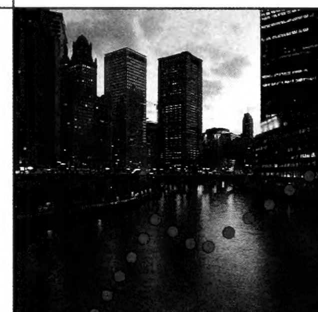
The Changing Illinois Environment: Critical Trends



Technical Report of the Critical Trends Assessment Project Volume 4: Earth Resources

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June 1994 ILENR/RE-EA-94/05(4)

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The Changing Illinois Environment: Critical Trends

Technical Report of the Critical Trends Assessment Project Volume 4: Earth Resources

Illinois Department of Energy and Natural Resources
Illinois State Geological Survey Division
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June 1994

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Printed by Authority of the State of Illinois
Printed on Recycled and Recyclable Paper

Illinois Department of Energy and Natural Resources
325 West Adams Street, Room 300
Springfield, Illinois 62704-1892

Citation: Illinois Department of Energy and Natural Resources, 1994. The Changing Illinois Environment: Critical Trends. Summary Report and Volumes 1 - 7 Technical Report. Illinois Department of Energy and Natural Resources, Springfield, IL, ILENR/RE-EA-94/05.

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

Volume 7: Bibliography

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*. Volumes 1-6 are synopsized in a summary 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 — high school science classes, 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 persons may write:

Critical Trends Assessment Project
Office of Research and Planning
Illinois Department of Energy and Natural Resources
325 West Adams Street, Room 300
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Copies of the summary report and volumes 1-7 of the technical report are available 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 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 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. 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, air emissions of particulate matter from manufacturing have dropped 87%, 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 of five of the state's 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 large reductions in numbers of all species over the last 40 years, apparently as 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 individual 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 the East St. Louis metro area.

- Much more research is needed on the ecology of large rivers, in particular the effects of human manipulation.

- The length of Illinois' longest stream gaging records is generally not sufficient 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 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.

CONTENTS

A GEOLOGIC PERSPECTIVE ON ECOSYSTEMS, EARTH RESOURCES, AND LAND USE

E. Donald McKay
Illinois State Geological Survey

Study of the environment in Illinois must broadly, objectively consider the impacts of human activities on the natural system. We must go beyond narrow measures of symptoms to an understanding of causes and effects. The balanced approach to environmental studies must include an understanding that the geologic setting is the foundation of the environment. The geologic processes at work in the natural system must be considered before our effects *on* nature can be distinguished from the effects *of* nature.

Modern society requires a constant supply of fuel, industrial minerals, and land resources. The availability of resources and the effects of their usage must be factored into a balanced environmental study, as it assesses all uses of the land for a proper perspective of society's potential to alter natural settings.

Many attempts to assess the impact of human activities on the environment have focused on ecosystems—natural plant and animal communities. Boundaries of forests, wetlands, prairies, caves, and lakes often coincide with geologic features. Some studies attempt to measure ecosystem "health" by observing the abundance or diversity of animal or plant populations. At times, researchers have overlooked the dependence of those populations on geologic settings and processes. They have sought to understand living components of the ecosystem without taking the holistic view.

Most people know that geology is the study of the history of the earth and life on the earth, especially as "recorded" in rocks. Geological studies reveal the geologic setting—the earth's solid form, composition, and fluids. The geologic setting provides the unique environmental conditions that determine the natural distribution of swamp, lake, river, floodplain forest, sand prairie, cave, and other ecosystems in Illinois. Even agriculture, which is not an ecosystem in the "natural" sense, is dependent upon the geologic setting and soils derived from geologic materials.

Geology is also the study of dynamic natural processes, some slow and some rapid, that change the form and composition of the earth. Processes such as weathering, groundwater flow, erosion, sedimentation, and continental drift can act slowly over thousands of years and produce dramatic but gradual changes. Flooding, earthquakes, landslides, and other geologic processes that result in rapid, sometimes catastrophic changes, we classify as hazards. The natural changes, whether beneficial or disastrous, are part of a dynamic natural environment within which life has evolved and which would exist even in the absence of human influence.

We have polluted, disrupted, or destroyed the natural settings of some areas of our state, but mostly, the impact of our actions is more subtle. Because we cannot live in Illinois without using the land and altering the environment through mining coal and other minerals, pumping groundwater, cultivating land, building cities, or burying waste, we must study and understand the influence as well as the impact of our activities on the environment. Geology not only includes the study of mineral, fuel, and land resources consumed by ever increasing human populations, but it also provides a vital perspective on the availability and use of resources.

From a geological perspective, some of today's critical challenges in the use and protection of the environment are to locate energy and mineral resources; assess and minimize the consequences of using the resources; safely dispose of solid, toxic chemical, and radioactive wastes; contribute to responsible land use for an expanding population; maintain safe and adequate water supplies; reduce the danger from earthquakes, landslides, and other natural hazards; and facilitate public understanding of earth science issues (National Research Council 1993).

To meet the challenges, we need basic information on

- the geologic setting of Illinois,
- the role of geology in ecosystems,
- natural geologic processes and their rates as the basis for understanding (1) the effects of human activities on the environment, and (2) the pathways and buffers between the sources of pollution, and the humans and ecosystems affected by pollution,
- geologic time as the context for understanding rates of environmental change,
- trends in land use and changes in the natural landscape of Illinois,
- geologic hazards.

We will use this information to

- promote public awareness and understanding of earth-related issues,
- fill the gaps in scientific data and knowledge relating to the geology of Illinois.

GEOLOGY AND EARTH RESOURCES

Geologic Setting and History

Illinois has a total land area of 55,645 square miles, a north-south dimension of 385 miles and a maximum east-west dimension of about 220 miles. The average elevation of about 600 feet above mean sea level makes Illinois the lowest of the north-central states.

Landforms, the products of geologic history, reflect the composition and surface of bedrock as well as the geologic processes that deposited and modified the glacial deposits overlying bedrock. About 2 million years ago, continental glaciers began moving across Illinois from the north via the Lake Michigan basin, from the northwest across Iowa, and from the east via the Lake Erie and Lake Huron basins. Today the central region of Illinois is surrounded to the north, west, and south by bedrock uplands covered in places by thin glacial deposits. In the central region, glaciers leveled the land by covering it with up to 500 feet of glacially transported debris. On top of the glacial deposits lie thick layers of loess—fine particles picked up by the wind from sediment-laden river valleys and blown across the land during the last glaciation 24,000 to 12,000 years ago. The loess deposits, rich in lime and able to hold soil moisture, are largely responsible for the fertile Illinois soils.

The landscape of the state has been divided into physiographic regions based on the topography of the bedrock surface, extent of the several glaciations, differences in glacial morphology, differences in age of the uppermost glacial deposit, height of the glacial plain above main lines of drainage, and the accumulation of glacial meltwater sediments in river basins and lake bottoms (Leighton et al. 1948). In an effort to map regional factors that control how and where ecosystems develop, Schwegman (1973) subdivided the state into 14 natural divisions. Many of his boundaries correspond to the physiographic and landform boundaries mapped by Leighton. The coincidence of physiographic and natural divisions further demonstrates the dependence of ecosystems on the geologic setting of Illinois.

Energy, Mineral, Water, and Land Resources

Illinois is rich in energy, mineral, land, and water resources. Without coal, petroleum, minerals and metals, water, and arable land—the sources of wealth supplied by nature—society could not function.

Coal is the major energy resource extracted in Illinois. Although it is found in several minable seams, the Springfield and Herrin Coals are the major producers. Where they occur near the surface in southern, western, and eastern Illinois, they are surface mined. Nearer the center of the state, the coals tend to occur at greater depths and have been mined underground.

Illinois has been a major producer of petroleum since the turn of the century. The largest pools are located in the southern and southeastern parts of the state, where oil is produced from Pennsylvanian and Mississippian rocks lying roughly between 1,000 and 3,000 feet deep.

Industrial minerals and metals, including stone, sand and gravel, peat, clay and shale, microcrystalline silica, fluorspar and associated minerals have been mined in many areas of the state. Significant economic deposits remain.

Groundwater aquifers with the capacity to yield potable (fit to drink) water to pumping wells occur in the glacial drift and bedrock throughout Illinois. The major aquifers occur mostly in northern and central Illinois, and also along the large rivers. Small supplies of groundwater, enough for a single household, can be obtained nearly anywhere in the state. But in some areas, aquifers with sufficient capacity to supply a small municipality are rare.

Arable land is one of our most important resources. Illinois has some of the most fertile soils in the world, and more than 80% of the state is crop land.

GEOLOGIC PROCESSES

Climate, erosion and sedimentation by wind and water, weathering, soil formation, and other geologic processes have shaped the earth's surface and continue to function at rates that are sometimes accelerated and sometimes slowed by human activity. But because the natural processes are so complex, their rates so variable, and their effects not well known, there may be considerable uncertainty about the natural versus human causes of a given effect.

The ongoing debate about global warming and climate change points out the complexity of distinguishing natural from human causes. Climatic changes much more dramatic than anything attributable to human activities have occurred repeatedly in the geologic past. The reasons for these natural changes, which even led to the glaciation of much of Illinois in the past few tens of thousands of years, are not obvious. The interaction of sociocultural activities and natural trends must be understood before future climatic trends can be predicted.

Soil erosion, accelerated by agriculture since the first plow broke the prairie of Illinois, is a natural process that has sculpted the land surface over many thousands of years. Studies need to be done to determine the natural rates of soil erosion when the Illinois landscape lay under native vegetation, and how soil formation balanced the processes of erosion.

Soil formation in a unique grassland setting has yielded the highly productive soils of Illinois. Weathering of different geologic materials (called parent materials) under different conditions of slope, climate, and vegetation for different lengths of time can produce widely different soils. Each soil is characterized by its horizons (layers), chemical nutrients, organic constituents, and physical moisture regime to which plants and animals have adapted. But this natural balance is often disturbed by human activities that produce soil loss, soil nutrient depletion (offset by fertilizers, pesticides, and irrigation), and degradation due to pollution. The potentially negative impact of intensive farming, for example, calls into question the sustainability of chemical-based agriculture around the globe.

Nature more than culture is implicated in coastal erosion along Lake Michigan. Research indicates that erosion is correlated with the natural fluctuations in lake levels, which are largely in response to climatic variation. Ongoing documentation of past lake level responses to climate may provide the "clues" (key factors) for predicting the rise and fall of lake levels, and point the way to protecting and preserving the Lake Michigan coastline.

Sediment transport and erosion are natural functions of flowing water. Dams, reservoirs, channelization, diversion, levee construction, and other stream or shoreline modifications alter the natural runoff and sediment-carrying characteristics of streams and rivers as well as the nearshore currents along shorelines in Illinois. Invariably, construction alters the natural rates of sedimentation and erosion. Studies show high rates of erosion and sedimentation in many disturbed settings throughout Illinois. Water erosion and transport may contribute another undesirable effect by distributing soil particles and pesticides eroded from agricultural land. Sedimentation may also store and effectively isolate some contaminants in bottom sediments of rivers, streams, and lakes. Later, contaminated materials may be recycled into the biosphere by dredging.

Wind erosion, transport, and sedimentation may also widely distribute contaminants. Long term studies of these processes, the transported materials, and the areas where airborne particles accumulate are also critical for interpreting how all processes interact in the natural environment.

Groundwater flow and solute transport may carry contaminants through the ground to a pumping well. But in many settings, the attenuation processes counteract the potentially negative effects. The natural buffering and adsorption properties of geologic materials may retard migration of contaminants, such as leachates from landfill wastes, which in other settings may contribute to contamination of ground and surface waters.

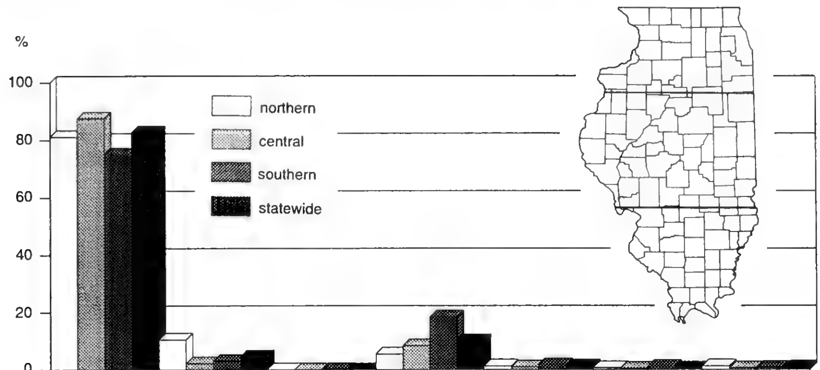
GEOLOGIC TIME

The perspective of geologic time reveals the environment as a natural system subject to natural change and evolution over periods of time much greater than measured, recorded, or directly experienced by humans. By examining the geologic record, we learn the significance of gradual natural processes that through the millennia have produced and continue to modify the major features of the modern landscape. We identify intervals for the possible recurrence of catastrophic earthquake, flood, and landslide events.

Continued study of the rates and characteristics of geologic processes operating through the geologic ages helps us to fully understand natural systems operating in the present. We develop the ability to distinguish responses of the natural system to relatively recent, human-induced changes.

TRENDS IN LAND USE

Agriculture; residential, commercial, and industrial development; highway, railroad, and airport construction; reservoirs; surface mining; landfills and other waste disposal facilities; and clearing of forests directly alter the natural landscape.



	agriculture	urban	range	forest	water	wetland	barren
northern	81.1	10.5	0	5.4	1.2	0.6	1.2
central	87.6	2.2	0	8.4	0.9	0.4	0.6
southern	75	3	0.1	18.4	1.7	1.1	0.7
statewide	82.7	4.6	0	10.1	1.2	0.6	0.8

Figure 1 Major categories of land cover in northern, central, and southern Illinois (from 1:125,000-scale land cover maps of the U.S. Geological Survey).

Agricultural uses dominate the land in all sections of Illinois (fig. 1). They take up 82.7% of the total area of the state. Forests cover 10.1% and urban areas cover 4.6%. All other types of land cover (water, wetlands, and barren) total 2.6% of the state.

Residential, commercial, industrial, transportation, and other urban areas cover only 4.7% of the state, far less than the 92.7% of the land covered by farms and forests (fig. 2). Residential development alone covers about 2.7% of Illinois. For comparison, reservoirs inundate 0.9% of the land; surface coal mines affect 0.8%; and landfills affect about 0.2%.

In terms of land area affected, agricultural and urban land uses are the largest contributors to modification of the natural landscapes, forests, and habitats of Illinois. At the same time, agricultural practices can contribute significantly to restoring forests and wetlands, whereas urban sprawl is the single largest contributor to permanent loss of habitat and arable land. Future trends in land use are likely to be similar, as urbanization continues to displace agricultural land.

Other land uses have affected smaller areas and will contribute much less to future changes in land use. Reservoir construction is unlikely to be significant in the future, as the most favorable reservoir sites have already been developed. Although other sites are available, environmental concerns are now overriding water supply and recreation issues. Trends in coal mining are away from surface mining and toward underground mining, which disturbs little surface land. Waste disposal in landfills is likely to increase as population increases; but the total land area occupied by such sites is proportionately very small.

Unnatural instabilities introduced by some land uses cause so-called "natural" hazards: subsidence over underground mines, accelerated erosion along coastlines and channelized streams, increased sedimentation in lakes and reservoirs, weathering of exhumed minerals, altered patterns of groundwater recharge and discharge, altered runoff, and flooding. Accelerated soil degradation occurs via wind and water erosion, compaction, and modification for agricultural, urban, and industrial land uses. (See previous section on geologic processes.) Once again, the problem is people—the many ways of living and making a living on the land.

Looking to the future, we should be highly concerned about the development of critical or vulnerable lands.

Coastal regions and wetlands, productive farm land, and unique or high quality habitats all require special consideration because of their special characteristics. Areas underlain by mineral and fossil fuel resources should be developed in ways compatible with the future extraction of the resource. Waste disposal sites should not only be engineered to isolate waste, but also be placed in locations where geologic conditions are most likely to isolate contamination from surface or groundwaters. The conservative, geological approach to siting waste facilities will undoubtedly reduce the potential for contamination and costly cleanups.

Earth science factors should be considered when planning land use and development. Public officials should seek input from geologists before making decisions and initiating actions that irrevocably alter patterns of land use. Geologists also have a civic duty to inform their elected representatives and fellow citizens about important earth science developments. Mineral resources and natural habitats should not be lost because of uninformed or misinformed decision-making.

TRENDS IN ENERGY AND MINERAL RESOURCE EXTRACTION

Advanced societies consume energy resources on a scale that represents one of the greatest changes on the earth over the past century. Few resource developments have affected the environment more than the burning of coal, oil, and gas. These modern consumption habits have developed because geoscientists have been able to discover and exploit energy resources with remarkable success (NRC 1993). These resources are nonrenewable, however, and mineral and fuel resource extraction inevitably results in resource depletion.

Coal Mining

Disruption of the land, habitats, and the way land was previously used are among the deleterious environmental effects of surface mining. Surface and groundwater are also likely to be polluted with soluble compounds released if weatherable materials are exposed

	agriculture	residential	commercial	industrial	transport	other urban	reservoir	surf. mine	landfill
%	82.7	2.7	0.8	0.3	0.4	0.4	0.9	0.8	0.2
sq. mi.	46018	1496	469	193	210	245	488	392	141

Figure 2 Selected categories of land cover types in Illinois (from 1:125,000-scale maps and related data of the U.S. Geological Survey and Illinois State Geological Survey, and data from the Illinois Coal Association).

to surface conditions. Decreased surface coal mining and improved reclamation practices have eliminated most harmful effects of modern mining and improved the quality of runoff. Modern practices include restoring the natural grade and covering the mined material with soil. Reclamation laws also require proof of agricultural productivity of reclaimed land.

Petroleum Production

Decline continues in the production of petroleum in the state. Many Illinois wells have low production rates and are only marginally profitable. Many wells are plugged and abandoned because of low oil prices and the economics of reworking old wells. Ongoing efforts to improve recovery from existing fields include secondary recovery methods and research investigations into the nature and properties of reservoirs. Although there are thousands of oil wells in Illinois, the surface area potentially affected by each is very small. Deleterious effects of petroleum production are generally limited to spills of oil field fluids, oil, and brine. Modern regulation of injection wells used for waterflooding and brine disposal ensure protection of underground sources of drinking water.

Most future oil production in Illinois will be from known fields. Although potential exists for new discoveries at greater depths than existing production, it is unlikely that giant new fields will be discovered.

Industrial Mineral Resources

Fluorspar is actively mined in southern Illinois. Lead has been mined in northwestern Illinois. Clay is no longer produced in significant quantities. Sources of aggregate, sand and gravel, and stone are found throughout the state. Increased surface mining of sand and gravel and stone production will be needed to meet growing demand for aggregate for construction and repair of roads and other infrastructure. Aggregate resources are being lost to other land uses as urbanization and other construction covers the deposits, especially in northeastern Illinois. Reclamation laws, which have led to improvements in the postmining condition of surface coal mines, do not apply to all sand and gravel and stone operations. Abandoned pits have been used for many other functions, including waste disposal, recreation, wildlife habitat, and wetlands. Some underground limestone mines are excellent sites for factories or storage facilities. Small amounts of peat, shale, and tripoli (microcrystalline silica) are still mined, but the environmental effects of such mining are minor.

TRENDS IN GROUNDWATER SUPPLY

Most parts of Illinois are rich in groundwater resources. Although there is no general shortage or depletion of groundwater resources, there is a need to find groundwater supplies in areas that have marginal aquifers. Currently, detailed geologic mapping is used to identify potential aquifers and provide information for detailed studies of their vulnerability to contamination. Expansion of geologic mapping to support this and other needs, such as cleanup or isolation of contaminated sites, must be a major priority in Illinois.

TRENDS IN DISPOSAL OF WASTES

Landfills have replaced dumps for disposal of municipal solid waste and some industrial residues and waste. Disposal of hazardous and chemical wastes is carefully regulated, as is the handling and disposal of low-level radioactive wastes. The number of landfills accepting municipal solid waste has steadily decreased in the past few years, while according to the Illinois Environmental Protection Agency (IEPA 1990, 1991, 1993), the available capacity of operating landfills has increased. The trend is clearly toward fewer, larger landfills. At eight sites in Illinois, deep injection of liquid wastes into wells is occurring, generally into zones that are thousands of feet below the surface. The injected fluids are unlikely to have any environmental consequences. These sites are carefully designed and monitored.

GEOLOGIC HAZARDS

Proper development and use of land contributes to amelioration of the economic effects of certain natural and human-induced earth hazards, including floods, earthquakes, landslides, and mine subsidence. The key to assessment of these geologic hazards is geologic mapping.

Land use in flood-prone areas is only partly controlled by insurance and floodplain construction regulations. Landslide and earthquake hazards are not as well defined geographically. Recent regional mapping of known landslides and landslide-prone areas is not sufficient to assess local hazards. Detailed geologic maps are needed to delineate materials and settings prone to mass movement.

Ongoing efforts to characterize the possible earthquake scenarios of the New Madrid and Wabash Valley Seismic Zones will help define probabilities of occurrence, frequency, and magnitude of seismic events likely to affect Illinois. It is very difficult, however, to predict the spectrum of local response of geologic materials to a given magnitude earthquake. Detailed mapping of geologic materials and studies to determine material response to seismic energy are needed. It is likely that Illinois will experience earthquake activity, potentially causing considerable ground shaking, liquefaction, and landslides in certain geologic settings. The greatest threat is from a large earthquake focused in the New Madrid Seismic Zone south of the state.

Soil gas entry into the home is the primary source of radon gas in indoor air. Currently, it is impossible to predict which Illinois homes are most likely to have elevated levels of radon. Research is needed to better define the geochemical and physical processes that contribute to seasonal and spatial variations in radon concentration. Once we understand what causes the variations, we can map the areas where people are at greatest risk of exposure to radon in their homes.

TRANSFER OF GEOLOGIC INFORMATION TO THE PUBLIC

The public needs to have a better understanding of the value of earth science information for planning how to use the land and its resources, while at the same time, avoiding or eliminating earth hazards. Much information about geologic setting and geologic processes; mineral, land, and water resources; and geologic hazards in Illinois is highly technical and published in scientific reports for the scientific community. How can it be more useful to communities at large? The public would benefit from popular writing on technical subjects. Easy-to-use maps, highly detailed at the local level, should be readily available for land-use decisions by county and local officials. There is also great need for more earth science education in the elementary, middle, and high schools of the state.

GAPS IN GEOLOGIC DATA

To assess critical environmental trends, we must set priorities for research in environmental geology:

- detailed geologic mapping that identifies the geologic setting of the state, so that we can identify resources, predict hazards, and assess the environment;
- studies of the nature and rates of geologic processes that directly influence ecosystems and indirectly, human health and well-being;
- studies of mineral reserves (fossil fuels, industrial minerals, construction aggregates, and water resources), including those economically inaccessible because of geologic setting, contamination, competing land use, or regulatory restriction;
- studies of the extent of soil, surface water, and groundwater degradation caused by use of pesticides, herbicides, and chemical fertilizers;
- studies of the social and environmental consequences of flooding, earthquakes, landslides, radon, mine subsidence, and other geologic processes and phenomena that we classify as hazards;
- identification of geologic settings capable of long term isolation of municipal, hazardous, and radioactive wastes;
- automation of the vast amounts of geologic information collected by state, federal, and local agencies, and industry.

THE UNIQUE PERSPECTIVE OF ENVIRONMENTAL GEOLOGY

Geologic settings and processes provide the unique environmental conditions that determine the natural distribution of swamp, lake, river, floodplain forest, sand prairie, cave, and other ecosystems in Illinois. The geologic and mineral wealth of the state—energy, mineral, land, and water resources—are as much a natural part of these ecosystems as the plant and animal populations. Ecosystem "health" and economic "wealth" are thus interdependent.

Geologic processes, some slow and some rapid, continually change the form and composition of the earth. Society's relatively recent modifications of natural conditions must be assessed within the perspective of dynamic and complex geologic systems that are as old as the earth. But these dynamic processes must be thoroughly understood before humanity's full impact on the environment can be assessed. Our future well-being within a global geologic setting depends on viewing our societal needs both to protect and to use the land—not as a conflict, but a challenge.

TRENDS IN ENERGY CONSUMPTION IN ILLINOIS

Subhash B. Bhagwat
Illinois State Geological Survey

Energy is consumed in various forms: primary energy in the form of oil, gasoline, and natural gas, and secondary energy in the form of electricity generated by burning fossil fuels such as coal or using nonfossil sources such as nuclear, solar, and wind power. The most commonly used measure of energy consumption is the British thermal unit (Btu). In the case of electricity, the input of energy is considered as energy consumption and not the Btu equivalent of kWh of electricity generated.

The total energy consumption in Illinois increased from about 2.7 quadrillion (10^{15}) Btu or quads in 1963 to about 4.2 quads in 1978 (fig. 3)—a trend interrupted by declines in 1974 and 1975 as a result of the dramatic oil price increases brought on by the Middle East war. (See bibliography for data sources.) The average annual growth rate in energy consumption in Illinois between 1963 and 1978 was about 3%. Energy conservation measures were effectively implemented during the 1979-1980 period of energy price increases due to the Iran-Iraq conflict and U.S. price decontrols. Illinois' energy consumption fell 20% in 4 years to 3.35 quads in 1982. Since then, consumption has risen inconsistently at an average rate of increase of 0.7% per year to 3.55 quads in 1990. Some increases in energy consumption since 1985 are due to a shift in the consumption pattern in favor of electricity, especially in the residential, commercial, and industrial sectors.

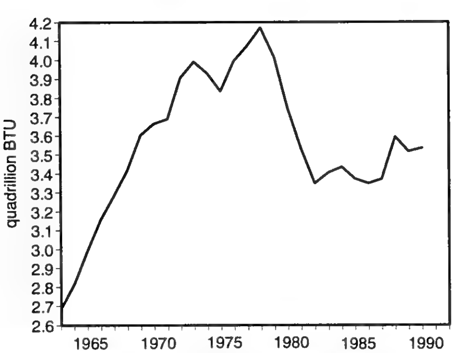


Figure 3 Energy consumption trend in Illinois.

Emissions of sulfur dioxide, nitrogen oxide, particulate matter, and carbon dioxide have decreased with the decline in total energy consumption since 1978. But the improvement in air quality is greater than the corresponding reduction in total energy consumption seems to indicate because an increasing amount of electricity is being generated by nuclear power plants. Nuclear electricity accounted for about 1% of total generation in the early 1960s. By 1990, about 56% of electricity was generated by nuclear power plants. The potential increases in emissions of CO_2, SO_x, NO_x, and particulates were substantially held down by the growth in nuclear electricity.

Nuclear energy may further increase its role in electricity generation as power plants overcome minor, unforeseen disruptions and stablize production. No new nuclear plants have been permitted in the past 15 years, so the future mix of energy consumption will depend primarily on how efficiently energy is used in the Illinois economy, and how decommissioning of nuclear power plants is paid for.

Despite nuclear energy, the consumption of coal for electricity generation in 1990 was about 42% higher than it was in 1960 because the overall demand for electricity was higher; however, the high point of coal consumption in the electricity sector was reached in 1980 at 71% above the 1960 level of consumption.

The efficiency of energy consumption can be measured by the inflation-adjusted dollar amount of the Gross State Product (GSP) per unit of energy consumed. Figure 4 represents, in terms of 1987 U.S. dollars, the GSP for each 1 million Btu of energy consumed. From 1963 to 1972, when the cost of energy was low, the efficiency measure fell from about $52 to $46 per million Btu. The efficiency of energy use improved to about $48 in the 6 years leading to 1978 and has since then rapidly grown to about $70 per million Btu in 1990. The efficiency of energy use should continue to grow in the residential, commercial, and transportation sectors as the efficiencies of building insulation, machinery, and appliances and automobile milage per gallon continue to improve. The magnitude of improvements remains uncertain because energy prices in general have stabilized and government codes and tax policies continue to change.

Efficiency improvements in the electricity sector have been slow. Although the heat rates (the amount of energy needed to generate 1 kWh of electricity) have improved by about 10% since the 1960s, about two-thirds of all energy input continues to be lost.

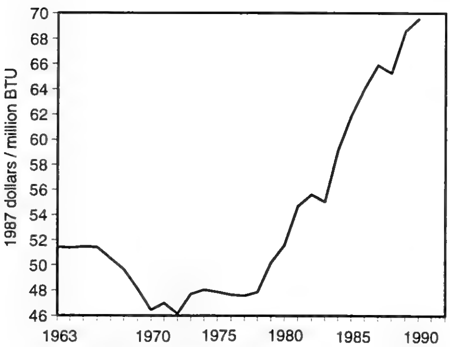


Figure 4 Illinois' energy efficiency.

Major energy savings can be achieved with every percentage point increase in the efficiency of converting primary energy into electrical energy. Currently, about one-quarter of Illinois' total energy consumption is accounted for by losses during the generation of electricity. As older, less efficient power plants are replaced by newer designs (currently on the drawing boards), efficiency will continue to improve. New technologies such as the Integrated Gasification Combined Cycle (IGCC) could play an important role in this respect; however, flue-gas scrubbers and other conventional pollution control devices consume energy and reduce the overall efficiency of electricity generation.

QUANTITY AND QUALITY OF COAL CONSUMPTION

Subhash B. Bhagwat
Illinois State Geological Survey

Total coal consumption in Illinois fell from 45 million tons in 1969 to 32.5 million tons in 1990 (fig. 5). About 80% of the 1969 consumption was accounted for by Illinois coal; the rest was imported from other states east of the Mississippi. With the advent of large-scale coal mining in Wyoming and Montana in the 1970s, imports into Illinois increased, mostly at the expense of in-state resources. By 1980, Illinois' share of total consumption had fallen to 51%. Western coals accounted for about 38% and other eastern coals for 11% of consumption.

Two factors played the most important role in this decline in the use of Illinois coal within the state: the low sulfur content of western coals and its low mine-mouth price. Although transportation costs often more than made up for the price difference, many utilities switched to low sulfur western coal to comply with requirements of the Clean Air Act regulations on SO_2 emissions, which went into effect in June 1971.

In the 1980s, the consumption of Illinois coal in the state stabilized at about 20 million tons (about 60% of consumption), while western imports declined sharply to 20% and eastern imports increased steadily, also to about 20% of total consumption. Revision of the Clean Air Act in 1977, increased productivity in Illinois mines, a general shift toward mining of lower sulfur coals in states east of the Mississippi, and more

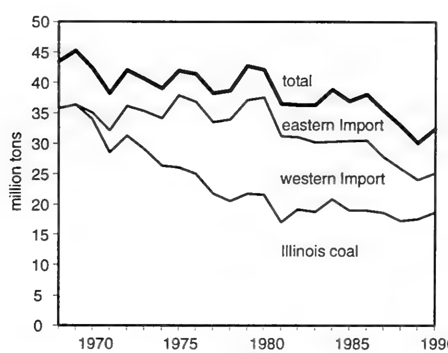


Figure 5 Coal consumption in Illinois.

sophisticated coal cleaning technologies all helped to bring about the stabilization.

Other influential stabilizing factors were the increasing role of nuclear power and declining energy prices after 1981. Electric utilities used the changed circumstances to reduce their dependence on higher priced western coals. The role of nuclear energy is especially prominent during the 1980s when coal consumption by electric utilities in Illinois dropped from 36 million tons in 1980 to 27 million tons in 1990 (fig. 6). Nuclear-generated electricity increased its share of the market from 27% to 56%.

As Illinois utilities consumed more western coal in the 1970s, the average heat value of coal consumed began to decline (fig. 7), falling from about 10,750 Btu/lb in 1969 to about 10,250 Btu/lb in 1979. (Data on coal quality are generally deficient during 1977-1978, the early years of the formation of the U.S. Department of Energy. This becomes evident in the following discussion of coal quality.) Imports of western coal declined in the 1980s; and the average Btu/lb of coal regained its pre-1970 level by 1990. The Btu content of coal is important for two reasons. First, the higher Btu coals generally contain less moisture and thus burn more efficiently; and second, the higher Btu coals reduce the total fuel costs because fewer tons of coal must be purchased and hauled.

An important indicator of coal quality is its sulfur content. Before the first clean air regulations were implemented in 1971, sulfur was not a factor that needed attention. Data on the average sulfur content of coal consumed in Illinois are available only since 1973, although there is still a gap for the year 1977 (fig. 8). The average sulfur content of coal consumed by electric utilities in Illinois fell from about 2.6% in 1973 to between 1.8% and 2.0% by the end of the 1970s and has since remained in that range despite the revision of the Clean Air Act in 1977. The 1977 revisions primarily affected power plants starting construction after September 1978. Since then, only one coal-burning unit has become operational, and its construction began before the 1978 deadline, so it was not affected by the change in regulations. As a result, there was no significant change in the average sulfur content of coal used in Illinois in the 1980s.

Some lowering of the average sulfur content of coal consumed in Illinois appears likely in the remainder of this century because of fuel switching by older plants. The

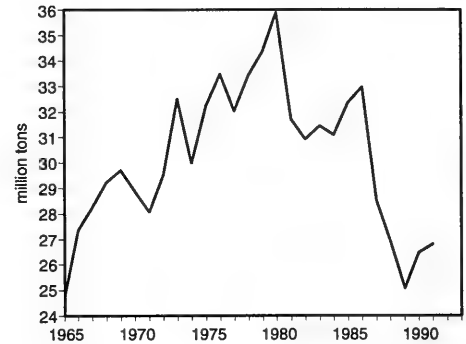


Figure 6 Coal consumption by electric utilities in Illinois.

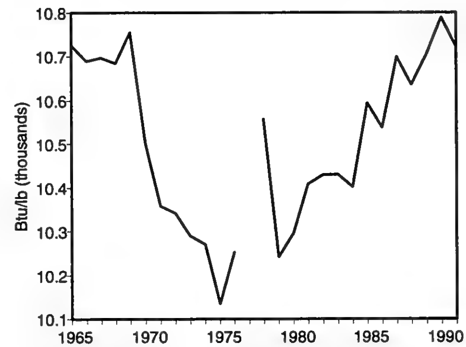


Figure 7 Btu/lb of coal consumed in Illinois.

1979 Clean Air Regulations, based on the 1977 revision of the Clean Air Act, were favorable to burning the cheapest fuel, regardless of its sulfur content. This was made possible because regulations required all new plants to reduce their SO_2 emissions potential by up to 90% as well as to meet the emissions limit of 1.2 lbs SO_2 per million Btu consumed. Only "scrubbers" could meet both requirements. Consequently, all new plants built after 1978 had to have some type of scrubber, regardless of the sulfur content of coal used. The 1990 Clean Air Act amendments reverse this virtual requirement and allow plants to meet the same stringent emission limits by freely choosing between scrubbers, fuel switching, and emission allowance trading. If high sulfur Illinois coal is economically competitive under the new circumstances, its use will increase. The record of

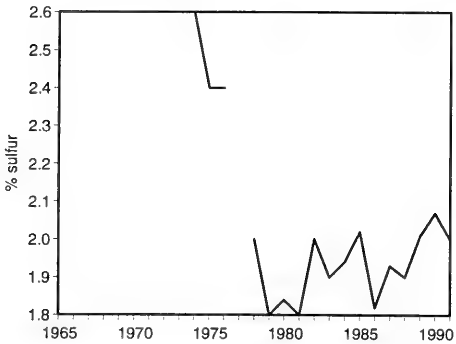


Figure 8 Sulfur in coal consumed in Illinois.

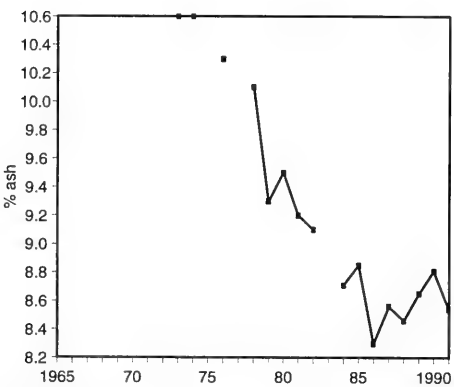


Figure 9 Ash in coal consumed in Illinois.

the 1980s indicates that it is not easy to remain economically competitive.

Another environmentally significant trend with economic consequences is the amount of waste generated by electric power plants. Currently, only four major Illinois power plants have scrubbers, producing only small quantities of gypsum wastes; however, generation of gypsum or a similar product could substantially increase in the decades to come. Methods must be found to utilize and/or dispose of these wastes, unless technologies such as the Integrated Gasification Combined Cycle (IGCC) become widely applicable.

Similarly, electrostatic precipitators generate large quantities of fine ash that can be, and often are, used in cement production and other construction-related applications. The generation of bottom ash depends primarily on the amount of "ash" or noncombustible material in coal. Data on ash content, like data on sulfur content, have only been available since 1973. The average ash content of coal consumed in Illinois' electric utilities has declined from about 10.6% by weight in 1973 to about 8.6% in 1991 (fig. 9). Based on coal tonnage and the average ash content, it is estimated that bottom ash generation in Illinois has declined by about 33%, from 3.5 million tons in 1973 to 2.3 million tons in 1991. This trend is likely to continue as more sophisticated coal cleaning technologies are used, reducing the ash content of coal. Illinois is already at the forefront in the nation in terms of the percentage of coal being subjected to physical coal cleaning. More than 95% of Illinois coal is physically cleaned before sale, as compared with an average of about 60% to 65% for other states east of the Mississippi River.

TRENDS IN COAL PRODUCTION

Subhash B. Bhagwat
Illinois State Geological Survey

More production data are available for coal than for any other mineral in Illinois. In this century, production of Illinois coal peaked at about 103 million tons in 1925. After the depression of the 1930s, production of Illinois coal rose again from about 34 million tons in 1932 to about 78 million tons during World War II. Production has fluctuated around the 60 million ton mark for the past 25 years, with the exception of a few years affected by miners' strikes (fig. 10).

Surface mining began in 1911 and peaked in 1967. The Surface Mining Act in 1971, which mandated reclamation of land after mining, and the depletion of surface minable reserves both contributed to a decline in surface mine production during the past two decades to about 16 million tons in 1991 or about 26% of total Illinois production.

The decrease in surface mining and the corresponding increase in underground mining has the consequence that more coal is being left unmined to support the earth's layers above underground mines. Modern room-and-pillar mines are designed to prevent subsidence by leaving about half of the coal in place for support. Most of these mines are expected to display no subsidence for many decades and maybe for centuries. The impact of subsidence depends on the magnitude, timing, and pattern of surface sinking as a result of mining. In contrast to room-and-pillar mining, longwall mining is designed for quick and uniform subsidence over the entire panel mined. Subsidence of large, contiguous areas above longwall mining panels is less harmful to structures and more predictable than checkerboard patterns of subsidence caused by conventional room-and-pillar mining. As a result, longwall mining methods have found increasing applications in Illinois coal mines.

Longwall coal mining in Illinois started in 1977. In 1992, almost 27% of underground mining or 21% of all coal mining in Illinois was done by the longwall technique. Eleven longwall units produced 12.7 million tons of coal in 1992. Longwall methods improve extraction

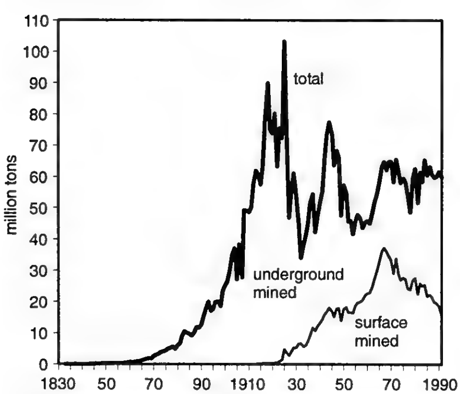


Figure 10 Trends in coal production in Illinois.

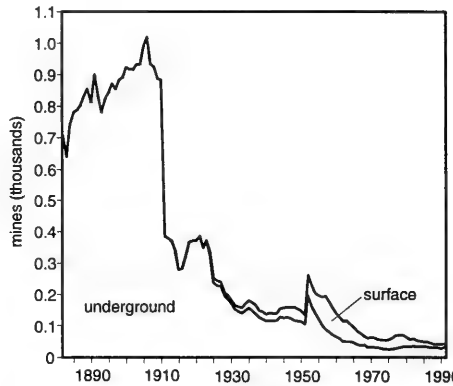


Figure 11 Number of mines in Illinois.

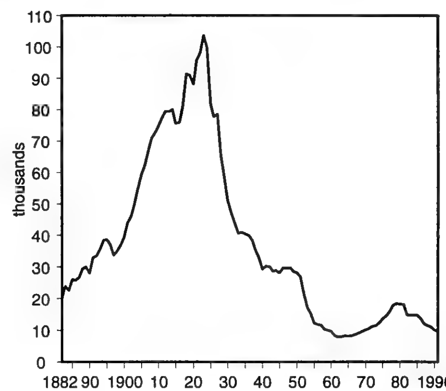


Figure 12 Coal mining employment in Illinois.

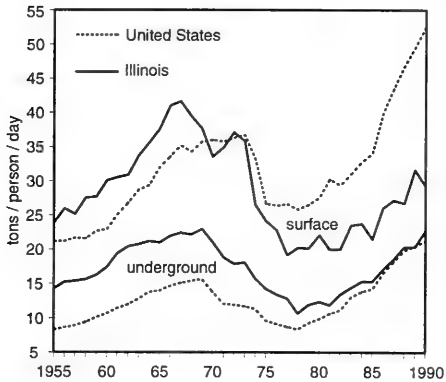


Figure 13 Trends in coal mining productivity.

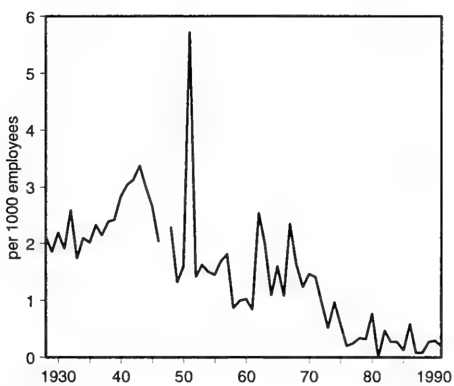


Figure 14 Fatal coal mining accidents in Illinois.

rates and reduce resource waste. At the same time, these methods also help improve productivity and reduce costs. The planned subsidence over longwall panels is a major safety and cost-saving feature in the long run. For example, a longwall machine shift produced nearly 2,400 tons in 1992, as compared with a conventional machine shift, which produced only 800 tons.

The size of coal mines in Illinois grew in the past 35 years, while the number of mines declined (fig. 11). The largest increase in size occurred in the 1955-1965 period. Another significant increase in mine size took place in the past two decades. Mechanization and larger equipment sizes led to lower mine employment (fig. 12) and higher labor productivity (fig. 13). After World War II, mine employment reached a low of 8,774 persons by 1962. From 1962 to 1972, production rose by 44% and employment rose by 42%. Labor productivity generally declined through most of the 1960s and 1970s because the number of person-days worked increased more rapidly than the total production. A substantial increase in labor productivity, accompanied by a decline in employment, followed in the 1980s and still continues. Employment reached a low of 9,667 in 1991. A major factor behind lower employment and higher productivity is the continuation of the trend toward lower real coal prices since the mid-1970s.

A point of concern to producers has been the loss of productivity advantage of Illinois mines vis-a-vis the U.S. average productivity. Illinois mines had a substantial advantage in underground and surface mine productivity over the U.S. average in the 1960s. In 1991, however, the productivity of Illinois' underground operations was the same as the U.S. average. The state's surface mine productivity was only 55% of the U.S. average because U.S. surface mine productivity has increased rapidly since 1978, when large new mines opened in Wyoming and Montana. In these western states, thick coal seams and relatively thin overburden offer ideal surface mining conditions.

Illinois coal mining has steadily improved safety in the past 60 years. Fatal accidents per 1,000 employees declined from about 2 in 1930 to about 0.3 in 1991 (fig. 14). The production pressure of the World War II years led to higher fatality rates. In some years such as 1951, major accidents disturbed the recognizable trend toward safer coal mines in Illinois.

TRENDS IN OIL PRODUCTION AND CONSUMPTION

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Illinois State Geological Survey

Since the peak oil production of about 148 million barrels in 1940, the oil industry in Illinois has generally been on the decline. Primary production, using the natural reservoir pressure for unaided flow of oil, declined consistently except in the early 1950s. Oil production rose in the 1950s as a result of secondary production methods—driving the oil out of reservoirs with water (fig. 15). But waterflooding could not stop the downward trend as oil fields were depleted. Unprecedented high oil prices in 1980-1981 gave the oil industry a strong incentive to boost production in the first half of the 1980s. Prices fell sharply in 1986 and have remained low since then. Total output by 1991 was about 19 million barrels. Between 1985 and 1989, the Illinois oil industry lost about 3,500 jobs, more than 50% of its total number of jobs.

Most Illinois oil wells are economically marginal, producing less than 2 barrels of oil per day. Daily production per well in Illinoisfell from about 7 barrels in 1963 to 2 barrels in 1990. At this level of daily output, newly drilled wells would not be economical. By comparison, the U.S. average production per well in 1990 was about 12 barrels per day (fig. 16). U.S. daily production per well had been as high as 18 barrels in 1972 as a result of the large oil finds in Prudhoe Bay, Alaska. It has since fallen back to pre-1965 levels.

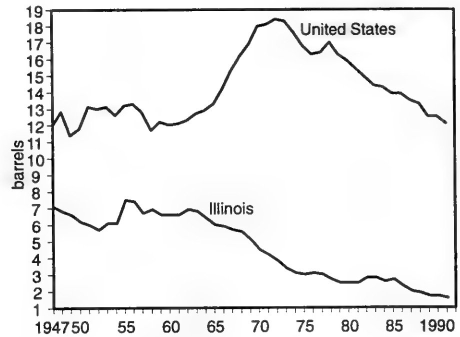

Figure 16 Oil production per well per day.

Innovation and research in oil production technology are urgently needed because current practices leave about 60% of known oil in the ground. Reservoir heterogeneity and other unfavorable geologic factors cause the loss of large quantities of oil reserves in the state at a time when more than 90% of the state's oil needs have to be met by out-of-state or overseas sources.

About 1960, when the brief surge in Illinois' oil production was foundering, oil consumption in the state was rapidly rising (fig. 17), up nearly 70% in less than 20 years. A temporary drop in consumption was observed after the 1973-1974 oil price increase. Because of the lead time required to respond to higher oil prices, consumption of oil in Illinois continued to increase during 1976-1978, but was already on the decline when another oil price hike hit world markets in 1980 and 1981. Since 1982, oil consumption in Illinois has averaged about 225 million barrels per year, as compared with the 1978 high of about 335 million barrels.

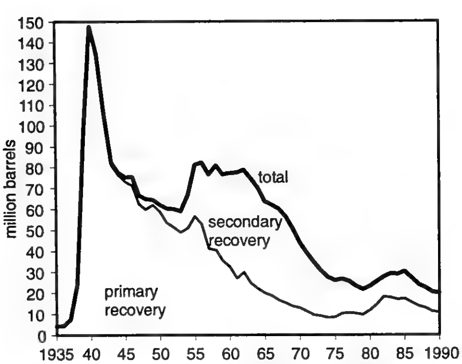

Figure 15 Annual crude oil production in Illinois.

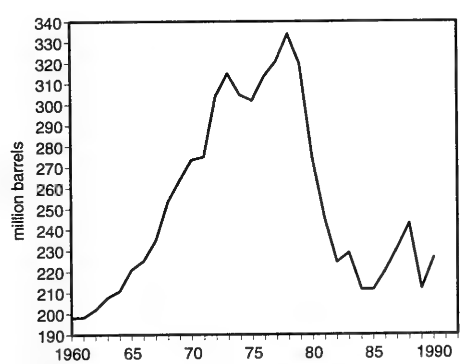

Figure 17 Oil consumption in Illinois.

CO_2 INJECTION FOR IMPROVED OIL RECOVERY

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A promising new trend in Illinois is the injection of CO_2 into some of the more than 600 oil fields within the state. The procedure has two important benefits. First, it reduces CO_2 emissions, which may contribute to global warming. Second, it is also expected to increase oil production from Illinois reservoirs.

Most of the 34,000 oil wells in the state are stripper wells that produce less than 2 barrels of oil per day and are close to their economic limit. In Illinois, more than 900 producing oil wells were abandoned and plugged in 1992 because they were no longer economical to operate. Since 1987, there has been a threefold increase in the plugging of producing oil wells (fig. 18). Also being plugged at an increasing rate are water injection wells, which could be used for injecting CO_2 into oil fields.

PRODUCTION AND SOURCES OF CARBON DIOXIDE IN ILLINOIS

The total CO_2 emitted in the state has been reduced from 280 million tons in 1970 to approximately 228 million tons in 1990. (All the reported CO_2 emission data in this report are from Office of Research and Planning, Illinois Department of Energy and Natural Resources, and should be considered as preliminary estimates.) The two most likely sources of CO_2 for subsurface injection are utilities and industries. Utilities emit approximately

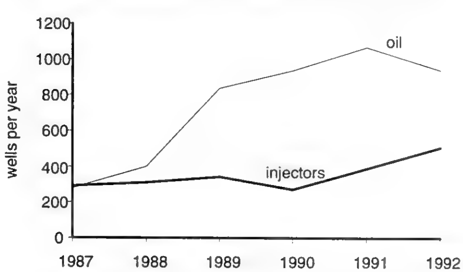

Figure 18 Oil production and water injection wells plugged in Illinois. (Data courtesy of Illinois Department of Mines and Minerals Oil and Gas Division.)

63.3 million tons of CO_2 during the generation of electricity; however, the CO_2 must be purified by separating it from the rest of the power plant stack gas. Industrial plants emit another 51.2 million tons of CO_2.

The oil industry is already experimenting with CO_2, formed as a byproduct of the manufacture of ethanol, to enhance oil production in the Illinois Basin. A major ethanol producer is located in Decatur, Illinois, which is within a 100 mile radius of many of the state's oil fields. Currently, the CO_2 from ethanol is being transported to the oil fields by refrigerated tank truck, a mode of transport that is not cost effective for injection of large volumes of gas. An alternative is to construct gas pipelines, although this method may not be economical either, given today's low oil prices.

APPLICATION OF CO_2 INJECTION INTO OIL FIELDS

Three significant applications of CO_2 in improved oil recovery in Illinois are miscible and immiscible floods and "huff and puff" (cyclic flood process). CO_2 injection is relatively new in Illinois, so not much data is available. In other parts of the country, huff and puff projects have been economical at current oil prices (Stewart-Gordon 1990). CO_2 miscible-immiscible flooding, usually considered uneconomical at less than $30 per barrel of oil (Petzet 1983), could become important if oil prices rise significantly.

Miscible and Immiscible Flood

Waterflooding has been the most widely used method of increasing oil recovery from older oil fields in Illinois. Because an oil field is rarely a single, continuous reservoir (reservoir heterogeneity), millions of barrels of oil in the reservoir are bypassed by the injected water. Also, the injected water cannot mobilize an equal or greater volume of oil, which is trapped in the pore space by viscous and capillary forces. CO_2 flooding, in addition to recovering some bypassed oil, can also recover some immobile oil trapped in the pore space.

Approximately 4.4 billion barrels of residual oil may still be recoverable in Illinois oil fields (U.S. Department of Energy 1989). Some of this oil should be recoverable by miscible and immiscible CO_2 flooding. During a miscible flood, the CO_2 is injected into the reservoir at a high enough pressure that the CO_2 and oil dissolve into one another; the capillary force is drastically reduced, and the oil and the CO_2 act as a solvent and flush the oil from the reservoir. In general, oil reservoirs that have depths greater than 2,500 feet and contain oils with an API gravity of 25° or greater are potential targets for CO_2 miscible flooding (Venuto 1989). More than 270 oil fields in Illinois meet this requirement (B.G. Huff, ISGS, personal communication 1993).

CO_2 is preferred over other solvents such as natural gas or nitrogen because CO_2 needs a much lower pressure to become miscible. In a reservoir in which the CO_2 miscible pressure is 1200 psig, the natural gas pressure required for mixing would be more than 5000 psig (Stalkup 1989). The higher pressure of the natural gas would fracture the reservoir and make miscible flooding impossible. Pure CO_2 must be used, however, because impurities such as nitrogen could raise the required miscible pressure to more than 2000 psig (Stalkup 1989).Thousands of tons of CO_2 are injected into the oil field during a miscible flood. In a large, 100 million barrel oil field, the requirement could be as high as 1 billion tons of CO_2 in a 5 to 10 year period (Stalkup 1989). Much of this injected CO_2 remains in the reservoir after completion of the flood. The actual amount of CO_2 retained depends on whether or not produced CO_2 is recycled back into the reservoir.

A CO_2 immiscible flood should be more efficient than a waterflood, although not as efficient as a miscible flood (Holm 1987). The difference between immiscible and miscible is that in a miscible flood, the CO_2 behaves as a solvent decreasing the capillary force that retains the oil in the reservoir rock. In an immiscible flood, the injected CO_2 causes swelling of the oil and reduces its viscosity, both of which make the oil flow more easily to the surface (Holm 1987). The cost and risk of this type of flooding is intermediate between miscible flooding and huff and puff. Immiscible CO_2 flooding is technically feasible in many Illinois Basin oil fields; however, the economics are uncertain.

Huff and Puff

Huff and puff may be the final attempt to get more oil from a well before it is abandoned (Stewart-Gordon 1990). The technique has been economical at the 1990 oil prices because each ton of carbon dioxide can add between 15 to 20 barrels of incremental oil (Miller 1990).

In huff and puff (cyclic CO_2 injection), the CO_2 is injected into a well at immiscible conditions; 2 to 4 weeks after the injection, the same well is put on production. The average estimated radius of CO_2 migration has been 73 feet for the most productive wells, and 144 feet for the poorer wells (Thomas and Monger 1990).

The amount of CO_2 injection depends upon field conditions. The minimum amount is usually 20 tons, and many huff and puff projects have used 120 to 4,000 tons of CO_2. Some major injection projects have recovered as much as 9,000 barrels of incremental oil per well (Stewart-Gordon 1990). Results of more than 200 applications of huff and puff (Haskin and Alston 1989, Miller 1990) show an average incremental oil recovery of 400 barrels for a 20 ton CO_2 project. A 120 ton CO_2 huff and puff will recover 1,000 to almost 4,000 barrels of incremental oil. Approximately 40% to 50% of the injected CO_2 remains in the oil reservoir after a huff and puff program. Only 10% of these projects did not succeed in increasing the oil recovery, and most of these failures were due to mechanical problems during the injection process (Thomas and Monger 1990).

CONCLUSIONS

Of the three different types of CO_2 injection projects, miscible flooding can be the most efficient for recovering additional hydrocarbons. Because it is also the most expensive and difficult to accomplish, it is best suited for large projects. Immiscible flooding is less costly because the injection pressures do not have to be as high. It is necessary to completely understand reservoir continuity, however, to have a successful flood using this method. Huff and puff is the least efficient in recovering additional reserves because only a small portion of the reservoir is contacted by CO_2. It is suitable for small projects because of its low cost and low risk.

In 1992, 941 oil wells were plugged. Many could be candidates for the huff and puff technique, but technical data are insufficient to indicate how many wells would react favorably to huff and puff. But assuming that huff and puff could be successfully applied to 800 plugged wells, and further assuming an average 20 ton CO_2 injection and a 50% recovery of the CO_2 per well, there could be an 8,000 ton reduction of CO_2 emissions per year and an annual increase in oil production of 320,000 barrels. In a more optimistic case of 120 tons of CO_2 injection and recovery of 2,000 barrels of oil per well, the CO_2 emissions would be decreased by 48,000 tons and oil production increased by 1.6 million barrels.

The CO_2 injection technology is a promising new trend that could reduce CO_2 emissions and increase oil recovery within Illinois. The mechanism for supplying CO_2 from the manufacture of ethanol is already in place and could be the most viable near-term source for this gas.

TRENDS IN NATURAL GAS PRODUCTION AND CONSUMPTION

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Illinois State Geological Survey

Natural gas is the cleanest-burning fossil fuel. But Illinois has only insignificant known reserves. Natural gas may be found at depths greater than the depth at which natural gas is currently produced in Illinois. The geology at 5,000 feet and deeper below land surface has not been explored well enough for a sound assessment of the potential for reserves of natural gas.

Lacking reserves at shallow depths, Illinois has produced little natural gas – an average of less than 1.5 billion cubic feet per year in the 1980s. During the same period, consumption of natural gas in Illinois, although declining slightly, averaged about 1.0 trillion cubic feet per year. The decade of the 1960s was the last to show an increase in gas consumption, which grew from about 0.5 to 1.2 trillion cubic feet, a rate of more than 8% per year (fig. 19). Since the 1971 peak, consumption has gradually declined as a result of energy-saving measures by consumers in response to price increases.

End uses of natural gas have also changed in the past quarter century (fig. 19). Consumption reached its peak in the electrical sector in 1970 and in the industrial sector in 1971, partly as a result of low, regulated prices. Price regulation was introduced in 1954 as a result of a Supreme Court verdict in the case of Phillips Petroleum

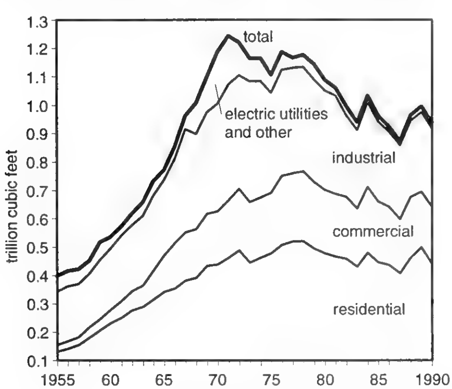

Figure 19 Consumption of natural gas in Illinois.

versus Wisconsin. The court interpreted the 1938 Natural Gas Act (NGA) to require regulation of wellhead prices for interstate markets, so the producer would be protected. By 1970, however, regulated prices began to lag behind market prices. Most of Illinois' supply of natural gas was purchased in the interstate market. Thus, lower prices were an incentive to use gas in industrial production as well as in electricity generation.

In 1978, the Natural Gas Policy Act (NGPA) was enacted in response to fuel shortages in the interstate market. The NGPA divided gas into categories according to the date of gas discovery and depth of gas deposits. At the same time, the Fuel Use Act of 1978 (FUA) restricted the use of natural gas in electricity generation. Gas shortages and concerns about supply reliability in the early 1970s had already reduced its use in electricity generation. Price increases of 1973-1974, supported later by the production incentives of NGPA and the demand restrictions of the FUA, further contributed to declining gas consumption. Another international oil price increase in 1979-1980 added an incentive to reduce consumption. Continuing the trend, industrial consumers contributed most to the reduction in consumption in the 1980s, although savings were also achieved in the commercial and residential sectors.

The NGPA also provided for gradual decontrol, beginning in 1985, of wellhead gas prices. The Federal Energy Regulatory Commission (FERC) changed the gas market radically in the latter half of the 1980s. FERC orders 486 and 500 made it possible for interstate pipelines to act as "open access transporters" of gas purchased directly from the producer. Order 451 permitted the price of the oldest (lowest priced) gas to increase, and order 490 permitted abandonment of old purchase contracts (signed under NGA) when they expired. So in the 1980s, the gas market became a free market, which contributed to greater availability and lower prices. In 1989, prices were entirely freed from controls under the Natural Gas Wellhead Decontrol Act of 1989. The excess of gas supply (bubble) over demand created by the increasing supply and falling demand was nearly gone by the end of the 1980s and early 1990s. Conditions favored greater price stability and even some increases.

Demand in the 1990s is expected to be influenced by two opposing factors. Energy conservation in all three major consuming sectors – residential, industrial, and commercial – will continue to exert a downward pressure on demand. Conversely, economic growth rates may fluctuate. Demand may not only grow slowly in the 1990s, but also show periodic ups and downs.

UNDERGROUND STORAGE OF NATURAL GAS

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Natural gas is stored in underground reservoirs so that adequate supplies of fuel are available when consumption is greater than wellhead production. During summer months, demand is lower and the stockpile is built up. During the winter when consumption is high, gas is withdrawn from the stockpile to meet consumer demand.

Large quantities of natural gas are stored in depleted petroleum reservoirs and in aquifers that do not supply water suitable for drinking. In the United States, most of he gas is stored in depleted gas reservoirs (Bond 1975). In Illinois, however, more than one-half of the storage fields, representing more than 90% of the storage by volume, are nonpotable (saline) aquifers (Buschbach and Bond 1974).

SOURCE OF DATA

The Illinois State Geological Survey (ISGS) began to gather and publish data on underground storage of natural gas in Illinois in 1961 (Bell 1961). The annual reports on the petroleum industry in Illinois (ISGS Illinois Petroleum series) included natural gas storage data up to 1981. For the next 5 years, the data were published without revision. In 1986, publication of the database ceased. An attempt was made in 1986 to obtain updated statistics, but only a few companies responded (B.G. Huff, ISGS, personal communication 1993).

The overall quality of the database on underground gas storage fields is inadequate. The initial data published in 1961 (Bell 1961) consisted only of the volumes of cushion gas and working gas capacity for each storage area. Later reports were more detailed and included operational history, number and type of wells, geological data, reservoir data, and yearly withdrawal volumes. Although yearly revisions were made through 1981, the data provided by gas storage field operators were neither consistent in quality nor regularly updated. Some revised data were obtained in 1986, but most data are 10 or more years out-of-date. Currently, the number of underground natural gas storage fields in Illinois is estimated to be 34.

The ISGS has also published several reports on the geology of individual storage fields (Bell 1961, Bond 1975, Buschbach and Bond 1967, 1974).

PAST TRENDS

The first successful attempt to store natural gas underground in Illinois occurred in 1951 at the depleted Waterloo oil field. Most natural gas storage areas were established during the late 1950s to the mid-1970s. Natural gas has been stored in rocks ranging in age from Cambrian to Pennsylvanian (about 600 to 225 million years old). Sandstone is the most common reservoir rock used for gas storage, although limestone and dolomite are used in a few storage fields.

Past trends in the siting of underground natural gas storage facilities are derived by considering the storage site location, type of storage reservoir, time of site development, and geologic age of reservoir rock. A major factor in the siting of storage fields in the past was access to preexisting pipelines that transport gas to major consumers. There is no discernable past connection between the time of site development and either storage type or geologic age of the reservoir rock.

Most natural gas has been stored in rocks of Cambrian and Ordovician age. In the northern half of the state, gas is mostly stored in the Cambrian Mt. Simon and Galesville Sandstones. The Ordovician St. Peter Sandstone is utilized in southwest Illinois. In the southern half of the state, Mississippian strata are the most common storage reservoirs. Gas is stored in Silurian, Devonian, and Pennsylvanian rocks in scattered areas throughout the center of the state.

The regional geology of the state is an important contributing factor in selection of the type of reservoir and field size most suitable for gas storage. Figure 20 depicts a map of Illinois divided into sectors. About one-half of the storage fields are in sector A and one-half in sector B. Natural gas storage fields in sector A occur only in nonpotable aquifers. This area contains few oil fields and oil production is from relatively shallow depths. Natural gas is stored in rocks deeper than either petroleum-producing horizons or freshwater aquifers. The storage fields in sector A are all large (10,000 MMcf potential capacity), except for the Pecatonica field.

Depleted oil and/or gas fields provide most of the storage in sector B. Plenty of depleted fields are available for gas storage because this area contains most of the

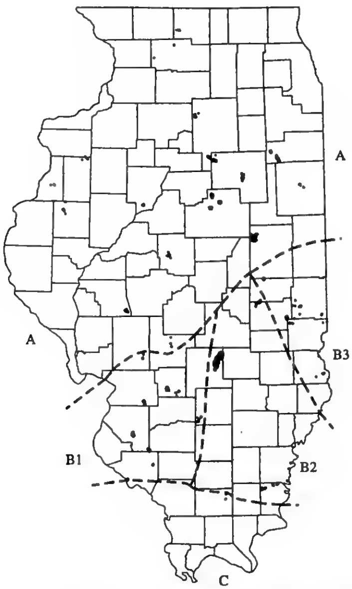

Figure 20 Map showing location of underground natural gas storage sites. Sector boundaries are based on differences in regional geology.

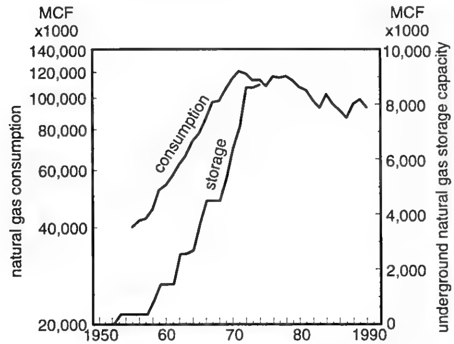

Figure 21 Chart depicting natural gas consumption and underground natural gas storage capacity in Illinois.

petroleum-producing fields in the state. Nonpotable aquifers in Cambrian and Ordovician rocks, the most common reservoirs in sector A, are significantly deeper in this sector, so they are more expensive to develop. Most storage reservoirs in sector B are in rocks younger than Silurian (less than 400 million years old). Also, most of the current storage fields are small. The Louden oil field is the only large natural gas storage field in this sector.

Two economic factors, price and demand, may have had an effect on the apparent suspension of developing natural gas storage fields. Natural gas prices began to increase in the middle 1970s, and demand subsequently began to decrease (S.B. Bhagwat, ISGS, personal communication 1993). The peak in natural gas consumption in Illinois coincides with the apparent halt in storage area development (fig. 21). Decreasing demand coupled with the increasing expense of maintaining cushion gas may have contributed to the halt in storage area development. It is also possible that pipeline companies had developed enough storage areas to handle consumer demand.

During the mid-1980s, consumers began to purchase natural gas directly from producers and use pipeline companies only for transporting gas. Thus, pipeline companies are increasingly becoming service operations. They are under the obligation to deliver adequate quantities of gas when needed but must compete with rival pipelines. So they are likely to be cautious about expanding and developing storage facilities. Also, storage facilities may possibly become independent businesses in the future.

ENVIRONMENTAL IMPLICATIONS

Construction and operation of underground natural gas storage fields in the United States are regulated by the Federal Power Commission (Code of Federal Regulations 1973). The Illinois Commerce Commission also regulates facilities in Illinois. In addition, permits to drill exploration and injection wells must be obtained from the Illinois Department of Mines and Minerals. A storage company may also have to give the Illinois Environmental Protection Agency and the Illinois Department of Mines and Minerals an environmental impact statement on potable aquifers on the proposed site.

State regulations do not permit the development of storage facilities in potable aquifers, although probably all storage sites occur underneath aquifers that yield water for drinking, irrigating, and related purposes. Pollution of these aquifers by gas leaking from the underlying storage can be a problem (Coleman et al. 1977). In the Manlove storage field in west-central Champaign County, natural gas was stored initially in St. Peter Sandstone. Soon after injection, gas was discovered to be migrating from the St. Peter up into overlying, glacial sand and gravel aquifers. Tests showed that the deeper Mt. Simon Sandstone had an impermeable cap that would seal in gas. It was subsequently used as the storage reservoir.

Aquifer pollution by leaking natural gas does not always make the water toxic to humans. But when gas displaces water in an aquifer, it may mean that the aquifer is no longer useful as a water source (Bays 1964). Because the gas is not under pressure, the concentration remains low in most cases. But a major leak could result in an explosion, causing damage to structures and injuries to the occupants. If gas is leaking from an underground storage facility, it may have to be abandoned.

When a depleted petroleum field is developed into a natural gas storage field, the impact on the environment is likely to be minimal. Fewer wells have to be drilled and access roads to wellheads are already available. By contrast, using nonpotable aquifers for gas storage involves greater start-up costs: more exploratory wells have to be drilled and access roads have to be built to each wellhead. Using depleted petroleum fields also has some drawbacks. Abandoned oil wells that have not been adequately plugged can leak natural gas or pollute potable groundwater. Conflicts can arise between producers extracting petroleum from one part of a field and companies storing natural gas in another part.

FUTURE TRENDS

Nonpotable aquifers in Cambrian and Ordovician are the most suitable for underground storage of natural gas because they have the largest storage capacities. Future exploration for such sites will continue in sector A (fig. 20). Large gas storage facilities are also likely to be developed in sector B3 within the La Salle Anticlinorium and near the edges of sector B2, where several large anticlinal petroleum fields occur. As large adequate structures become difficult to find, exploration for sites in Cambrian and Ordovician rocks may move to sectors B1 and B3, where these rocks are deeper but have been used for gas storage in a few fields in the past. Cambrian and Ordovician rocks in sectors B2 and C are significantly deeper than in other parts of the state, so they are not likely to be targets for gas storage sites.

The ongoing gradual depletion of petroleum reservoirs will provide sites that have potential for gas storage. Depleted petroleum reservoirs have the additional advantage of being "tested by nature." Most of these facilities will be in sector B.

Smaller gas storage facilities may become more common in the future as the number of potentially large storage sites decreases. Many small petroleum reservoirs occur in sector B, which is well served by gas pipelines. In fact, the gas pipeline system in the state is so extensive that there are few geographic restrictions to storage sites. In the deeper parts of the Illinois Basin (sectors B and C), storage sites may be developed in nonpotable aquifers beneath depleted petroleum fields or beneath preexisting gas storage facilities. Sector C, the most structurally complex area in the state, will be the most difficult to explore for suitable gas storage sites.

STONE, SAND AND GRAVEL INDUSTRY

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Critical to the infrastructure and economy of Illinois is the stone, sand and gravel industry, also called the aggregates industry. In terms of the dollar value, the production of aggregates currently ranks second only to the production of coal in Illinois. In the past, the oil industry in Illinois has often surpassed the aggregates industry in dollar value because of the high price of oil, especially during 1979-1985 and before the early 1960s.

Roads, bridges, railroads, waterways, airlines, water and electricity supply lines, sewer systems, and telecommunications make up the state's "physical" infrastructure. The development and maintenance of this infrastructure as well as the construction of commercial, industrial, and residential structures depends greatly on the availability of aggregate resources. In the absence of local sand and gravel and stone resources, Illinois would have to spend another $1 billion or more per year to import aggregates from other states. The price of aggregates, low unit-value products, is sensitive to the cost of transportation, which can triple the price of a shipment to a customer 50 miles away from the source.

Since 1950, the production of aggregates has almost tripled from about 34 million to 100 million tons in 1990. The trend has been toward greater use of stone than of

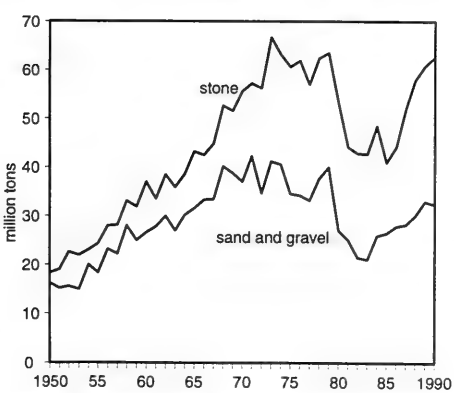

Figure 22 Illinois stone , sand and gravel production.

sand and gravel (fig. 22). Stone production grew more rapidly from 1950 to 1973 than did sand and gravel production, primarily because the size and shape of stone make it more suitable than sand and gravel for the production of concrete. (Stone can be crushed easily to any size, and crushing creates sharp, angular particles in contrast to the rounded particles of sand and gravel.)

The 1973-1983 period was marked by a decline in stone as well as in sand and gravel production. Economic recessions experienced by the United States in 1975 and 1982 were triggered by bouts of inflation in 1973-1974 and 1979-1981. The resulting decline in construction activities was interrupted only by 2 years of relative growth in 1978-1979. Since 1983, the growth in sand and gravel and stone production has not lost its momentum. Once again, stone production is outperforming sand and gravel production in Illinois.

An important growth factor for the stone industry is the use of the carbonate materials, limestone and dolomite, for pollution control. Limestone can be directly used for this purpose or first converted to lime. Four coal-burning utilities in Illinois currently use limestone or sodium carbonate to remove SO_2 from flue gases. Their limestone consumption is estimated to be about 300,000 tons per year. (Historical data are not available.) Lime also has other industrial and agricultural uses. The demand for lime and limestone is small in comparison with the total demand for crushed stone.

Quicklime and hydrated lime, other derivative stone products, are used primarily in the steel industry. Figure 23 shows Illinois' consumption for the past 35 years. It reached a peak of about 1.2 million tons in 1974, but has historically fluctuated between 0.6 and 1.2 million tons. A major decline in consumption to a 25-year low point occurred between 1978 and 1982 as a result of the declining usage in the steel industry and the 1982 general recession. From 1982-1990, consumption picked up again, increasing by about one-third or at an annual rate of about 4%. Most increases since 1987 have occurred because of increased use by chemical firms and municipal water-treatment plants.

Intensely competitive markets, in which real dollar prices per ton of the commodity did not change appreciably over the past two decades have forced sand and gravel and stone producers to take cost-cutting measures. Economies of scale have improved productivity. Production from large mines as a percentage of total production has increased significantly since the early

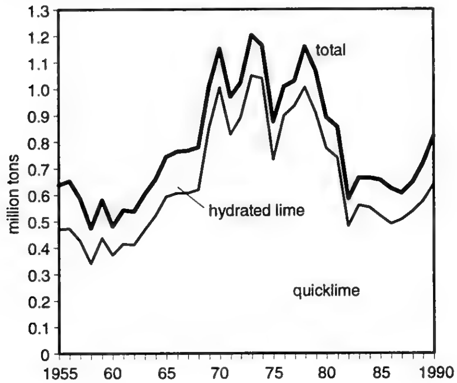

Figure 23 Illinois quicklime and hydrated lime consumption

1980s. In 1982, about 32% of Illinois' sand and gravel came from operations producing more than 800,000 tons per year; the largest pit produced a little less than 900,000 tons per year. In 1990, nine pits in Illinois were each producing more than 1 million tons, and they accounted for about 49% of the state's production. Between 1982 and 1990, as smaller operations closed or consolidated, the number of sand and gravel pits declined in Illinois from 169 to 143.

A similar trend toward larger operations was also observed in the stone industry, although the number of operations actually increased from 169 in 1983 to 178 in 1989. In 1983, about 36% of the state's stone was produced in quarries with a capacity to deliver more than 900,000 tons per year. Their share increased to 58% in 1989.

Urban expansion, engulfing pits and quarries, has contributed to the trend toward fewer, but larger production units. As demand continues to rise, the production of smaller pits overrun by urban sprawl must be taken over by other pits. The result is expansion of the remaining pits. One benefit is that the closed pits and quarries will, in many cases, be made into ponds and lakes that are managed and used in environmentally acceptable ways. Some sites may play an important role in the creation of wetland habitats.

Many of the most important known deposits of aggregate materials are in northeastern Illinois, which is undergoing rapid urban development. Urban and environmental planning must be combined with comprehensive resource exploration to ensure wise and sustained utilization of Illinois' aggregate resources.

ISGS scientists doing field work indicate that a significant number of operations may be going unaccounted for because of seasonal or short-term operation and/or a lack of response to data solicitation by the U.S. Bureau of Mines (USBM). Producers' rights to proprietary production information are protected under Public Law 96-479, the National Materials and Minerals Policy Act of 1980. Producers exercise that right and require that production data not be published for geographic areas smaller than the four zones in Illinois, as agreed upon by the producers, the USBM, and the ISGS.

The future prospects of the aggregates industry will be determined by several factors:

1. Total demand will be determined by economic growth in general and growth in the construction industry in particular. Federal and state government priorities for rebuilding of the infrastructure may significantly increase and focus demand.

2. Availability of and access to sand and gravel and stone resources may be increasingly limited in the future as urban expansion renders reserves unminable. Examples of such cases are known in the Chicago area. Operators are being forced to resort to underground mining, where possible, or to relocate to remote sites. The more remote the source, the greater the transportation costs.

3. Quality specifications for aggregates have changed during the past two decades. As a result, markets are less favorable for sand and gravel than for stone. The shift in demand could further strain the stone supply.

OTHER MINERALS PRODUCED IN ILLINOIS

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Illinois State Geological Survey

Industrial sands, clays, fluorspar, tripoli, zinc, lead, silver, copper, peat and some gemstones have historically been produced in Illinois, although in smaller quantities than coal, oil, and construction aggregates. Data on production of these other minerals are mostly proprietary, but the production data on industrial sands and clays are available for publication.

Illinois ranks first among states producing industrial sands in the United States. From the end of World War II to the early 1960s, the state's production of industrial sands averaged about 3 million tons per year (fig. 24). Production rose significantly during the later part of the 1960s, fluctuated greatly in the 1970s, and averaged about 4.5 million tons per year since then. Industrial sands, now produced only in La Salle County, have a wide variety of applications. Unground silica sand is used primarily in manufacturing glass, but also for producing industrial molds, and sand blasting, grinding, and polishing various materials. Railroad traction and filtration are two other uses for unground sand, which is also suitable for propping open the fractures formed when oil reservoir rocks are hydraulically fractured to stimulate oil production. Ground sand is used in chemicals, abrasives, enamels, pottery, porcelain, tile, and as various fillers. High purity silica sands are the basic raw material in many high technology applications, such as computer chips and electronic circuits.

Figure 24 Industrial sand production in Illinois.

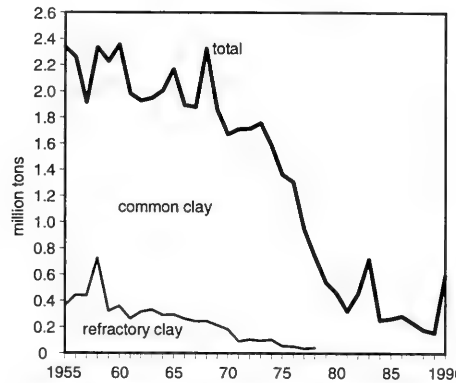

Figure 25 Common clay production in Illinois.

The industrial sands of Illinois are important raw materials mined in an area that is advantageously located near Chicago and served by an excellent network of roads and waterways.

In contrast to the industrial sand industry, Illinois' clay industry has suffered from market competition in the past 25 years. Common and refractory clay production averaged about 2 million tons per year from 1955 to 1965 but declined to about 0.2 million tons by 1989 (fig. 25). Production of refractory clays has all but ceased. The decline is largely due to intense competition from clays and clay products such as bricks produced in Georgia, Alabama, Texas, and North Carolina and shipped at favorable freight rates on trains returning to Illinois after delivering grain to the Gulf Coast. Contributing factors are changes in demand pattern and poor management by small operators.

Illinois has always been a major producer of fluorspar. During the past two decades, Illinois remained the nation's number-one fluorspar producer. Production data are confidential, however, because only one major fluorspar producer has remained in the business. Currently, more than 90% of U.S. fluorspar is produced in Illinois.

RECLAMATION OF ABANDONED MINED LAND

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Extraction of mineral and nonmineral resources from the earth by surface and underground mining has had a significant impact on the natural environment of the affected areas. The impact of the modified land on both the economic and social environments of the area is generally negative.

Unreclaimed mined lands often result in altered land use patterns, erosion, water pollution (acid runoff), siltation, and landslides (Roberts 1979). To avoid these problems and restore the natural, economic, and social environments to the affected lands of Illinois, the State established reclamation practices. Reclamation is the restoration of the land surface previously affected by surface and underground mining to the condition of optimum productive use for the future. Productive use of land includes the establishment of forests, pastures, and crop lands; enhancement of wildlife and aquatic resources; establishment of recreational, residential, and industrial sites; and conservation, development, management, and appropriate use of natural resources for compatible multiple purposes (Surface Mined Land Conservation and Reclamation Act 1971). Federal and state legislatures have passed laws regulating both mining and reclamation procedures.

DATA

The Illinois Department of Mines and Minerals (IDMM) is responsible for collecting data on the reclamation efforts of the mining industry in Illinois. The IDMM publishes an annual report, which includes lists of the acres mined in the state, number of mining permits issued, and number of acres affected by reclamation. Reclamation of land mined and abandoned before laws required reclamation are not in the IDMM annual report. The "pre-law" lands are reclaimed under the auspices of the Abandoned Mined Land Reclamation Council (AMLRC). The AMLRC maintains an inventory of reclaimed and remaining abandoned mine problem sites within the state.

A compilation of the acreage affected by coal mining was first published in 1963, and collection of data for surface mining of minerals other than coal started in 1972 (IDMM 1992). During the late 1970s, the methods of gathering and cataloging data were reorganized, resulting in inaccuracies (generally due to undercalculation) in the acreage affected by surface mining (S.B. Bhagwat, ISGS, personal communication 1993).

PAST TRENDS

In Illinois, the first regulatory bill involving reclamation of surface mines was introduced and defeated in the legislature in 1929. Other attempts to pass similar bills were defeated until the Open Cut Land Reclamation Act, which took effect on January 1, 1962 (Klimstra and Jewell 1974). This act required that spoil ridge tops on all open pit mines be leveled, graded, and revegetated. In 1968, requirements for reclamation were increased by the Surface Mined Land Reclamation Act. The Surface Mined Land Conservation and Reclamation Act (SMLCRA) was passed by the Illinois Legislature in 1971 and subsequently amended periodically. The SMLCRA specifically required filing a conservation and reclamation plan before the start of mining. It also contains reclamation regulations associated with the surface mining of sand and gravel, limestone, silica, and clay/shale. Mine sites where the overburden is less than 10 feet thick, or operations that affect less than 10 acres during the state's fiscal year, are exempt from the act. Operators of such sites do not have to apply for surface mining permits.

The Illinois Abandoned Mined Lands Reclamation Council (AMLRC) was first established in 1975 to reclaim coal mine sites abandoned prior to implementation of federal coal mine reclamation regulations. Initial funding was provided by General Assembly appropriations. In 1977, the federal Surface Mining Control and Reclamation Act (SMCRA) was passed, requiring all states to develop regulatory programs that, at a minimum, met the requirements of the federal regulations. This law, unlike previous Illinois reclamation bills, regulated only coal mines. Section 402 of the act established a fund for use in reclaiming coal mines abandoned prior to enactment of the bill. (Mining companies were charged fees of $0.35 per ton of surface-mined coal, $0.15 per ton of underground-mined coal, and $0.10 per ton of lignite.) To be eligible to receive the federal abandoned mine reclamation grants, states were required to regulate active coal mining.

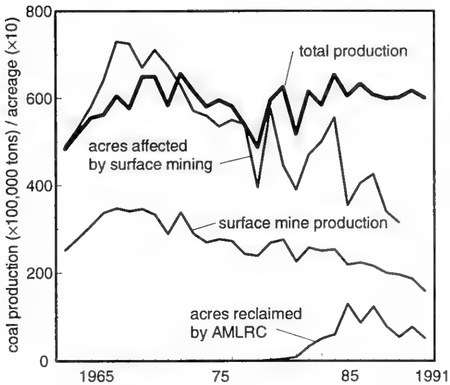

Figure 26 Coal production versus reclamation.

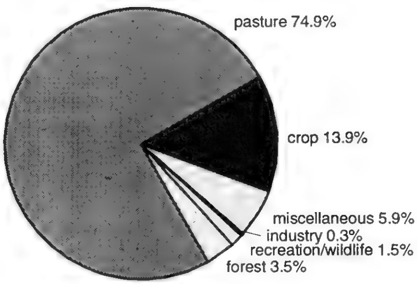

Figure 27 Land use of reclaimed coal surface mines (1972-1985).

In 1980, Illinois passed the Surface Coal Mining Land Conservation and Reclamation Act (SCMLCRA), which enabled the state to enforce the permanent regulatory program under the federal SMCRA. Also in 1980, the State amended the Abandoned Mined Lands and Water Reclamation Act, which established the AMLRC as the agency to administer the federal reclamation funds in Illinois. In 1989, this act was amended to include the reclamation of unreclaimed noncoal sites that contain safety hazards; however, Illinois law restricts the amount of money that can be spent annually on reclamation of noncoal sites.

Reclamation of lands affected by mining generally is classified into three categories:

1. "Pre-law" coal refers to land mined and abandoned prior to passing the 1977 federal reclamation act. This acreage is eligible for reclamation by the AMLRC.

2. "Post-law" coal refers to land mined after the law was passed. Affected acreage has to be reclaimed by the mine operators.

3. Noncoal refers to other surface mine operations, generally involving the extraction of clay/shale, fluorspar, limestone, industrial sand, and gravel.

Most acreage affected by mining in Illinois is from surface coal mining, which since 1963, has affected slightly more than 3,000 to more than 7,000 acres annually (fig. 26). The amount of affected acreage peaked during the late 1960s, then declined at a rate of about 375 acres annually. The decline parallels a gradual decrease in production of coal produced from surface mines together with an increase in production from underground mines (fig. 26). Since the SMLCRA was enacted, reclaimed coal surface mine acreage has been dominated by pasture and crop lands (fig. 27) because these types of reclaimed acreage were the main focus of the regulations. In the late 1970s, the AMLRC began to reclaim lands affected by "pre-law" coal mining (fig. 26). Since the early 1980s, the Council has reclaimed annually about 500 to 1,000 acres, and overall, a total of 8,582 acres of land affected by coal mining (Nutt 1992). Most of the acreage reclaimed by the AMLRC was mined for coal; but recent amendments to the Abandoned Mined Lands and Water Reclamation Act allow the Council to reclaim previously abandoned noncoal mine sites for a period of 5 years, starting in 1989 (St. Aubin 1990). The SMCRA stipulates that these abandoned mine sites, although unrelated to coal mining, may be reclaimed by the Council, if the site is considered to be an extreme danger to the public.

The amount of acreage reclaimed from noncoal surface mining since 1972 peaked in the early 1980s at about 800 acres, although the aforementioned reorganization of the database may have influenced this datum (fig. 28). The acreage amount gradually declined until recently. Most of the reclaimed land has been used either as pasture or for industrial and commercial sites (fig. 29). Very little has been reclaimed as crop land, but there is no crop land reclamation requirement for noncoal mines. Most noncoal mine sites only affected small plots, relative to the size of coal mine lands. Many of these sites are near established towns, and smaller plots are more attractive for industrial and commercial development than for agricultural use.

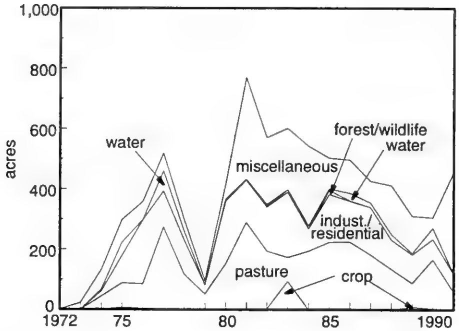

Figure 28 Use of reclaimed acreage from noncoal mines.

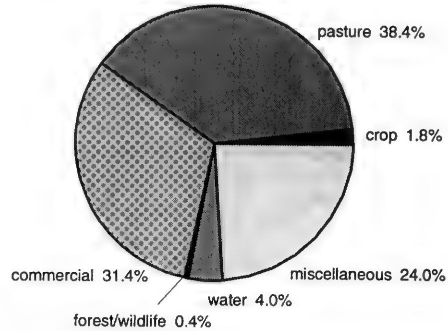

Figure 29 Use of reclaimed acreage from noncoal mines (1972-1991).

ENVIRONMENTAL IMPLICATIONS

The elimination of public health, safety, and environmental problems at abandoned mine sites is the primary focus of the Illinois abandoned mine reclamation program. The ultimate goal is the restoration of the natural environment of an abandoned mine site. Reclamation of abandoned mines offers many benefits (from Croke and others 1979):

1. Protection of public health and safety by eliminating hazards such as open mine shafts, unsafe dams, leaking methane, coal refuse fires, and dangers associated with mine subsidence.

2. Aesthetic improvement of landscapes and development of recreational areas.

3. Decrease in erosion, downstream siltation, and restoration of stream beds.

4. Elimination of sources of acid run-off to surface and groundwater resources.

5. Restoration of vegetative cover for wildlife habitats, erosion control, and agricultural or conservation purposes.

6. Stimulation of the local economy through jobs related to construction, conservation, and recreation as land is restored to useful condition.

FUTURE TRENDS AND IMPACTS

As long as the current mining and reclamation laws continue to be renewed and enforced, the trends of reclamation during the past 10 to 15 years should continue. The amount of acreage reclaimed by the mining industry should parallel the amount of acreage affected by surface coal mining, which is likely to continue decreasing (fig. 26). Noncoal mining operations, which affect significantly smaller amounts of acreage, may increase slightly as demand for raw construction materials increases.

The AMLRC will also continue its reclamation efforts for abandoned mine sites as long as coal mining continues in Illinois and a satisfactory level of funding is derived from the Abandoned Mined Lands reclamation fee assessment on active mining. Coal operators will no longer be required to pay the reclamation fee after the year 2004, when funding for the AMLRC expires. More than 9,000 acres of abandoned mined lands are still considered to be in need of reclamation (Nutt 1992).

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No.
	ILENR/RE-EA-94/05(4)		

4. Title and Subtitle
The Changing Illinois Environment: Critical Trends
Technical Report of the Critical Trends Assessment Project
Volume 4: Earth Resources

5. Report Date June 1994

6.

7. Author(s) Bhagwat, Subhash B., Leetaru, Hannes E., McKay, Donald E., Weibel, Pius C.

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Illinois Department of Energy and Natural Resources
State Geological Survey Division
615 East Peabody Drive
Champaign, IL 61820

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
Illinois Department of Energy and Natural Resources
325 West Adams Street
Springfield, IL 62704-1892

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)
The geologic setting is the foundation of the environment. Ecosystems are influenced by and depend on geologic settings and processes. Geology provides the unique environmental conditions for the existence of ecosystems. Human activities such as agriculture, forestry, mineral extraction and manufacturing depend on geologic settings. These activities can permanently influence ecosystems. Trends in Illinois in land use, extraction and consumption of fossil fuels and industrial minerals and disposal of wastes have been captured and interpreted in the contexts of geology, the environment and the ever changing regulatory conditions. Land use in Illinois is historically dominated by agriculture. However, the fastest growing land use type is urban expansion. Mineral extraction in Illinois has generally declined. Past impacts of the mineral industries on the environment have moderated as a result of new industrial attitudes. Of growing future concern is not only the availability of fuels and minerals but of clean water. Safe waste disposal must go hand-in-hand with reduction of pollution from industry, agriculture and households. Understanding the geologic context is critical.

17. Document Analysis a. Descriptors

Aggregates	Minerals	Petroleum industry
Geology	Natural gas	Sands
Gravel	Natural resources	Underground storage
Land use	Oil recovery	

b. Identifiers/Open-Ended Terms

Abandoned mined lands	Illinois	Oil consumption
Coal consumption	Natural gas consumption	Oil production
Coal production	Natural gas production	Stone, sand and gravel industry
Energy consumption		

c. COSATI Field/Group

18. Availability Statement No restriction on distribution.
Available at IL Depository Libraries or from
National Technical Information Services,
Springfield, VA 22616

19. Security Class (This Report) Unclassified

20. Security Class (This Page) Unclassified

21. No. of Pages 28

22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

Printed by the authority of the State of Illinois.
Printed on recycled and recyclable paper.
3,400/June 1994