen dioxide and VOC are precursors of ozone.

Predator. Any organism that catches and kills other organisms for food.

Protozoa. Subkingdom of animals consisting of minute creatures such as amoeba. Present in virtually all Illinois habitats.

-R-

Radon. Naturally occurring chemical element of atomic weight 222, produced by the radioactive decay of radium-226 and uranium-238. Radon occurs in trace amounts in most geologic materials, including soils.

Reactive. Any chemical that is quick to form new compounds with other substances.

Recreation day. One day spent by one person in some recreational activity; a measure of use pressure on recreation facilities.

Relict. Surviving as a remnant of a vanished type or species.

Remediation. In environmental terms, the undoing of past environmental damage, as in cleaning up a hazardous waste site.

Reservoir. Large manmade lake constructed to control floods or supply drinking water.

Retention pond. Manmade body of water typically used to trap sediments and/or excessive runoff.

Riparian. Of or relating to the banks of a watercourse, usually a stream or river.

Row crop. A crop planted in rows sufficiently far apart to be cultivated for weed control. Corn and soybeans are the most common row crops planted in Illinois.

-S-

Sand forest. Forest occurring on soil that contains substantial amounts of sand.

Savanna. Mixture of trees, shrubs, and prairie vegetation, sometimes regarded as a transition community between forest and prairie. One of eight natural communities found in Illinois.

Secondary-growth forest. Forest that has grown up in an area after the forest that existed prior to European settlement was logged or otherwise destroyed.

Secondary recovery. Methods of petroleum production such as flooding old wells with water to force more oil toward nearby production wells.

Sedimentation. Accumulation in one location of soil particles eroded from different locations. *See* siltation.

Silica. Sand-sized particles of quartz used in the manufacture of glass and in polishing.

SILTATION. The accumulation of silt. Distinct from sedimentation in that siltation usually involves only finer particles.

SLUDGE. The watery residue left by secondary sewage treatment processes.

SLURRY POND. Surface impoundment in which fine particles suspended in water, as from coal-cleaning operations, can settle out of solution.

SNAG. Standing dead tree.

SPECIES. A group or class of plants or animals (usually constituting a subdivision of a genus) having certain common and permanent characteristics that clearly distinguish it from other groups.

SPECIES ASSOCIATION. Group of species of plants or animals that usually occur together in the same kind of habitat.

SPOIL. Material excavated during mining or dredging.

STANDARD METROPOLITAN STATISTICAL AREA (SMSA) Unit of population measurement used by the U.S. Census Bureau, corresponding roughly to a city's metropolitan area.

STRIP MINING. The excavation of shallow deposits of coal or other minerals by the removal of surface soils.

SUBSIDENCE. Lowering of the land surface as a result of the collapse of subsurface tunnels, as from mining.

SULFATES. Compounds containing the sulfate ion, which consists of one sulfur atom and four oxygen atoms.

SULFUR DIOXIDE (SO_2). Pungent, colorless gas that can be produced during petroleum refining or when fuels containing sulfur compounds are burned.

SULFUR OXIDE (SO_x). Any of several oxides of sulfur. Oxidized and combined with water in the atmosphere, sulfur dioxide can produce an ultrafine mist of sulfur trioxide (SO_3) or sulfuric acid.

-T-

THREATENED. In preservation law, of or relating to any species that is likely to become an endangered species within the foreseeable future throughout all or a significant part of its range.

TILING. Installation of tiles (usually earthenware or plastic pipe sections) under a farm field to drain away excess water.

TILL. Unsorted and unstratified glacial drift consisting of a mixture of clay, sand, gravel, and boulders of varying sizes and shapes.

TILLABLE. Capable of being cultivated.

TIMBER. Live trees of commercial species at least five inches in diameter.

TOPOGRAPHY. Configuration of the land surface, including both its natural and manmade features.

TOPSOIL. Uppermost soil layer, also known as the A-horizon.

TOTAL DISSOLVED SOLIDS. Measure of inorganic salts and other substances dissolved in water.

TRANSMISSIVITY. As applied to groundwater, the degree to which water may diffuse through deposits of sands, gravels, or rock in an aquifer.

TURBIDITY. Haziness or muddiness. Applied to water and the atmosphere.

-U-

UNDERSTORY. Vegetation layer occurring in a forest below the canopy formed by the largest trees.

-V-

VASCULAR PLANTS. Plants that contain special conducting tissue (xylem and phloem); these include ferns, conifers, and flowering plants.

VECTOR. Agent capable of transmitting a pathogen, or disease-carrier, from one organism to another.

VERTEBRATES. Animals with a backbone.

VINYL CHLORIDE. Flammable gaseous compound used chiefly for making vinyl resins.

VMT. Vehicle miles traveled.

VOLATILE ORGANIC COMPOUNDS (VOC). Large family of substances in common industrial use, including toluene, acetaldehyde, benzene, hexane, etc. Some are toxic; also PRECURSORS of OZONE.

VOLATILIZE. Evaporate, or pass off in vapor.

-W-

WATCH LIST. Unofficial list kept by the staff of the Illinois Endangered Species Protection Board of SPECIES that are not currently listed as ENDANGERED or THREATENED, but that are nevertheless rare or vulnerable and could eventually qualify for listing as endangered or threatened if current trends continue.

WATERSHED. The area of land drained by a given stream or stream system.

WATER TABLE. Zone of total saturation near the surface.

WET DEPOSITION. *See* ATMOSPHERIC DEPOSITION.

WINDTHROW. Uprooting of trees by the wind.

WOODY PLANTS. Plants that have woody stems and live for several to many years, i.e. trees, shrubs, and woody vines.

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