ANL/AA-11 (DRAFT)

# NATIONAL COAL UTILIZATION ASSESSMENT

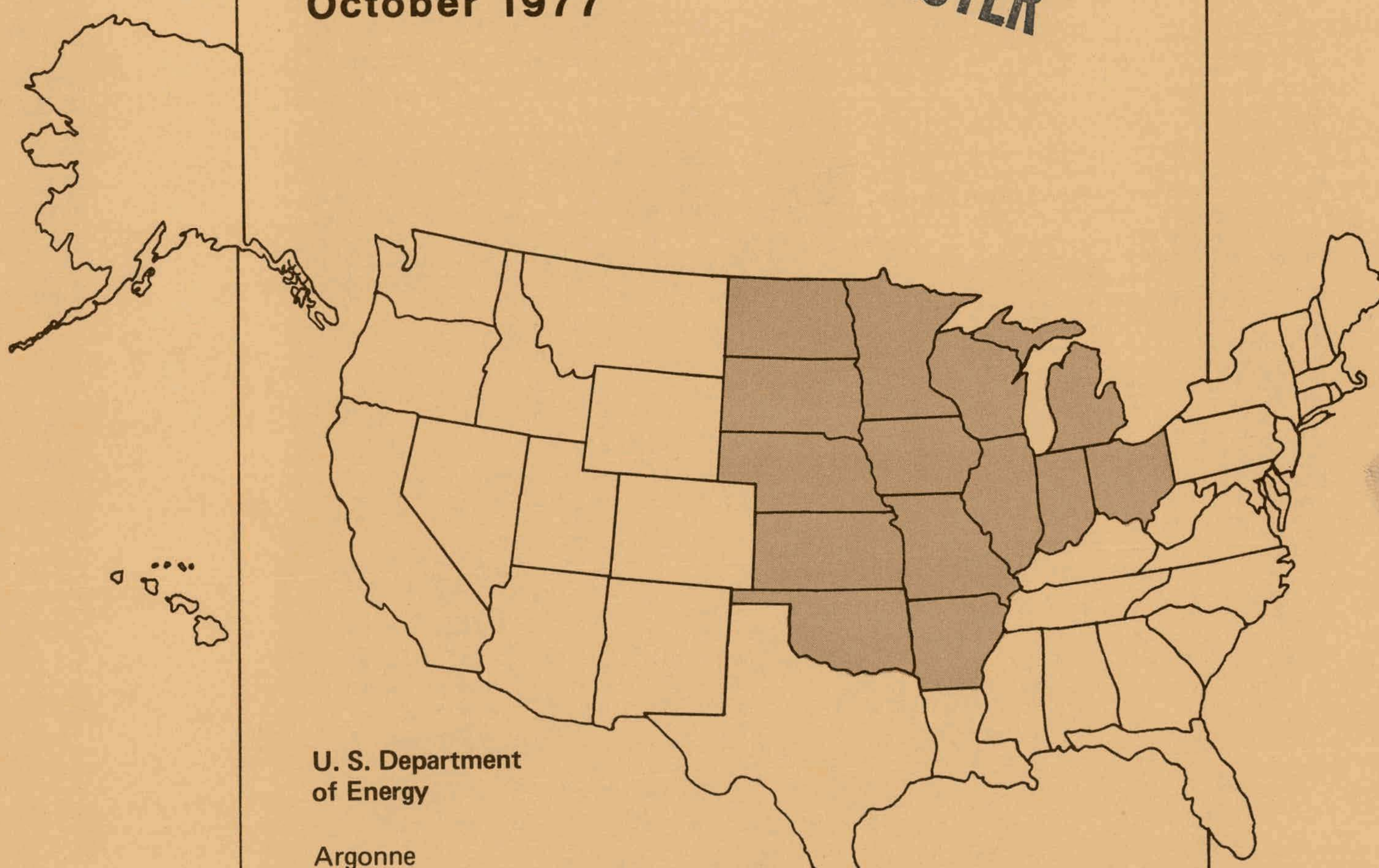
U of C-AUA-USDOE

## An Integrated Assessment of Increased Coal Use in the Midwest: Impacts and Constraints

Volume I

MASTER

**October 1977**



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## An Integrated Assessment of Increased Coal Use in the Midwest: Impacts and Constraints

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# PREFACE

This study was performed as a part of the Argonne National Laboratory Regional Studies Program, which is sponsored by the Department of Energy, Assistant Secretary for Environment, Division of Technology Overview.

The purpose of the Regional Studies Program is to assess the impacts and consequences associated with alternative energy options on a regional basis, and to identify and analyze alternative mitigation and solution strategies for increasing the acceptability of these options. Program leadership is provided by Argonne's Energy and Environmental Systems (EES) Division. The assessments are conducted primarily by staff from three ANL Divisions: EES, Environmental Impact Studies (EIS), and Biological and Medical Research (BIM) Other research institutions and consultants also contribute.

The National Coal Utilization Assessment (NCUA) is being conducted as a part of the Regional Studies Program. This particular study is focusing on impacts and constraints on increased coal utilization. In addition, a major focal point for the study is the identification and analysis of alternative solution strategies applicable to these constraints and problems. The contributors and their responsibilities for conducting this study are designated on the following page. The study results are presented in two volumes. Volume I contains the Executive Summary and Major Findings. Volume II contains detailed information on Energy Supply and Demand, Siting, and Impacts.

L. John Hoover, Director
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# 1.0 EXECUTIVE SUMMARY

The objectives of the National Coal Utilization Assessment (NCUA) are to: (1) provide the Department of Energy (DOE) with the impact and impact-management information needed to ensure that environmental and social concerns receive appropriate emphasis in DOE coal R&D programs; (2) identify and analyze strategies to alleviate potential problems or constraints associated with increased coal use; and (3) work closely with state and regional agencies and DOE to present the NCUA findings in a useful manner.

This report documents Argonne's examination of:

- Technology characteristics;
- Energy supply and demand trends;
- Siting constraints on coal-related facilities;
- Impacts of increased coal use on water availability, land use, and coal reserves;
- Impacts on air and water quality and ecosystem;
- Effects of trace-element emissions from coal combustion/conversion;
- Social and economic impacts; and
- Health risks.

The assessment, which covered 14 states*, placed significant emphasis on identifying the coal-related problems and risks that are of particular concern to state and regional agencies and commissions. This was accomplished by meetings between Regional Studies Program staff and personnel from governmental groups from all 14 states. Problems found to be of general concern included increased air pollution, the effects of Prevention of Significant Deterioration (PSD) and other air-quality regulations, potential water-use conflicts, and acid mine drainage. Other issues included the price and availability of alternative energy sources, transportation constraints on coal use, and lack of information on new coal technologies. The table on the following page details the overall concerns of regional agencies.

The energy supply/demand and siting analyses, described in detail in Sec. 3, formed the bases for the impact assessments. Siting patterns (see Sec. 5) which specified megawatts of power generation capacity per county were developed

*Arkansas, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, and Wisconsin.

based on: (1) the four scenarios described in Sec. 2; (2) consideration of environmental restrictions, population densities, seismic risk, and public lands; and (3) characteristics of the technologies involved. These siting patterns were then used in the impact assessments present in Secs. 7, 8, and 9.

The major findings of the Midwest assessment are presented on the following pages. Based on the impacts and constraints identified, the program staff is now analyzing solution strategies to mitigate adverse effects. Particular attention is being given to resolving conflicts of coal use with air quality and water availability and to managing socioeconomic impacts.

Air Quality

The major air-quality constraints on coal use are related to the short-term National Ambient Air Quality Standards (NAAQS), high existing concentrations of pollutants, PSD standards, and exposure to sulfates.

In general, the increments of pollutant concentrations for coal-utilization facilities alone are significantly less than the NAAQS. An exception is the 24-hour standard for $SO_2$, which will limit electrical-generation capacity at a single site to about 3000 MW if existing New Source Performance Standards (NSPS) are assumed. If it is assumed that the 24-hour standard for $SO_2$ will be a limiting factor in counties with more than 3000 MW of coal-fired capacity, then 24.6% (36,600 MW) of the region's coal-fired capacity will be affected in 2000.

Central power stations and coal-conversion plants are constrained in siting options because of existing or projected emissions from other sources, particularly if those emissions prevent attainment of the NAAQS. If conflicts occur in areas of high emission density, or where ambient standards are now violated, then 47% (70,000 MW) of regional coal-fired capacity will be affected by 2000.

Implementation of the mandatory Prevention of Significant Deterioration (PSD) areas identified in the 1977 amendments to the Clean Air Act should not be a significant constraint on coal utilization. The key factor in the magnitude of future constraints imposed by PSD regulations is how and where additional nonmandatory Class I areas will be designated. At the extreme, if the Class I areas designated by earlier versions of the Clean Air Act are implemented, 31%, or 45,700 MW, of regional coal-fired capacity will be affected.

A significant increase in exposure to sulfates in the central and eastern United States, where levels are already high, is expected from increased Midwestern coal use if NSPS sulfur emission rates are assumed. The magnitude of these impacts appears to depend more on total regional emissions than on the geographical distribution of emission sources.

The primary effects of increased levels of coal development are exacerbations of siting constraints related to PSD areas and increased population exposure to sulfates. In general, siting constraints from existing air-quality problems are more prevalent in the industrialized eastern part of the region; the mandatory Class I PSD areas and related constraints are more numerous in the western states.

Water Availability

Although cumulative water supplies in the 14-state study region are adequate to satisfy foreseeable energy requirements, significant water shortages that could constrain energy siting patterns or development of competing water uses are likely in localized areas. In 2020, 1.4% (9300 MW) of the region's total electrical generating capacity is sited in areas in Nebraska and Kansas where water problems could be severe, and measures such as reallocation of water supplies or use of dry cooling may be necessary. In addition, 14.2% (93,000 MW) of the total regional capacity is sited in areas that may require development of reservoirs and groundwater, and other measures to increase water supply. These ares are scattered throughout the region, being found in all the states studied except North and South Dakota, and Arkansas.

The differences in water consumption for alternative coal-development options are relatively minor, because the largest fraction (90%) of water use in power generation is for cooling and thus is largely independent of substitutions between nuclear and fossil fuels. Integration of regional energy and water resources planning will become unavoidable as energy processes account for an increasing fraction of total regional water demand; water for energy use grows from 2% of all consumptive uses in 1975 to 18% in 2020.

Water Quality

Water-quality impacts are primarily restricted to areas with insufficient water resources. Coal mining will continue to have a significant effect on water quality in smaller streams draining the major coal regions unless strict control practices are maintained. Coal-conversion plants may cause localized water-quality problems; however, the effluent characteristics of these plants are not well-known. Other uncertainties result from questions of the degree of treatment to be applied to air and water pollutants, and indirect effects associated with urban development in areas of intensive coal-related activity. The level of water pollution will be proportional to the degree of coal development; major water-quality impacts appear to be associated with coal conversion plants and acid and alkaline mine drainage.

The greatest relative effects of coal development appear to be in the Missouri River Basin, where sufficient dilution water may not be available to assimilate mine drainage and waste water from conversion facilities. Water-quality standards for iron, manganese, ammonia, sulfates, and total dissolved solids (salinity) will probably be exceeded more frequently than they are now and in more locations in this basin. High salinity is already a significant problem in the region. The Ohio River Basin will have increased problems with acid mine drainage if strict adherence to federal guidelines is not maintained; deep coal mining is anticipated to increase by 350% in this basin by 2020.

Social and Economic Impacts

A significant amount of the coal development anticipated between 1975 and 2020 occurs in counties susceptible to severe local social and economic impacts, as shown below:

| | Additions in High Impact Areas | | |
|---|---|---|---|
| Type of Development | 1975-1985 | 1985-2000 | 2000-2020 |
| High-Btu Gasification | 100% | 86% | 89% |
| Low-Btu Gasification | ---- | 100% | 67% |
| Liquefaction | ---- | 100% | 83% |
| Electrical Generation | 38% | 31% | 45% |

The timing, magnitude, and nature of local socioeconomic impacts depend upon the characteristics of both the host community and the coal technology involved. Typically these impacts will entail inadequate public services due to insufficient government revenues; and disruption of social patterns caused by rapid changes in the size and demographic makeup of the local population. The impacts are determined by the assimilative capacity of the locality as well as by the relative employment and capital requirements of the technology. The local area's economic and demographic characteristics govern its assimilative capacity; examples of these traits include:

- Size and age/sex composition of the population,
- Population density in the impact area and adjacent areas within commuting distance,
- Proportion of secondary (retail, commercial, service) employment to basic (coal-related) employment in the community, and
- Size and location of regional trade centers.

Socioeconomic impacts are primarily local but in some areas they are likely to be severe because of both economic and demographic conditions and the potential for coal development. These areas include major portions of North Dakota (in the Fort Union Coal Basin) and limited areas in southern Illinois, Indiana, and Ohio. In general, these are rural counties with abundant coal reserves and small populations within reasonable commuting distance. Increased coal development will increase the number of counties with serious socioeconomic impacts. Coal liquefaction has the potential to cause the greatest impacts, followed by high-Btu gasification, electrical generation, low-Btu gasification, and mining.

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## 2.0 MAJOR FINDINGS

As a part of the National Coal Utilization Assessment (NCUA), two types of studies are being undertaken -- (1) impacts and constraints, and (2) the solutions to these problems. This section delineates the principal constraints and causal factors identified in conducting this study. This information is intended to be the basis for detecting practical solution studies that need to be undertaken in the region in the future. The following studies are presently under consideration:

1. <u>Resolution of Conflict between Air Quality and Coal Use</u>

   This study would consider both siting and technology options. The technology options include emerging DOE technologies for coal utilization and conversion (i.e., low-Btu gasification), add-on emission controls, variations in stack height, intermittent or supplementary control systems, and smaller unit facilities. Evaluation of siting alternatives for resolving air-quality conflicts will consider tradeoffs from increased siting in areas with: low-population areas, less sensitive ecosystems, preferable climate (e.g., reduced inversion frequency); and greater distances from PSD areas.

2. <u>Resolution of Conflict between Water Resources and Coal Development</u>

   Resolution of water shortages for future energy development in specific areas need to be investigated by using one or a combination of the following options: (a) regulation of stream flow by reservoirs: (b) development of groundwater resources; (c) reuse of waste water from municipal, industrial, or agricultural sources; (d) purchase of water rights from competing users; (3) use of less intensive water-use technologies, e.g., dry cooling; (f) interbasin transfer; (g) alternative siting; and (h) use of advanced, more efficient technology.

3. <u>Management of Socioeconomic Impacts</u>

   Local socioeconomic impacts from coal utilization result from changes in employment, population, demographic characteristics of population, and pressures for public and private services. In this analysis the following options for resolving socioeconomic coal conflicts will be evaluated:

- Rate of development;
- Transport of coal vs. transport of conversion or combustion products; and
- Size of the facility.

In addition, financial management options for mitigating short-term growth problems will be evaluated. Options, including (a) industry assumption (internalization) of social costs; (b) prepayment of taxes by industry; (c) state bond banks; and (d) federal impact assistance, will be evaluated for their ability to enhance or mitigate the short-term beneficial and adverse socioeconomic impacts of coal development.

Also, an analysis will be made of the management options for moderating and directing changes in local employment and population after construction of facilities. The analysis includes, for example, company towns, industrial diversification, and regional development plans.

We also hope that new issues for impact analysis can be identified as in a part of this assessment or by user interaction. Specific topics that need future emphasis include transportation of coal on the Great Lakes and the impacts and consequences of solid-waste disposal.

As a part of the NCUA, significant emphasis was placed on interactions with state and regional agencies and groups to disclose environmental concerns they perceive as being associated with increased coal use. Section 2.2 summarizes the results of this interaction. The information acquired was used to guide not only the initial direction of the NCUA but also selection of future studies.

Sections 2.3 through 2.13 contain the principal findings of this assessment in regard to energy supply and demand patterns, siting patterns and problems, and impact analysis. Energy Supply and Demand (Sec. 2.3) identifies the potential pattern for energy utilization on a state basis and indicates the role of coal in each of the states in the region. The siting analysis summarized in Sec. 2.4 presents the resulting siting patterns and problems. For this analysis, the following criteria were used to identify potential siting patterns:

- Generating capacity requirements;
- Load center distribution;
- Water availability;
- Air quality;
- Public lands;

- Population density; and
- Seismic risk.

The subsequent subsections of Sec. 2 present the major findings in regard to potential impacts and constraints. Information is presented on:

- Water availability/competition with other users,
- Coal resources availability; production and depletion of reserves of coal;
- Land use;
- Air-quality levels for regulated pollutants; regulatory constraints
- and long-range transport of sulfates;
- Impacts on water quality of mining, combustion, and conversion;
- Releases of trace elements and the potential impacts on ecosystems and health;
- Ecosystem impacts including aquatic and terrestrial effects and effects of gaseous pollutants on agricultural productivity;
- Social and economic effects; and
- Health effects, including public and occupational impacts of mining, transport, combustion, and conversion.

The major findings in each of the impact areas are discussed in a brief, capsulized overview of significant potential constraints to coal use. This is followed by (1) a delineation of the principal differences between the various coal development options (scenarios analyzed), (2) information on the contribution of the various elements of the coal fuel cycle to the impact category, and (3) an overview of the implications within the region.

## 2.1 PURPOSE OF THE NCUA

The purposes of the NCUA are:

- To provide DOE with the necessary information on impacts and management so that environmental and social concerns receive the necessary emphasis in structure and priority in the DOE Coal RD&D (Research, Development and Demonstration) programs.
- To identify and analyze mitigation strategies to deal with potential problems or constraints to clarify the available options on coal use and their resultant effects.
- To work closely with state and regional agencies and with the RD&D and planning programs within DOE to present the data and options in a manner directly applicable to the decisions that will be made.

Possible strategies to be considered include: the present RD&D and new research, siting patterns, interagency coordinations, planning guidelines, regulatory programs, monitoring options, and financial/growth management options. These strategies need to be established early to avoid delays in the siting of coal facilities because of unanticipated problems and constraints.

Alternative ranges of coal supply and use for 1975-2020 have been analyzed. This period is divided into three terms:

- near-term (1975 to 1985),
- mid-term (1985 to 2000), and
- far-term (2000 to 2020).

The range will be established by using scenarios based on the following cases:

- Case 1 -- Simple extrapolation of recent trends (base case).
- Case 2 -- Expanded use of coal-derived electric energy in the mid and far terms.
- Case 3 -- Expanded use of coal-derived oil and gas (synfuels) for the mid and far terms.
- Case 4 -- Combined high-coal electric and high synfuels.

Following is a general description of each scenario. Economic growth and demographic patterns are assumed to take on "best-estimate" values for Recent Trends and all other scenarios.

Recent Trends

The concept of this scenario is straightforward. It represents an estimate of future patterns of coal utilization based on recent trends. It is "surprise-free" in the sense that no major changes in governmental regulatory policy or social institutions are assumed.

This scenario is the benchmark against which all other coal scenarios in this study can be compared. In general, the base scenario is predicated on many of the national and regional assumptions used for the FEA reference case. An effort was also made to ensure methodological consistency with the current scenario work being done for ERDA.

High Coal Electric

The principal difference between this case and the Recent Trends Scenario is in the increased use of coal for electricity generation (i.e., substitution for nuclear). The 1985 mix of coal and nuclear is left at the Recent Trends level because utility expansion plans are fairly well established to that time. By varying only the coal fuel mix, one sets the potential for a comparison at some future date with a "low nuclear electric" scenario. In 1985, coal contributes 59%. It grows to 62% in 2000 and decreases to 50% in 2020. In the Recent Trends Scenario, coal provides 50% in 2000 and 38% in 2020.

Accelerated Synfuels

This scenario is for a major growth of conversion of coal to synthetic fuels. The difference between this accelerated case and Recent Trends is negligible until after 1985. By 2000, the accelerated synfuels output is almost 6 quads greater than the 2.74 quads in the Recent Trends case for that year.

Although many factors can be postulated for accelerated production of synfuels, this increase is assumed to be due mainly to technological advances. Improvements in the efficiency and reliability and reduction in costs of coal conversion processes are assumed to make synfuels more competitive with natural gas and oil.

From preliminary cost analyses, it is assumed that high-Btu synthetic gases will be the major product of these conversion plants, particularly in the near-to-intermediate term. However, production of low-Btu gas from coal for power plants is considered to be a pollution control method and not synfuel conversion.

Accelerated Coal Electric Synfuels

This scenario is developed around a simultaneous expansion of uses of coal for electric power generation and for the production of synthetic oil and gas. It represents the maximum level of coal extraction considered in the NCUA. It is assumed to be due to the same new technology advances that produced the other two accelerated coal scenarios.

Synfuel conversion and direct combustion in industry are lowered marginally in this scenario under the assumption that the higher extraction costs implied by this level of concentrated development would eliminate some of the marginal users. The mix of synfuel products and regional market distribution for synfuels is generally similar to the accelerated synfuels case.

## 2.2 COAL-RELATED ISSUES IDENTIFIED BY STATE AND REGIONAL GROUPS

As a key element of the NCUA*, "major emphasis will be placed on an identification and understanding of the problems and risks associated with coal utilization." The assessment presented here accomplishes that objective, in part, by analyzing the impacts of alternative coal development plans. However, an extensive effort was also undertaken to identify those problems and risks associated with coal development that are of particular concern to state and regional groups and commissions to ensure that both the current analysis and future studies are of practical use. From the issues identified by the state and regional entities, an agenda** of future and ongoing analysis is being prepared. This report will identify studies as ongoing, to be undertaken, or unfunded, as well as the audience interested in the study.

Identifying state and regional problems required several steps. First, a file of energy and environmental agencies, groups, and commissions was developed. Then, a standard introductory letter describing the National Coal Utilization Assessment and the need for interactions with state and regional groups was sent to appropriate individuals in each agency or commission. This letter, which is shown in the Appendix (Coal Related Issue Identification), presented four major questions and requested that a meeting be held to discuss the questions in person. The questions were:

- What are the important environmental problems and issues surrounding the use of coal in your state/region?
- What factors may constrain the use of coal technologies?
- What management options are under consideration to control problems and influence coal use?
- What is the state infrastructure related to energy planning, development, and regulation? What is the structure of the commission and how does it function relative to other environmental, regulatory, and planning groups in the region?

A few weeks after the letter was received, staff members of the Regional Studies Program traveled to the appropriate office to discuss these questions.

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**Project Plan 1977-1979, National Coal Utilization Assessment*, ERDA (March 1977).
***Agenda for Analysis, Assessment and Research*, in publication, Argonne National Laboratory (1977)

A listing of the dates, locations, and attendees at each of the meetings is included in the Appendix. From detailed notes taken during the discussions, a draft letter report to be sent to ERDA's Division of Technology Overview in Washington was prepared. Next, this draft was sent to each agency or commission representative for his or her comments. Finally, the comments were incorporated into a final letter addressed to Dr. Ray Cooper, Acting Assistant Director of the Integrated Assessment Program at ERDA (see Appendix).*

Through this series of meetings, three major categories of problems and issues were identified.** These categories, summarized in Table 2.2.1, are: problems of general concern, problems or issues identified by several states or regions, and issues identified by only a few groups.

### 2.2.1 Problems of General Concern

Coal-related problems of general concern include: increased air pollution; effects of Prevention of Significant Deterioration and other federal air quality regulations; potential water-use conflicts, acid mine drainage, and other problems related to reclamation of "orphan" lands; price and availability of alternative energy sources; transportation constraints; and lack of information on new coal technologies. These are summarized in the following paragraphs.

#### Increased Air Pollution

Perhaps the most important problem stressed in the interviews was the increase in air pollution that will result from increased coal use unless advanced emission-control technologies are used. This issue is of particular importance to states in the eastern half of the region. Here the increased use of local high-sulfur coals could aid the economy of coal-producing states such as Ohio and Illinois but would result in higher sulfur dioxide emissions. Use of systems to control sulfur emissions to eliminate this problem often results in secondary environmental impacts. Officials in many states are also concerned about the increase in particulate levels due to increased use of either eastern or western coal. Increases in hydrocarbon emissions, washout of trace air pollutants and their dispersion through aquatic and terrestrial

*These letter reports have been complied into *Coal Related Issues Identified by State and Regional Groups* in publication (1977).

**This activity is continuing.

| State/Region \ Problem/Issue | General Interest | | | | | | | | | Some Region-Wide Interest | | | | | | | Selected Interest | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Increased Air Pollution | Env. Regulatory Constraints | Water Use Conflicts | Land Reclamation/Acid Drainage | Sludge/Fly Ash Disposal | Price & Avail. of Alternative Fuels | Transportation Constraints | Need for Technology Assessments | Economics of Pollution Control | Industry Conversion | Socioeconomic Impacts | Trace Elements | Agriculture - Coal Conflicts | Rail Transport | Industrial Colocation | Transmission Lines | Changing Federal Energy/Env. Regs. | Recreation/Fisheries - Coal Conflicts | Transportation Tradeoffs | Local Political Conflicts | High Consumer Costs | Env. Tradeoffs Between Technologies | Loss of Industry | Dispersed Energy Markets |
| Arkansas | X | X | | X | | X | | X | | X | | | X | | | | | | | | | | | |
| Illinois | | X | X | X | | X | | | | | | X | X | | | | | | | | | X | | |
| Indiana | X | X | X | | X | | | X | X | | | | | | | | X | | | | | | | |
| Iowa | | | X | X | X | X | | | | X | | | X | | | | | | | | | | | |
| Kansas | X | X | X | X | X | | | X | | | X | | | X | | | | | | X | X | | | |
| Michigan | | X | X | | X | | | X | X | X | | | | | X | | X | X | | | | X | X | |
| Minnesota | X | | X | | X | X | | X | X | | X | X | | X | X | X | | X | | | | | | X |
| Missouri | X | | X | X | | X | X | X | X | | | X | | | X | | X | | | | X | | | |
| Nebraska | | X | X | | | | X | | X | X | X | | | X | | X | X | | | X | | | | X |
| North Dakota | | | | | | | | X | | | X | | X | | | X | | | X | X | | | | |
| Ohio | | | X | X | | | X | X | X | X | X | | X | | | | | | | | | | X | |
| Oklahoma | X | X | X | X | X | X | X | X | | | | | | X | | | | | X | | | | | |
| South Dakota | X | | X | | | | X | X | | | X | X | X | X | | X | | X | | | | | | |
| Wisconsin | X | | X | | X | X | X | X | X | X | X | X | | X | X | X | | X | X | | X | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Great Lakes Basin Commission | X | | X | | X | X | X | X | X | | | X | | | X | | | | | X | | | | |
| Ohio River Basin Commission | | | X | | | | | | | | | | | | | | | | | | | | | |
| Ozarks Regional Commission | | X | | X | | | X | | | X | | | | | | | | | X | | | X | | |

Table 2.1.1. Overview of Issues Identified by State and Regional Groups

ecosystems, and effects of increased carbon monoxide levels on global weather patterns were also identified as important problems by some state and regional planners.

Environmental Regulatory Constraints

While there is a general concern over the impacts of increased air pollution, a related problem is that of meeting federal standards designed to control pollution. Many states are having difficulty in meeting National Ambient Air Quality Standards for sulfur dioxide; and in Nebraska and Kansas, where drought has increased naturally high dust levels, particulate levels are increased by natural sources. Federal Prevention of Significant Deterioration regulations, if enforced could potentially limit siting of new coal facilities. Officials in almost every state, along with the Ozarks Regional Commission, believe that the incremental pollutant levels allowed under the regulations combined with the creation of "buffer zones" around public lands would almost completely eliminate construction of new coal-fired generating plants or other facilities in rural areas where air quality is now high.

Water-Use Conflicts

Conflicts over water use related to coal development are expected to increase throughout the region. While both coal-fired generating plants and gasification plants require much water, water demands for municipal and industrial supply, agriculture, and recreation are also increasing. Water is relatively plentiful in the eastern part of the region, but this area is also more industrial and populous. Industry and utility plants already occupy many potential sites for future coal facilities along the Great Lakes and the Ohio River. In the western states, industrial and municipal demands are less, but total water supplies are also less and agriculture consumes large amounts.

Impacts of Extraction on Water Quality

Coal extraction as well as use can have potentially negative impacts on the water resources in the Midwest. Although every state with active coal mining now has laws regulating mine operation and land reclamation, the problem of recovering orphan lands mined out before passage of the laws remains.

Representatives of environmental and reclamation agencies in the mining states are concerned about the high acidity of water draining from these orphan lands. Acid drainage can have deleterious effects on aquatic and terrestrial ecosystems and ultimately on human health.

## Disposal of Sludge and Fly Ash

Disposal of solid and liquid wastes from emission-control systems is a concern expressed by many Midwestern states. The fly ash removed by electrostatic precipitators often contains potentially toxic elements, such as mercury and boron, as well as radioactive elements, while "scrubbers" produce a sludge containing environmentally noxious calcium sulfite. Utilities and environmental planners in many states have a need to find suitable landfill sites for disposal of these materials. In Wisconsin, where soils are sandy and precipitation frequent, state agency representatives are confronted with the problem of leaching of noxious substances from disposal sites for fly ash. Some states, such as Iowa, have clay soils, which would minimize seepage or leaching from landfills. However, these soils underlie prime agricultural land and agency officials believe that they would encounter local opposition to locating disposal sites.

## Price and Availability of Alternative Fuels

State and regional officials must also consider the cost of coal development compared with those of other energy sources. One concern expressed is the high cost of installing and operating pollution-control devices, such as scrubbers and precipitators, on new and existing conventional coal-fired power plants. Officials in the eastern coal-bearing states believe that the costs of these sulfur-control systems combined with the availability of low-sulfur western coal may prevent continued or increased use of the reserves in their states. In both the energy-consuming and -producing states, agency representatives noted that uncertainty about the price and availability of both fossil fuels and other energy sources (such as solar power, peat gasification, and biomass conversion) made long-range planning for coal use extremely difficult.

Transportation Constraints

Transportation problems may also slow development of coal in the Midwest. Officials in states as diverse as Ohio, Wisconsin, and Nebraska, and the Ozarks Regional Commission, believe that existing rail networks, cars, and engines, could not haul the amount of low-sulfur coal that could be required in the next 20 years. Many of the officials mentioned that secondary rail lines in rural areas are being increasingly abandoned; this change could prevent conversion to coal by industry and utilities as well as construction of new coal facilities. In the Great Lakes states, planners said that the barge and ship fleet along with the rail network may be inadequate if the northeastern states begin to import western coal. Interstate coal haulage was most commonly regarded as a possible problem area, but Missouri officials expressed concern about the capacity of the rail network for hauling local coal to in-state consumers.

Need for Technology Assessments

Another concern throughout the region is the lack of information on new coal technology. Many energy planners are uncertain about the costs, technical feasibility, and environmental impacts of both emission control systems and advanced technologies. Some said that flue-gas desulfurization is an efficient method of sulfur control, and others said that the high costs, sludge disposal problems, and operating difficulties make these systems impractical. Still less is known about gasification, liquefaction, solvent refining, and other newer technologies.

### 2.2.2 Problems Identified by Several Groups

Other coal-related problems were mentioned at several meetings but were not as common as those discussed above. They include the high capital costs and technical problems both of converting industrial plants from other fuels to coal and of constructing new coal conversion plants (such as for gasification or solvent refining); feasibility of co-location of coal-fired electric generating or gasification facilities with industry; and the impacts of increased rail transport of coal. Representatives of the states and regions mentioned fugitive dust, seismic impacts, increased accidents, and disruption of community services as problems associated with increased coal hauling by rail.

Other problems of interest to several agencies and commissions include conflicts between agriculture and coal development; dispersion of potentially toxic trace elements from coal combustion or from the waste products of emission-control systems; sudden changes in employment and population with construction of new coal or coal-related facilities; and the impacts of electric transmission wires from coal-fired generating plants.

### 2.2.3 Problems of Selected Interest

Finally, only a few of the persons with whom we met identified the following as important problems or issues associated with increased coal use in their regions: changing federal energy and environmental policies; conflicts between coal development and agricultural lifestyles, land and water use; loss of industry due to decreased coal mining, federally enforced fuel conversions, or environmental regulations; conflicts between recreation and fisheries and coal development; environmental tradeoffs between alternative coal technologies; local political controversies over coal facility siting; high electricity costs due to costs of coal conversion and environmental controls; difficulties in providing electricity to dispersed consumers in rural areas; and environmental and economic tradeoffs between transporting the coal vs. the product (e.g., electricity).

## 2.3 IMPLICATIONS OF ENERGY SUPPLY AND DEMAND*

*The growth rate of energy demand for the region has slowed dramatically in recent years. The results presented here are premised on a continued lower growth rate (2.38% in 1975-1985, 2.77% in 2985-2000, and 1.52% in 2000-2020). Total energy demand will double about every 35 years. Growth rates in the last 25 years have been 3.25%.*

### Differences in the Coal Development Options

*The contribution of coal in fulfilling regional energy demand will grow steadily (from 26% in 1975 to 34% in 2020) but will increase substantially if coal use for electric utilities and synthetic fuels is accelerated (coal supplying 43% in 2020 for the Accelerated Synfuels and High Coal Electric Scenarios).*

Figure 2.3.1 shows that, in 1975, coal supplied about 26% of the region's requirement. This percentage represents an end point in several decades of decline in coal utilization. Under the Recent Trends Scenario, coal would capture a 34% share by 2020 and 43% under the Accelerated Synfuels and High Coal Electric Scenarios.

The largest end user of coal is likely to remain electric utilities, followed by industrial users and synthetic fuels. Figure 2.3.2 shows that utility and industrial users account for virtually all of current demand. The rate of growth in electric utility demand is slowed by a reduced demand growth for electrical energy (6% historically, 4.7% for 1975-1985, and 4% for 2000-2020). Perhaps more than in any other region, nuclear energy and coal are in close competition for the utility market in the Central Region. Thus, any increases in nuclear capacity will come at the expense of coal. The Recent Trends Scenario allows for a modest growth in nuclear power, which displaces coal baseload generation. Under the High Coal Electric Scenario, the rate of nuclear growth is assumed to slow drastically between 1985-2000; consequently the demand for coal grows at about the same rate as demand for electrical energy. The absolute levels of utility steam coal used in the region are very significant, as high as 372 million tons per year (mtpy) by 2000 and 623 mtpy in 2020 in Recent Trends, compared to 459 mtpy in 2000 and 820 mtpy by 2020 for

*The findings presented here, while based on analysis and historical patterns and estimates of future energy and economic parameters, are strongly influenced by the initial scenarios chosen for analysis.

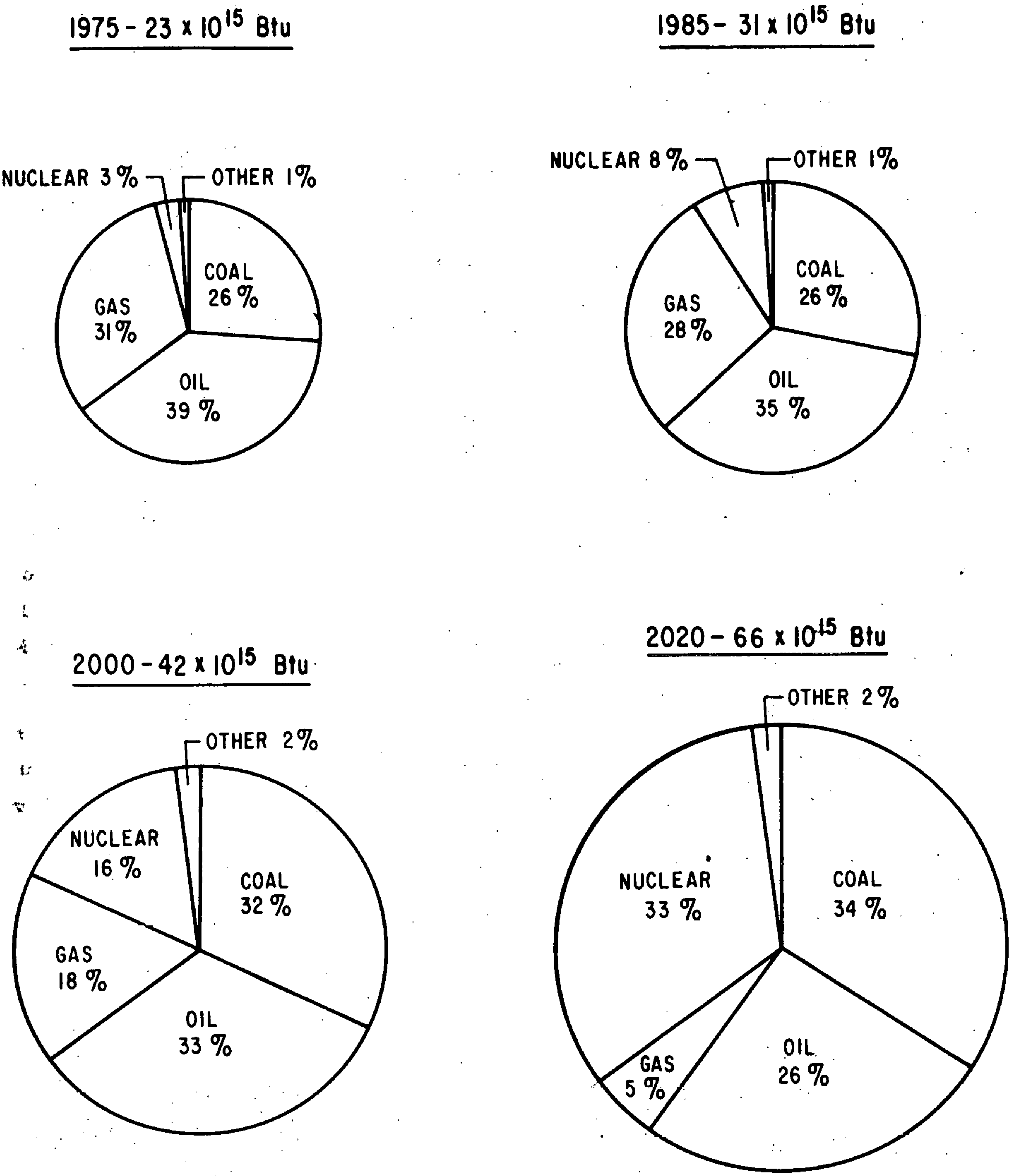


Fig. 2.3.1 Regional Energy Resource Consumption (Recent Trends Scenario)

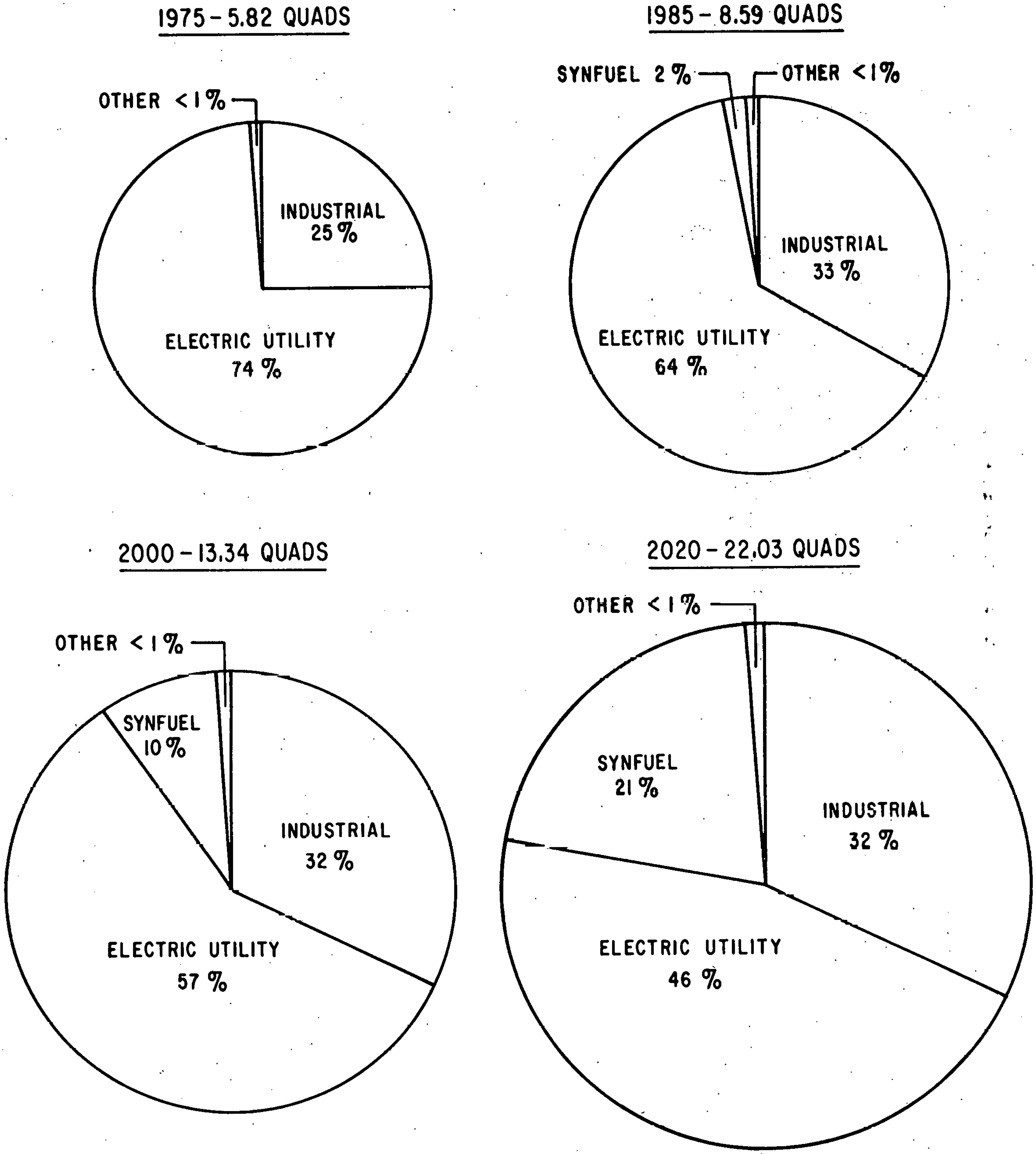


Fig. 2.3.2 Shares of Coal Demand by End Use (Recent Trends Scenario)

the High Coal Electric Scenario. The level of utility coal use now is 178 million tons. In the long term, the synthetic fuels industry could begin to surpass industrial coal use (see Fig. 2.3.2), especially with accelerated synfuels development. Individual synfuels plants consume large amounts of coal (5-10 million tons/year for a facility, depending on size and coal heat content). Under the Recent Trends Scenario, synfuels require 90 mtpy in 2000 and 207 mtpy in 2020. In comparison, for the Accelerated Synfuels, the requirements are 217 and 442 mtpy.

Utility Coal Use

*Growth rates of electricity forecast for all states are between 3.7 and 5.7%, while historical growth rates generally are 6-8%. Coal capacity grows from 85 GWe in 1975 to 150 GWe in 2000, but as a percentage of total generation, it declines from 67% in 1975 to about 60% in 2000, even for the High Coal Electric Scenario. The greatest concentration of direct coal combustion in the region is, and will likely continue to be, in the industrialized states in the east, which maintain 66% of the region's coal capacity.*

Total capacity for the region (see Fig. 2.3.3 for Recent Trends) grows to 296 GWe in 2000 and to 653 GWe in 2020. The region roughly maintains its existing fraction of the nation's total capacity (25%). In most states, the percentage of generation from coal increases between 1975 and 1985. In four states (Ohio, Indiana, Illinois, and Michigan), the ratio of coal generation declines due to an increase in nuclear power. The Recent Trends Scenario shows a gradual decline in the ratio of coal generation after 1985, while the coal generation ratio for the High Coal Electric grows through 2000 and then declines.

Table 2.3.1 shows the concentration of direct coal combustion in the eastern portion of the region. Ohio is the region's leading user of coal, while Indiana, Illinois, and Michigan also use large quantities. In total, these four states maintain 66% of the region's capacity. The largest coal-capacity additions for 2000 occur in Ohio, Indiana, Kansas, and Oklahoma. Although coal use grows significantly in the western portion of the region, these states are thinly populated and have lower absolute demands for electricity than industrialized states. A key difference between the Recent Trends and High Coal Electric Scenarios is the degree of increased coal use in Ohio, Indiana, and Illinois compared with other states. The increments of coal use in these

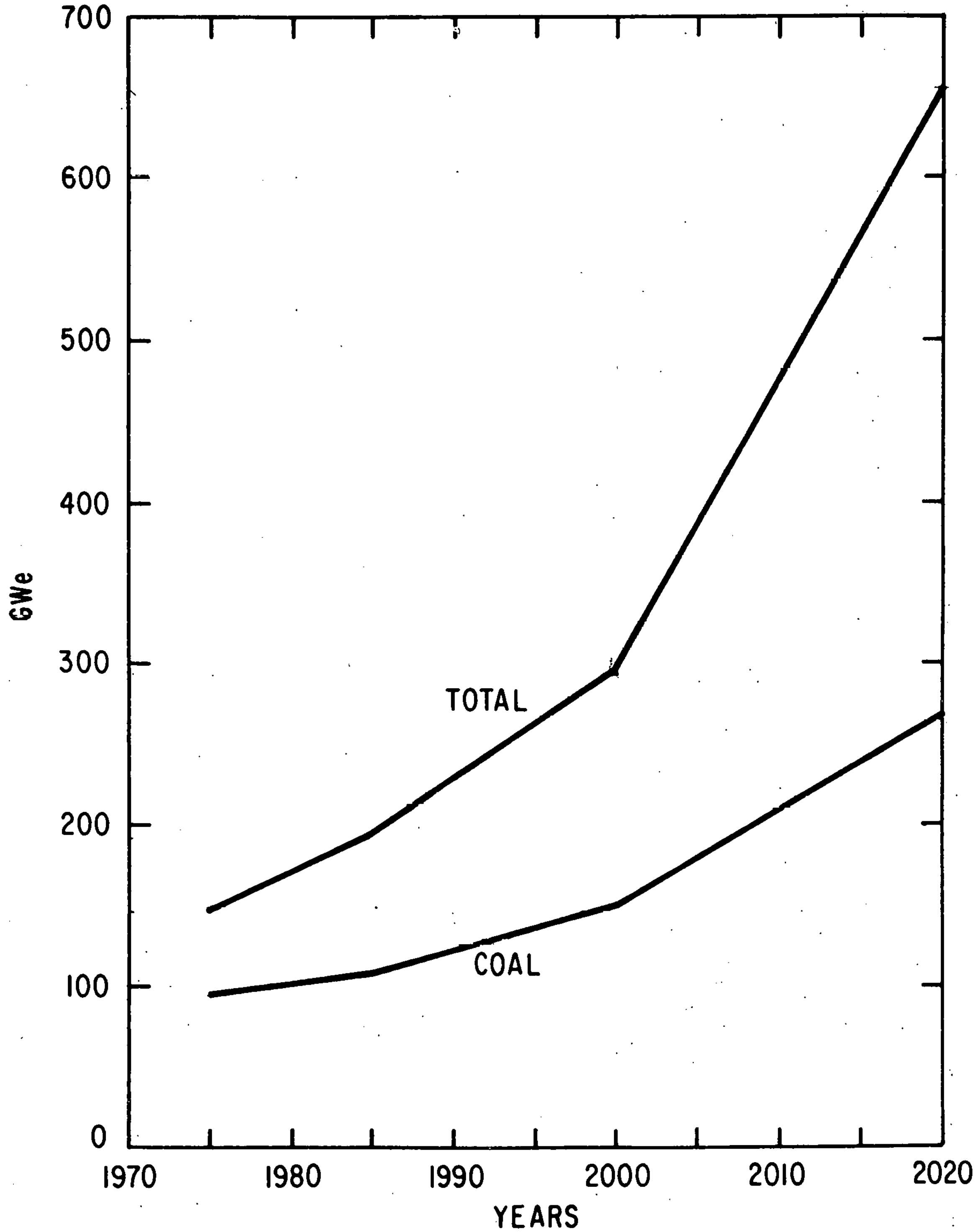


Fig. 2.3.3 Growth in Regional Electric Utility Capacity

Table 2.3.1 Capacity Growth, 1975-2020: Recent Trends Scenario (in GWe)

| States | 1975[a] | | 1985[b] | | 2000[b] | | 2020[b] | |
|---|---|---|---|---|---|---|---|---|
| | Total Capacity | Coal Capacity | Total Capacity | Coal Capacity | Total Capacity | Coal Capacity | Total Capacity | Coal Capacity |
| Ohio | 25.2 | 22.4 | 36.0 | 27.5 | 59.5 | 41.2 | 127.8 | 61.1 |
| Indiana | 13.4 | 12.4 | 20.6 | 16.4 | 34.4 | 20.7 | 76.4 | 39.9 |
| Illinois | 25.5 | 15.7 | 38.1 | 16.7 | 54.6 | 19.5 | 123.0 | 40.1 |
| Michigan | 18.9 | 11.6 | 23.3 | 12.1 | 33.6 | 15.9 | 66.3 | 32.7 |
| Wisconsin | 8.9 | 5.4 | 11.7 | 6.1 | 15.8 | 6.3 | 33.8 | 9.7 |
| Minnesota | 6.8 | 2.9 | 9.1 | 4.5 | 14.2 | 7.5 | 34.5 | 14.5 |
| Iowa | 5.4 | 2.9 | 5.6 | 3.1 | 7.9 | 4.2 | 17.7 | 7.5 |
| Missouri | 11.0 | 8.1 | 14.1 | 8.5 | 20.3 | 10.4 | 45.2 | 18.8 |
| North Dakota | 1.2 | 0.8 | 2.7 | 2.0 | 5.0 | 2.0 | 12.2 | 5.4 |
| South Dakota | 2.1 | 0.6 | 3.1 | 1.4 | 5.5 | 1.7 | 12.6 | 1.9 |
| Nebraska | 3.8 | 1.0 | 5.0 | 1.3 | 8.4 | 4.4 | 22.2 | 9.3 |
| Kansas | 5.9 | 0.9 | 7.1 | 2.7 | 12.0 | 6.5 | 31.8 | 13.5 |
| Arkansas | 4.7 | 0 | 4.9 | 0.5 | 6.4 | 1.2 | 11.8 | 3.3 |
| Oklahoma | 7.9 | 0 | 11.4 | 5.0 | 18.1 | 7.0 | 37.8 | 8.6 |
| Regional Total | 140.7 | 84.7 | 192.7 | 107.8 | 295.7 | 148.5 | 653.1 | 266.3 |
| U.S. Total | 505.7 | 227.4 | 770.0 | 308.0 | 1316.0 | 408.0 | 2780.0 | 556.0 |

[a]Source: Federal Power Commission, "FPC News", 9(43):27 (Oct. 22, 1976).

[b]Estimated

states for the year 2000 are 13.7, 4.30, and 2.80 GWe in the Recent Trends Scenario and 18.5, 13.2, and 11.2 GWe in the High Coal Electric Scenario. Additions for other states total 19.9 GWe for Recent Trends and 25.6 GWe for High Coal Electric.

Oil, Gas, and Synthetic Fuels

*Even a greatly expanded use of coal does not necessarily reduce the dependency of the region on oil imports; however, synfuels can significantly contribute to supplying the region's gas needs.*

The region now produces only about 24% of its oil requirements, with most of this production concentrated in Oklahoma. Synfuels would supply only 10% of the region's requirements in 2020 under the Accelerated Synfuels Scenario. Total gas demand for the region is forecast to drop from its present 6.73 quads to 4.6 quads by 2020. In this period, coal could supply 50-80% of the region's gas requirements.

Coal Production and Flows

*Major coal production in the region will be concentrated in a few states. Illinois and North Dakota together will produce 58% of the region's total production under the Recent Trends Scenario. While production within the region grows substantially, imports to the region will continue to grow as a percentage of total coal use. Specifically, imports to the region from the Northern Great Plains will grow from 20% to 50% of regional requirements in 2000.*

Current trends indicate that the sources of coal to supply higher demands for it will be increasingly in the west. Coal imports from the Northern Great Plains* are likely to be a growing share of total regional coal supplies (see Fig. 2.3.4). The share of local production from the Interior Province slightly declines. The strength of this shift to the west may be diminished by institutional and physical constraints on the availability of western coal. Yet, the sheer abundance of strippable coal reserves in the Northern Great Plains seems to make it a major source of supply in the long term. The effect of a best-available control-technology provision requiring the use of FGD with low-sulfur coal is as yet unknown, but it could potentially alter this pattern of coal use.

*Implications of development of eastern vs. western coal resources will be analyzed in the near future. Analyses of the tradeoffs between alternative levels of development will be conducted.

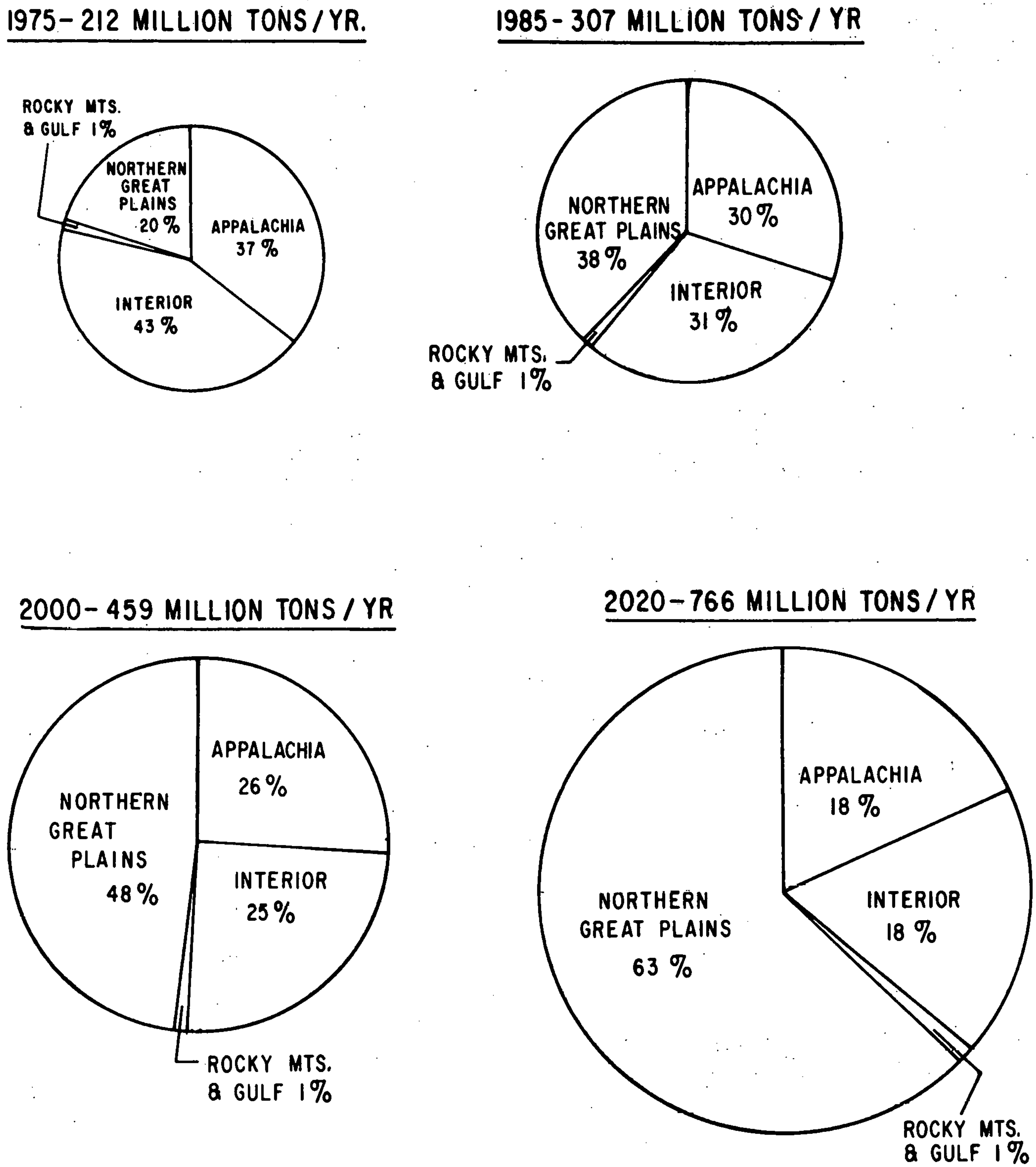


Fig. 2.3.4 Sources of Steam Coal for Electric Utilities and Industrial Users in Recent Trends Scenario

Within the region, major coal production will be concentrated in a handful of states -- Illinois (38%), Indiana (8%), Ohio (18%), Missouri (4%), and North Dakota (28%), account for 96% of production under Recent Trends, with less production in Iowa, Kansas, Oklahoma, and Arkansas (see Fig. 2.3.5). In terms of the rate of development, production in North Dakota, Missouri, and Oklahoma may grow fairly rapidly.

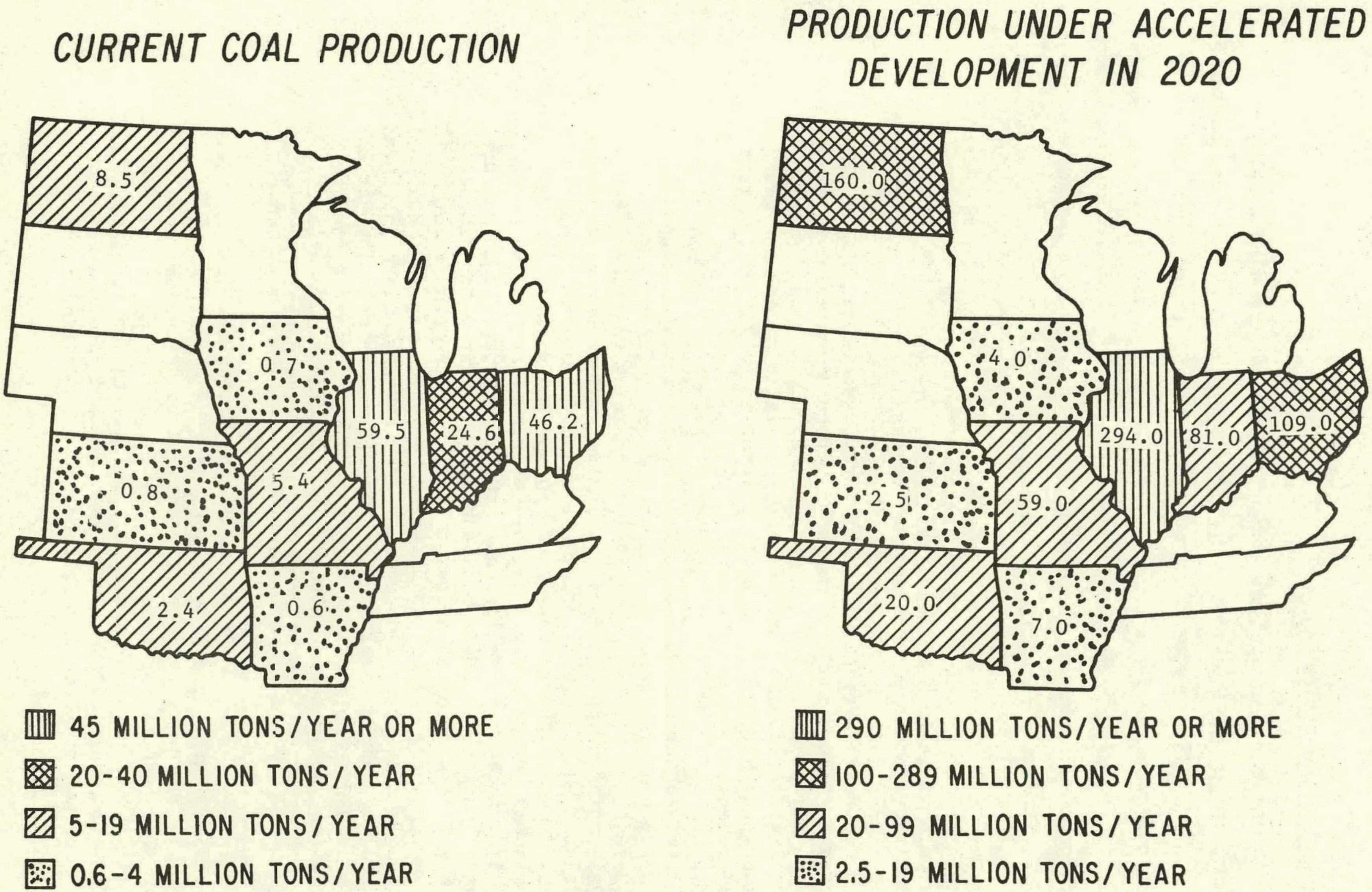


Fig. 2.3.5 Coal Production Trends

## 2.4 SITING OF COMBUSTION AND CONVERSION FACILITIES

### 2.4.1 Combustion Facilities

*Significant constraints were encountered in determining sites for required capacity for most of the states in the region.* The siting patterns that have traditionally developed cannot persist much longer. The average transmission distance for three example areas will increase by 88% by the year 2000. The exponential growth of capacity requirements (even with conservation) coupled with growing resource scarcity and environmental constraints are forcing certain shifts in siting patterns for central power plants:*

- A movement of sites away from the load centers: Figure 2.4.1 illustrates the increase in average transmission distance from siting areas to load center for 1975 and 2000. Most additions occurred outside load centers.

- Concentrated siting near major water resources: 55% of the capacity additions for the year 2000 occur on major waterways (Great Lakes and the Ohio, Mississippi, and Missouri Rivers). Capacity additions on the Illinois, Arkansas, and Muskingum Rivers increase the percentage to 70% of the region additions.

- Increased water conservation and storage: water consumption due to evaporative cooling losses reached 20% of the 7-day/10-year low flow on nearly all tributaries (excluding the Ohio, Mississippi, and Missouri Rivers) in the region. Significant water shortages were encountered in Oklahoma and Kansas. By the year 2000, 60% of the sited capacity in Oklahoma requires supplemental water sources, and by 2020, 70% of the water requirements are unaccounted for in surface water supplies. Reservoirs and ground water were viewed as potential sources to alleviate this resource constraint. However, more drastic conservation measures may be required if these sources prove inadequate. The siting pattern in Kansas requires supplemental sources for 27% of the capacity for the year 2020. Other states have enough surface water for the cooling requirements, although the distribution of these supplies often does not coincide with load-center locations.

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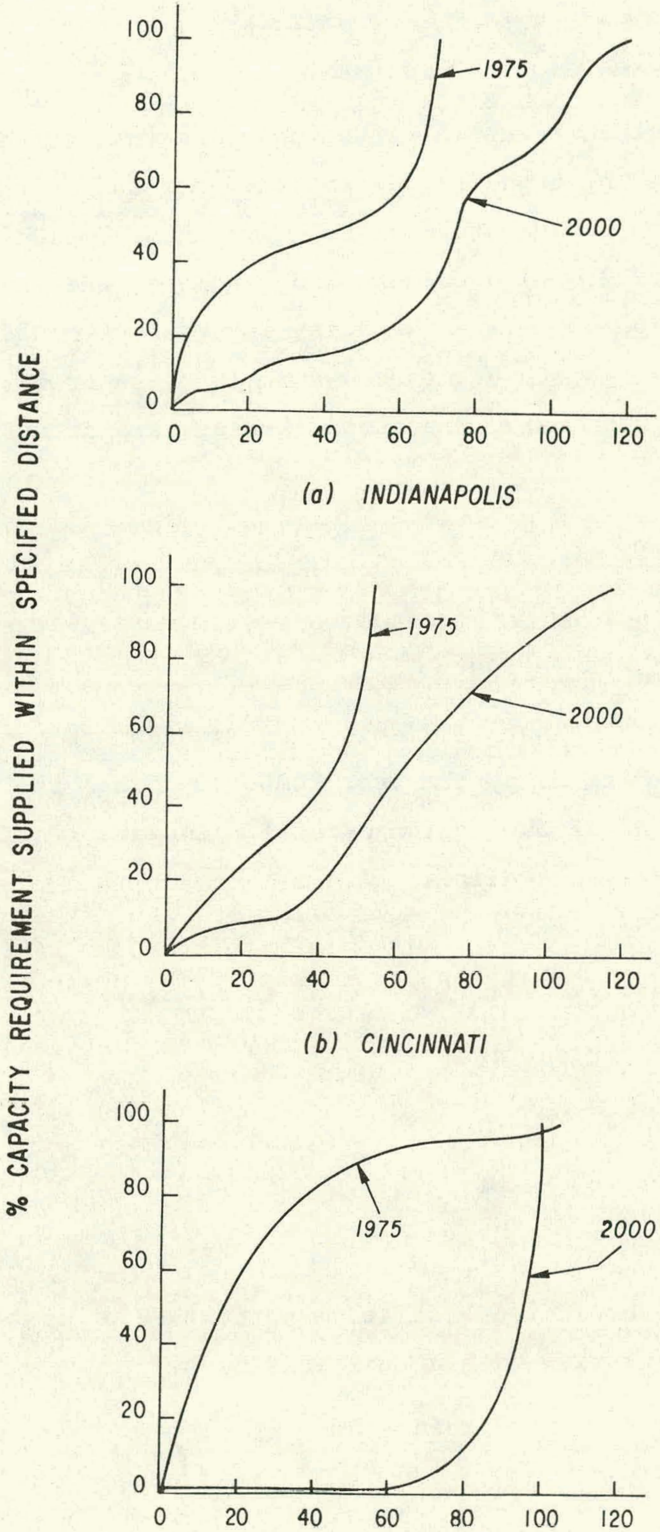
* The analysis conducted here did not indicate these constraints as insurmountable; however, studies are required to define and develop solutions. The results obtained here are influenced by the siting criteria used (see Sec. 5.0) and do not include the constraints identified as a result of the impact analysis and reported in Secs. 6-9. The feedback of these impact results to the siting is being carried out.




(c) OKLAHOMA CITY
DISTANCE FROM LOAD CENTER, MILES

Fig. 2.4.1. Increasing Transmission Distances

Differences in Coal Development Options

*Siting patterns for electrical generating facilities do not differ significantly among the coal development options.*

The High Coal Electric Scenario is the only one that affects combustion facilities. Total generating capacity remains the same as for the Recent Trends Scenario, but a shift from nuclear to coal capacity occurs. The largest increases in coal capacity (see Fig. 2.4.2) occur in Ohio, Indiana, and Illinois. In Indiana, for the year 2020, coal-fired capacity increases from 56% to 88% of the total generating capacity. North Dakota shows an increase from 38% to 64%. States such as Michigan, Wisconsin, Minnesota, Kansas, and Arkansas show little or no change.

Regional Overview

*Coal-fired capacity (and total capacity requirements) is concentrated in the eastern portion of the region.*

The states of Ohio, Indiana, Illinois, and Michigan account for 66% of the coal-fired capacity sited by the year 2000. Ohio has the largest share, which amounts to 28% of the regional total. Indiana requires 14%, Illinois has 13%, and Michigan requires 11%.

*At the river basin level, the Great Lakes, Ohio, Upper Mississippi, and Missouri basins account for 94% of the coal-fired capacity by the year 2000.*

The individual proportions are:

- Ohio River - 31%
- Great Lakes - 29%
- Upper Mississippi River - 20%
- Missouri River - 14%
- Arkansas River - 6%

The following figures indicate relative percentage of capacity sited on the main stem and on tributaries within these basins.

| Basin | Main stem | Tributaries |
|---|---|---|
| Ohio | 36 | 64 |
| Great Lakes | 54 | 46 |
| Upper Mississippi | 25 | 75 |
| Missouri | 57 | 43 |
| Arkansas | 26 | 74 |

The relatively high percentage of coal-fired capacity sited on tributaries in the Ohio and Mississippi River basins result from interpretations

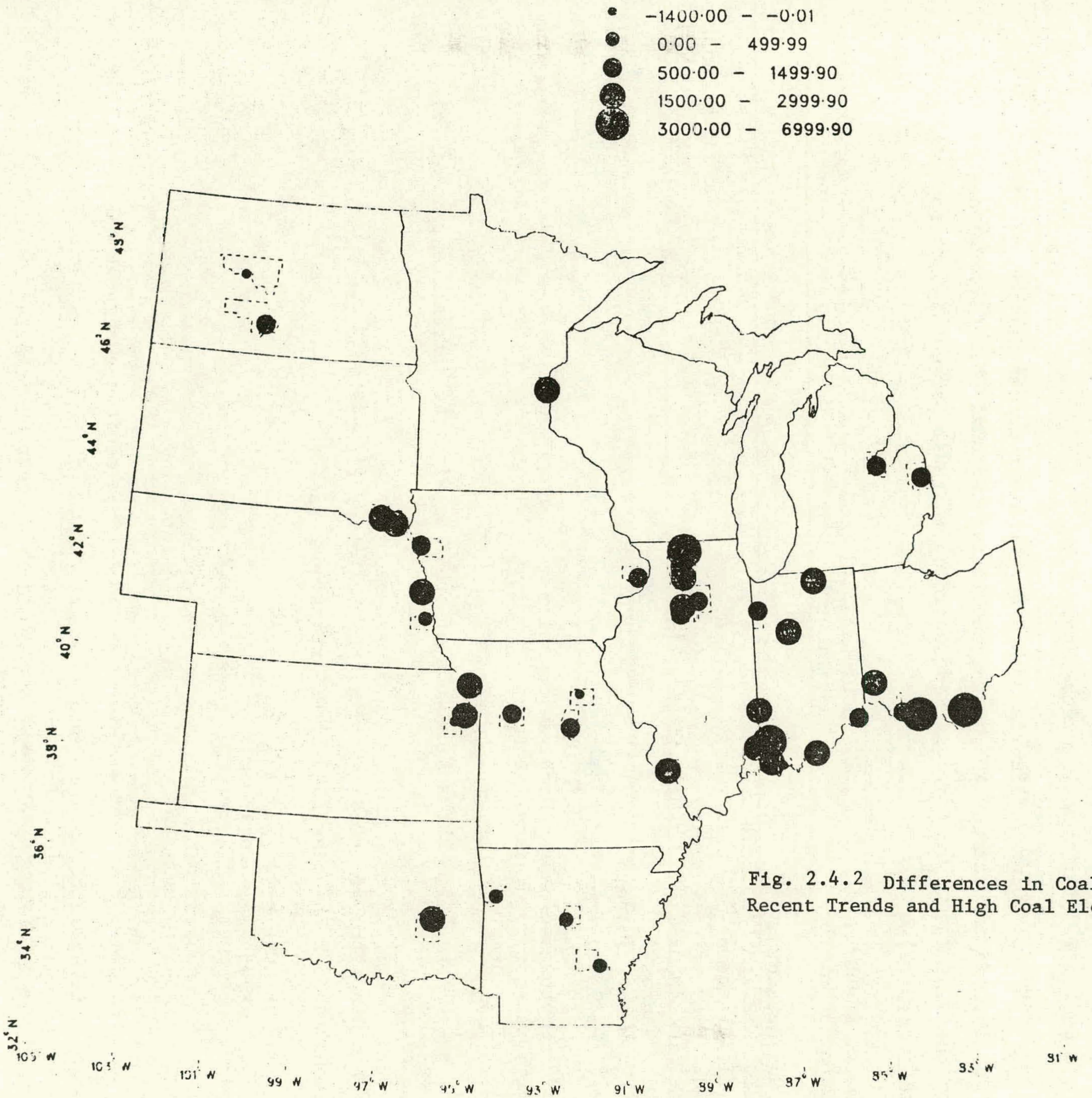



Fig. 2.4.2 Differences in Coal Capacity Between Recent Trends and High Coal Electric Scenarios

of the constraints on water consumption. Because of (1) the seasonal nature of low flow conditions, (2) the bimodal distribution of electricity demands, and (3) the operating characteristics of nuclear and coal-fired plants, an attempt was made to site a disproportionate amount of coal capacity along tributaries (see Sec. 5.2.3 for further discussion).

The following WRC Subareas show the greatest concentrations of sited capacity and account for 40% of the cumulative regional coal-fired capacity by the year 2000. They are ranked according to their percentages of regional additions.

| Water Resource Council Subarea | % of Regional Coal Additions by 2000 | % of Cumulative Regional Coal Capacity by 2000 |
|---|---|---|
| 504 Muskingum | 7.1 | 5.4 |
| 410 Western Lake Erie | 6.5 | 5.7 |
| 411 Southern Lake Erie | 6.0 | 5.3 |
| 1023 Missouri-Sioux City-Oklahoma | 5.8 | 3.8 |
| 1027 Kansas | 5.5 | 2.4 |
| 713 Lower Illinois | 4.3 | 5.4 |
| 509 Cincinnati-Little Miami-Ohio | 4.0 | 5.2 |
| 404 Southwestern Lake Michigan | 1.3 | 7.7 |
| 714 Mississippi-Kaskaskia-St. Louis | 0 | 5.5 |

Figure 2.4.3 shows locations of subareas with the largest concentrations of regional capacity.

In terms of added capacity, the following figures show percentage additions through the year 2000 by major drainage basin:

- Ohio River - 27
- Great Lakes - 23
- Upper Mississippi River - 16
- Missouri River - 22
- Arkansas River - 12

Figure 2.4.4 shows locations of coal-fired additions through the year 2000. Siting patterns are shown in Figs. 2.4.5 and 2.4.6.

The percentages of these additions that occur on tributaries vs. mainstems are shown below:

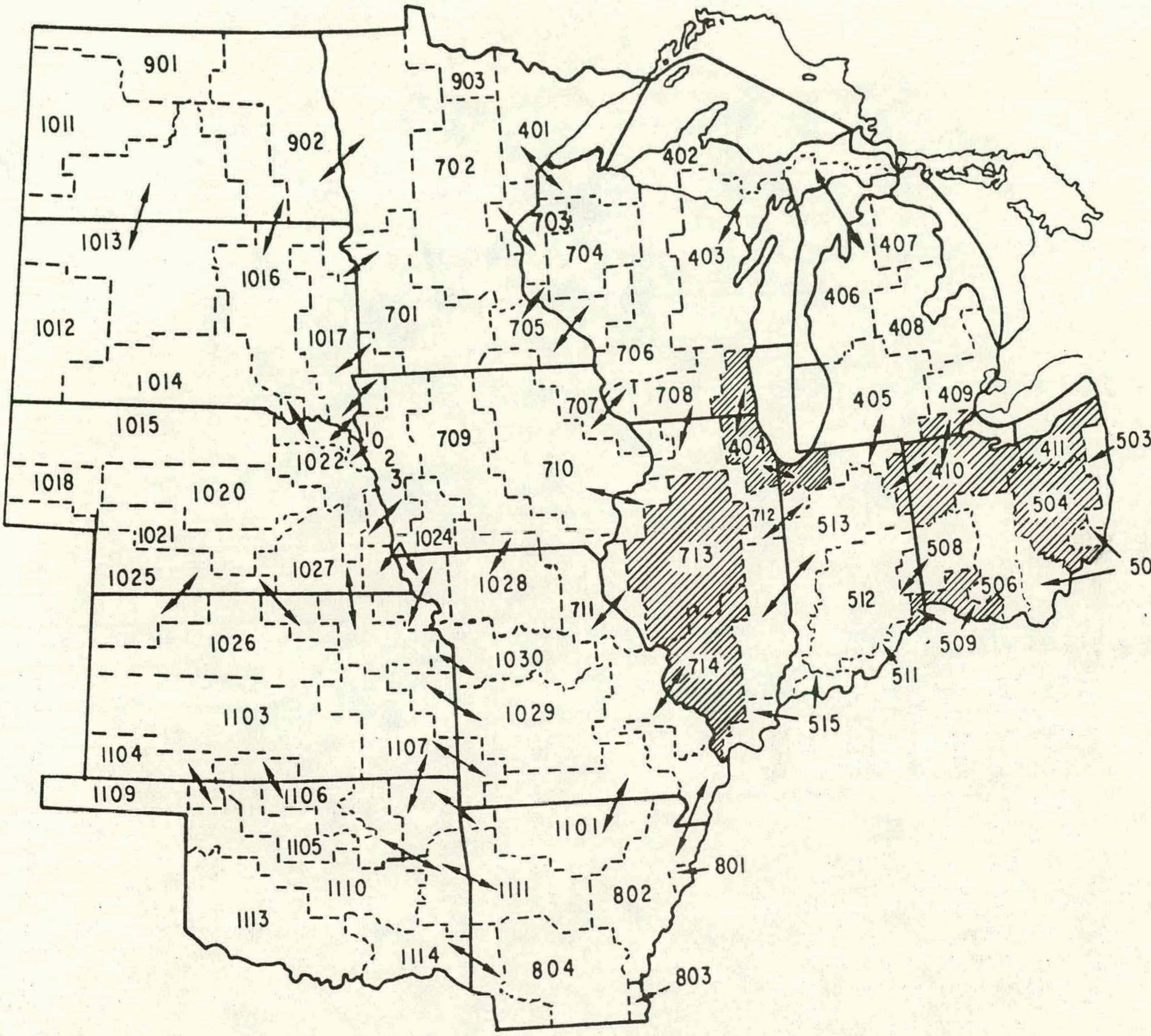



Fig. 2.4.3 Water Resource Council Subareas with Largest Concentrations of Electrical Generating Capacity

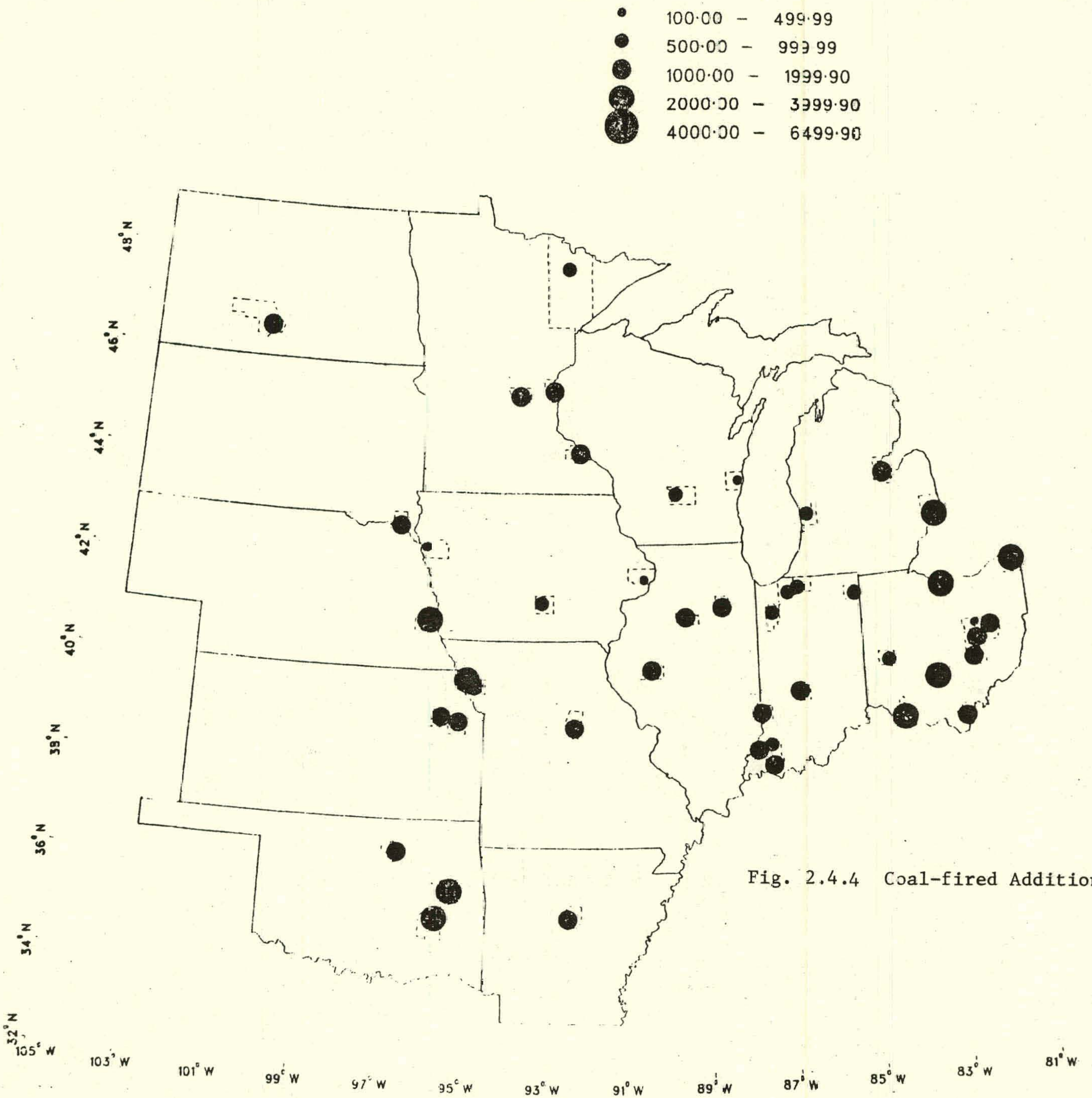



Fig. 2.4.4 Coal-fired Additions Through 2000

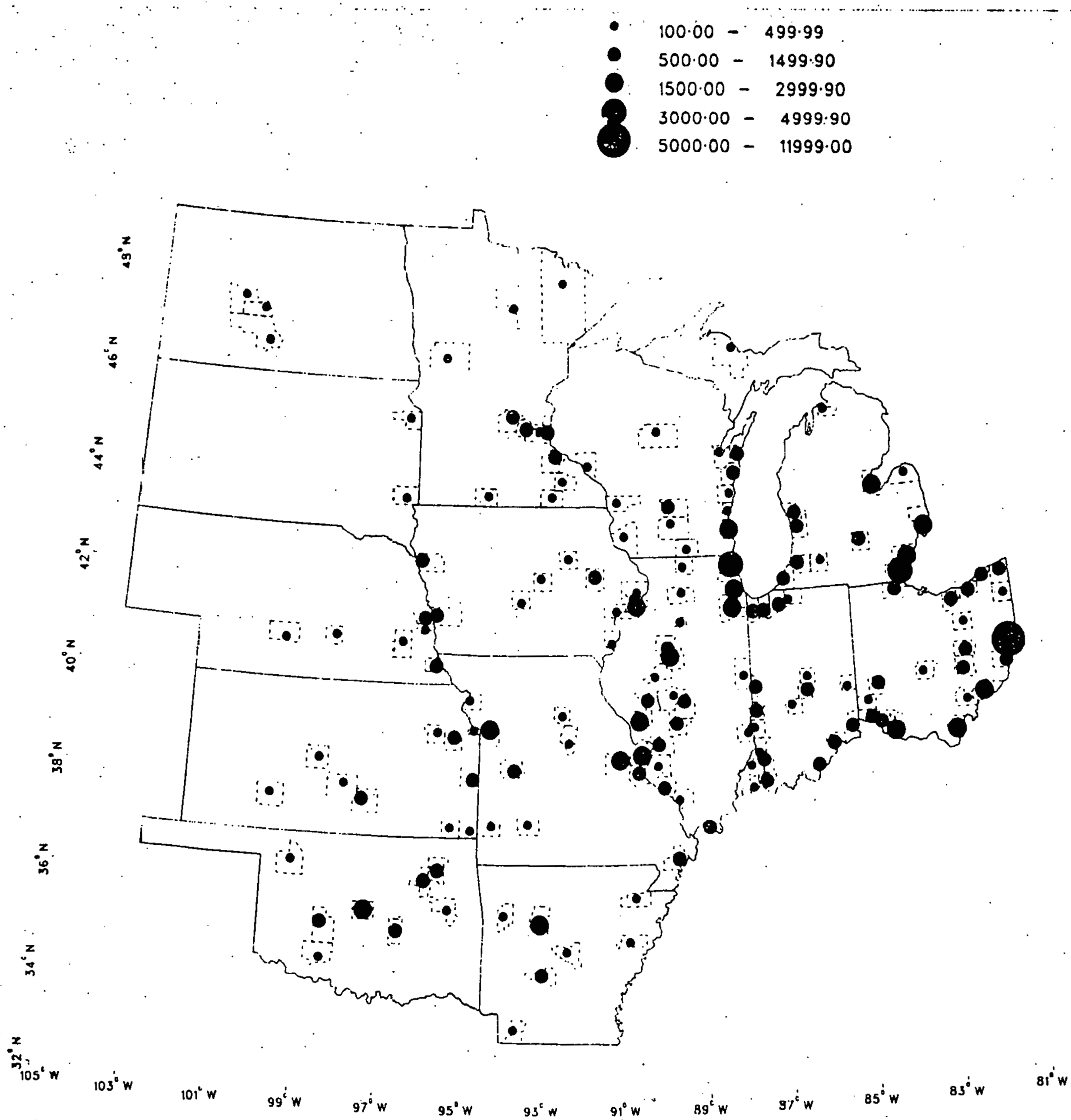



Fig. 2.4.5. Siting Pattern for 1975

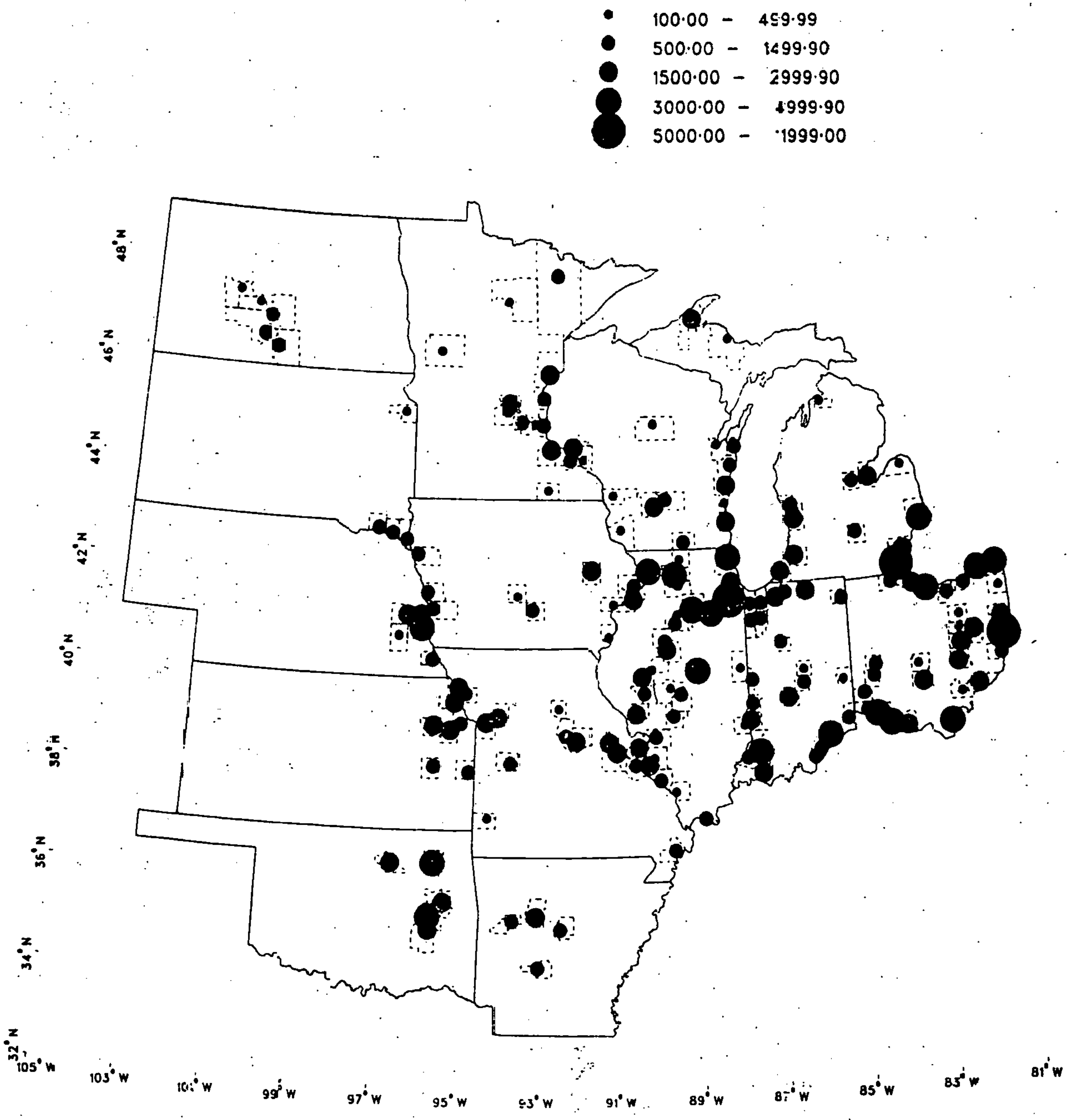



Fig. 2.4.6. Siting Pattern for 2000

| Basin | Main Stem | Tributaries |
|---|---|---|
| Ohio River | 35 | 65 |
| Great Lakes | 99 | 1 |
| Upper Mississippi River | 22 | 78 |
| Missouri River | 86 | 14 |
| Arkansas River | 13 | 87 |

*The most apparent potential siting conflicts arise in Ohio, Illinois, and Oklahoma.*

Ohio -- the capacity requirements of Ohio are more than a fourth of the total regional demands, but the siting criteria based on air quality are more restrictive in this state than any other in the region. Population density and the air-quality constraint limit siting near Lake Erie in the north. Alternative water supplies are primarily available in the south along the Ohio main stem, away from the major northeastern load centers.

Illinois -- Problems arise in siting capacity near the load centers. The Chicago area requires 60% of the total state capacity. However, air quality and population density prevent siting in the metropolitan area and prevent the use of Lake Michigan as a water source. The Illinois River is used heavily to site additional capacity, as far to the northeast as possible.

Oklahoma -- Although air-quality problems cause some siting limitations, difficulties in siting are almost entirely due to limited water supply.

Similar problems arise to some extent in all parts of the region. In general, the problems are not as severe as in these three states.

### 2.4.2 CONVERSION FACILITIES

*Significant constraints were encountered in siting synfuel plants in the region.*

Sites for coal conversion plants were restricted to areas having both coal and water. Because such areas are scarce, development is fairly concentrated.

- Only five states in the region (North Dakota, Missouri, Indiana, Ohio, and Illinois) were determined to have adequate mineable coal reserves in localized areas to provide the lifetime requirements for conversion.

- Within each of these states, the coincidence of water resources and coal reserves leaves little margin for alternative siting patterns.

Differences in Coal Development Options

*The Accelerated Synfuel Scenario shows more than a doubling of conversion facilities from Recent Trends levels by the year 2020.*

A total of 64 plants are located by 2020 in the accelerated case; there are 29 plants for Recent Trends. Figures 2.4.7 and 2.4.8 show that development in the accelerated case follow the same patterns shown by the Recent Trends Scenario. The primary difference is a greater concentration for the accelerated case.

Regional Overview

Conversion facility sites are limited to North Dakota, Missouri, Illinois, Indiana, and Ohio. Illinois and North Dakota have the largest share of plants, each having 31% of the Recent Trends total for the year 2020. Missouri has the smallest number, with two plants in 2020, and a supplemental water source is required for one of these.

The Ohio, Illinois, and Missouri Rivers provide the water needed for all of the synfuel plants, except for one plant in Missouri that requires a reservoir. The Ohio and Missouri Rivers each have ten conversion facilities sited by the year 2020. The Illinois River has eight.

The most restrictive constraints on siting synfuel plants are in Iowa and Kansas, where large coal reserves exist but water resources are not near. As a result, no conversion facilities are sited in these states. Other states, such as South Dakota, Nebraska, Oklahoma, Minnesota, Arkansas, Wisconsin, and Michigan, do not have enough mineable coal reserves to support the 30-year lifetime requirements for conversion.

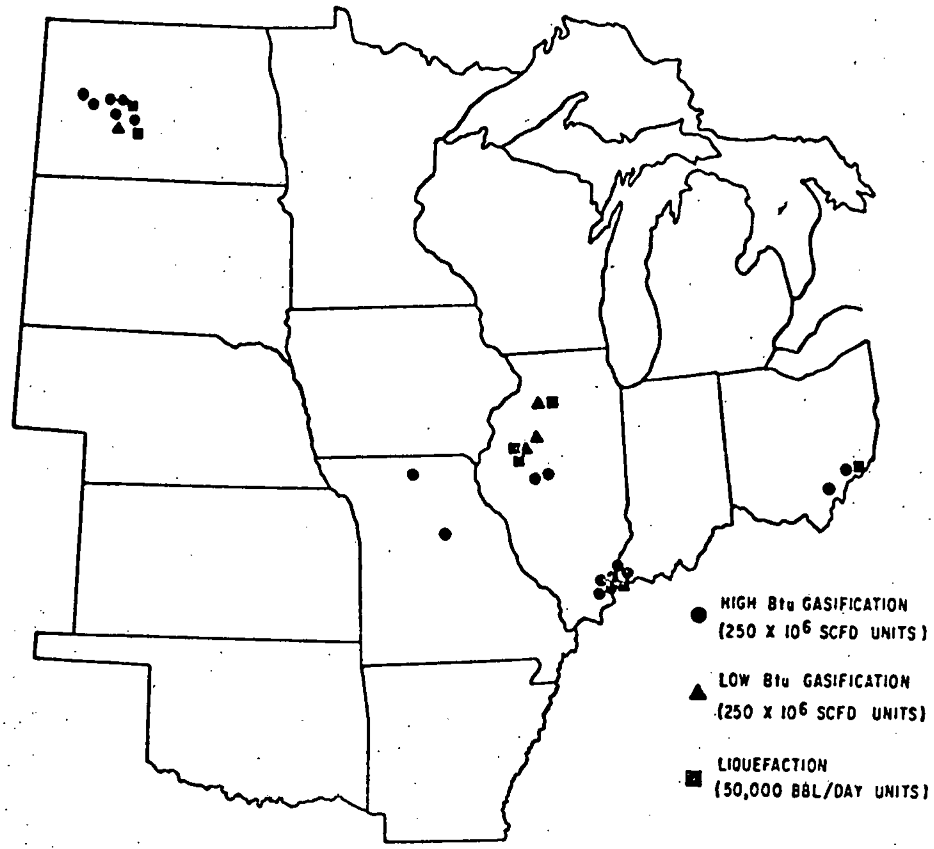



Fig. 2.4.7. Synfuel Plant Siting Pattern for the Year 2020 -- Recent Trends Scenario

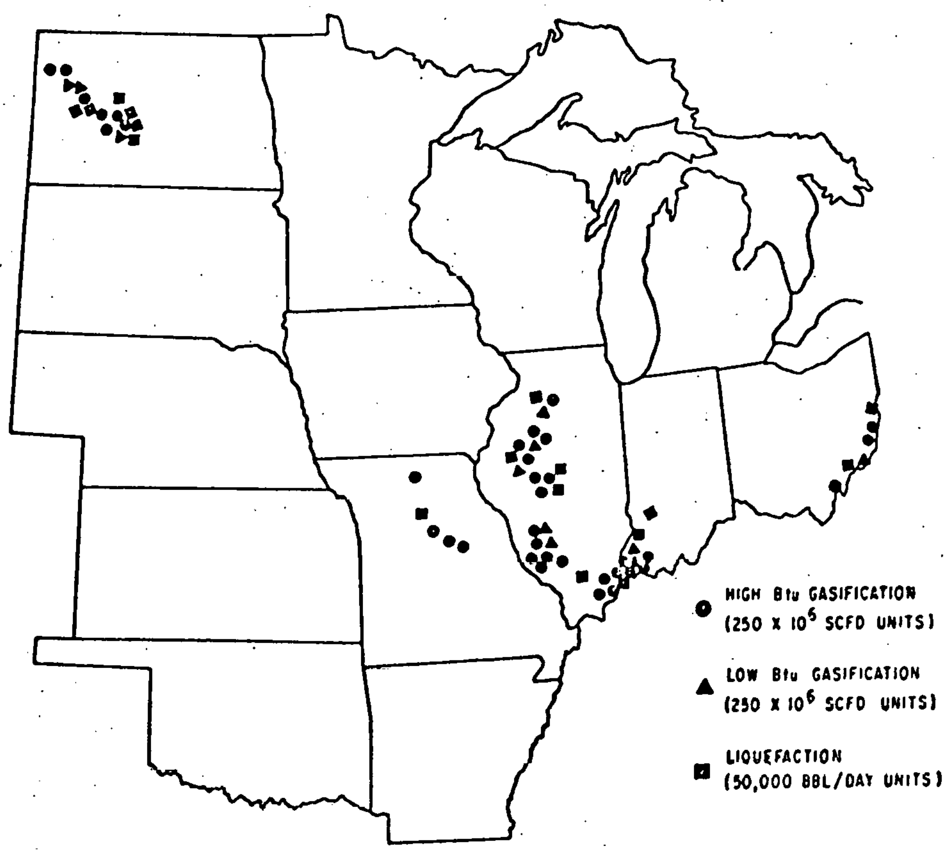



Fig. 2.4.8. Synfuel Plant Siting Pattern for the Year 2020 -- Accelerated Synfuel Scenario

## 2.5 WATER AVAILABILITY

*Although cumulative water supplies are adequate in the region to satisfy foreseeable energy requirements, significant water shortages that would constrain energy development patterns or development of competing water uses are likely to occur in various localized areas or subregions within the region. In the year 2020 1.4% (or 9300 MW) of the regional electrical generation capacity is sited in areas in which water problems could be severe, and strong mitigation measures such as reallocation of water supplies or use of dry cooling may be necessary for siting energy facilities. In addition 14.2% (or 93,000 MW) of the regional capacity is sited in areas which may require development of reservoirs, groundwater, and/or other measures for water-supply enhancement. The integration of regional energy and water resources planning will become unavoidable as energy processes absorb an increasing fraction of total regional water demand. Specifically, water for energy grows from 2% of all consumptive uses to 18% in the year 2020.*

### Differences in Coal Development Options

*The differences in water consumption for coal development options are less than 5% (see Fig. 2.5.1). Water resource problems are not affected by the options.*

The largest fraction of water use in electrical generation is for cooling. The amount is largely independent of substitutions between nuclear and fossil fuel capacities, where total generation remains constant. Compared to the Recent Trends Scenario, the High-Coal Electric Scenario consumes 4% less water in 2020 because of the slightly increased efficiency of fossil facilities. For the Accelerated Synfuel Scenario, water consumption increases by 5% as imported liquid and gaseous fuels are replaced by synfuels. Large amounts of water are consumed in producing these fuels.

### Impact of Coal Fuel Cycle Components

*The largest water consumption is in evaporation (90% of total consumption) during cooling in electrical generation and synfuels production. Large variations in water consumption for coal utilization are due mainly to differences in sites, processes, and water-conservation practices. For example, dry cooling can reduce consumption by as much as a factor of 80 below that with cooling ponds.*

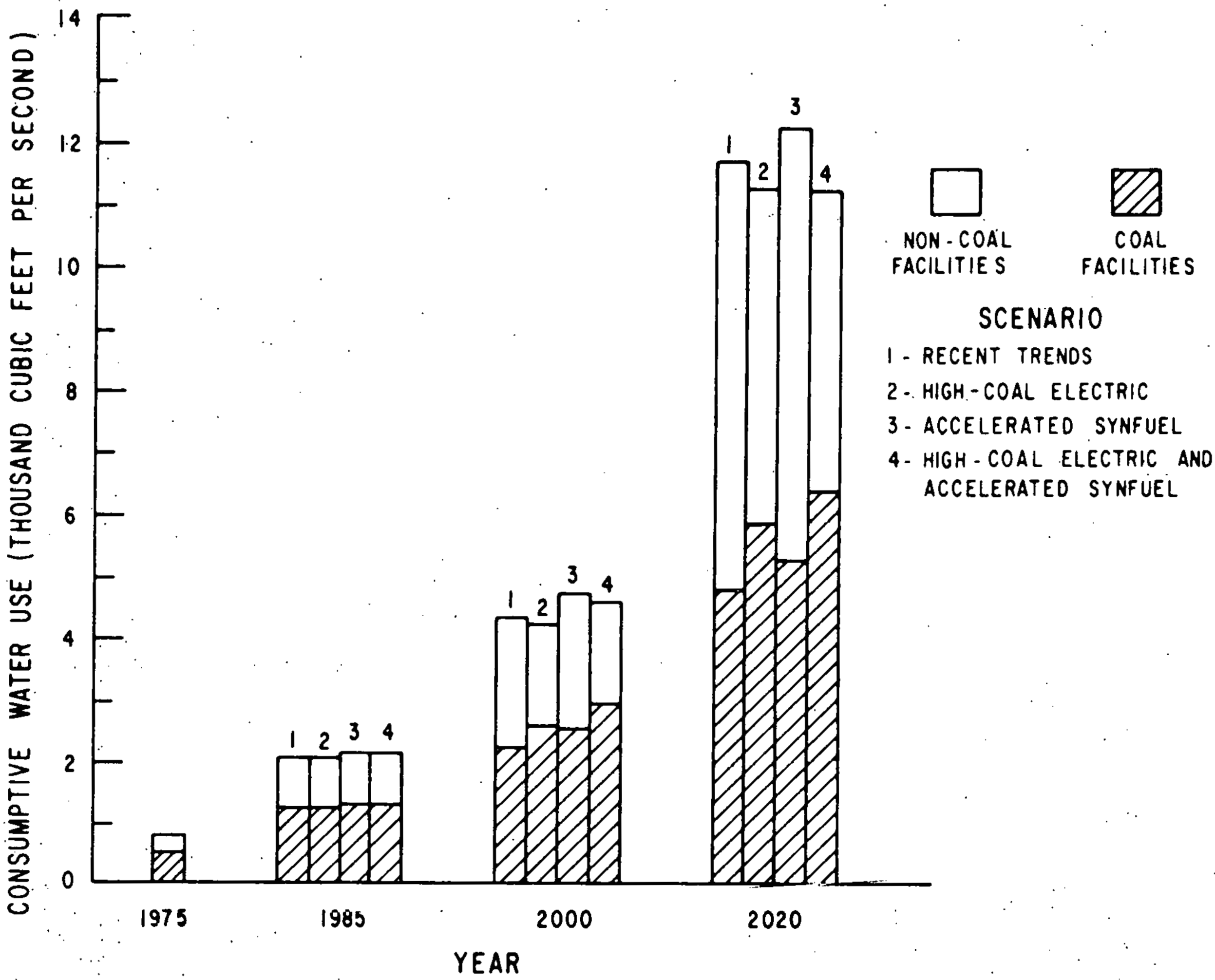



Fig. 2.5.1. Energy-Related Regional Water Consumption for Alternative Scenarios

Table 2.5.1 lists the water requirements assumed in the study and the estimated minimum based on environmental conditions existing in the more arid western states. These estimates assume use of evaporative cooling because of the current EPA guidelines*, which state that closed-cycle cooling ponds and cooling towers are to be used at new units; all other cooling systems, such as once-through and cooling lakes, are prohibited unless an exemption is obtained. In the study region, the Great Lakes, and the Ohio, Mississippi, Missouri, and Arkansas Rivers and their major tributaries might support once-through cooling for many power plants. This use would reduce water consumption of these facilities by about 50%. For some other areas, such as the Omaha and Kansas City areas on the Missouri and the Twin Cities on the upper Mississippi, once-through cooling could, on a limited basis, also be used if appropriate criteria for site spacing are observed.

The water requirements for coal extraction and cleaning are significantly less than that for coal combustion (2%) or conversion (~5%) unless a long-term commitment is made to irrigating crops in reclaimed areas. An indirect impact of extraction on water resources is the disruption of aquifers, but the extent of this is unknown. Process water requirements for coal conversion, flue-gas desulfurization, and waste disposal are also secondary to cooling requirements.

*Regional Overview*

*In the study area the major basins of the Mississippi, Ohio, Missouri, and Arkansas Rivers, and the Great Lakes together have enough fresh water to exceed the demands of energy facilities (see Table 2.5.2). In aggregate, energy will require at most 15% of the monthly flows at 95% exceedance level. However, low-flow conditions (e.g., 7-day/10-year low flows), seasonal variations, or demands by competing water users will cause potential water shortages in localized areas (see Fig. 2.5.2). These areas in total account for 102,000 MW, or 25.6% of the regional capacity.*

When other siting factors, such as distance from load centers and land use are considered, about 84.4% of the regional capacity (or 550,000 MW) for

*U.S. Environmental Protection Agency, *Effluent Guidelines and Standards, Steam Electric Power Generating Point Source Category*, Federal Register 39(196):36186-36207 (Oct. 8, 1974)

Table 2.5.1. Water Requirements for Coal Utilization

| Unit Facility | | Water Consumption | | | | Mining and Reclamation[a], |
|---|---|---|---|---|---|---|
| | | Standard Case | Conservation Case[a] | | | |
| | | Acre-ft/yr | Acre-ft/yr | % Cooling | % Other[b] | Acre-ft/yr |
| Electrical Generation | 3000 MWe cap. @ 35% eff.; 70% load factor | 31,300 | 23,400 | 92 | 8 | 450 |
| High Btu Gasification (Synthane) | $250 \times 10^6$ scf/day cap.; 90% load factor | 12,400 | 7,300 | 70 | 30 | 350 |
| Liquefaction (Synthoil) | 100,000 bbl/day cap.; 90% load factor | 12,400 | 9,400 | 93 | 7 | 690 |

[a] Based on conditions in Beulah, N.D., EPA-600/7-77 Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States; Feb. 1977, by H. Gold, et al.

[b] Water requirements in process, flue gas desulfurization, waste disposal, pond evaporation, and others

Table 2.5.2. Surface Water Discharges from Major Basins and Water Requirements for Energy Development

| Basin | Discharge (cfs) | | Energy Requirements [a] | |
|---|---|---|---|---|
| | Mean Annual | 95% Monthly Exced. | cfs | % of 95% Exceed. |
| Missouri | 70,800 | 13,400 | 1,938 | 14.5% |
| Arkansas-White-Red | 92,900 | 7,700 | 1,036 | 13.5% |
| Upper Mississippi | 187,000 | 43,700 | 3,327 | 7.6% |
| Ohio | 276,000 | 42,200 | 3,000 | 7.1% |
| Great Lakes [b] | 201,900 | 116,000 | 2,334 | 2.0% |
| Lower Mississippi | 615,000 | 150,000 | 55 | <1% |
| Souris-Red-Rainy | 9,300 | 450 [c] | 3 | <1% |

[a] Steam electric power and synfuels plants for Recent Trends Scenario in 2020; wet cooling towers assumed for cooling. Includes only energy facilities in the study region.

[b] Based on outflow of Lake Erie into the Niagara River.

[c] Minimum monthly flow.

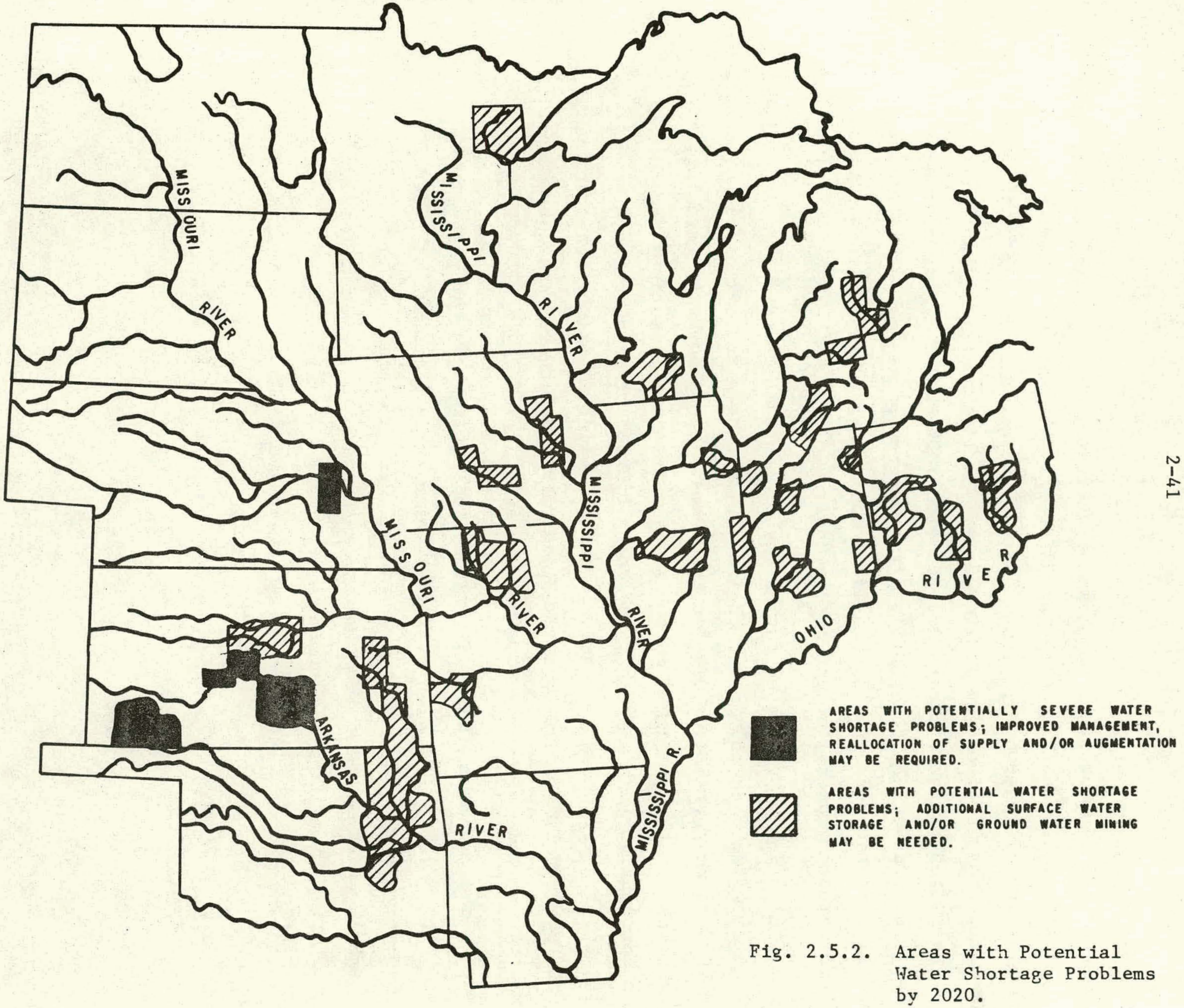



Fig. 2.5.2. Areas with Potential Water Shortage Problems by 2020.

the Recent Trends Scenario in 2020 can be sited on or near these major water resources without creating major water shortages for competing users. About 14.2% of the regional capacity (or 93,000 MW) for this scenario would require development of reservoirs, ground water, or other enhancement of water supply in water-short regions (see Fig. 2.5.2). In limited areas, containing 1.4% of energy generation capacity for 2020 (or 9300 MW), the potential water shortages are so severe as to prohibit siting energy facilities or to require other equally drastic measures, such as interbasin transport, limiting allocation to other competing users, or use of dry cooling.

Although water needed for energy production now is only a small fraction of total water consumed in the region, it increases from 2% of all consumption in 1975 to nearly 18% in 2020 for the Recent Trends Scenario (see Fig. 2.5.3). The surface water resources must also be maintained to satisfy demands for non-consumptive instream uses, including hydroelectric power generation, navigation, water-oriented recreation, fish and wildlife maintenance, and water quality control. Identification of additional water-use conflicts can be expected as these instream requirements are further defined.

Some rivers in the study region, most of them in the western states (see Fig. 2.5.4), have high salinity, which could limit use as a water supply for energy generation. In the year 2020, 2700 MWe, or less than 1% of regional capacity, would be sited in these areas. High salt concentrations in water circulating in cooling and conversion process systems could cause scaling, fouling, and corrosion. Expensive water treatment would be required for energy facilities on these rivers. Further evaporative water loss could increase salinity.

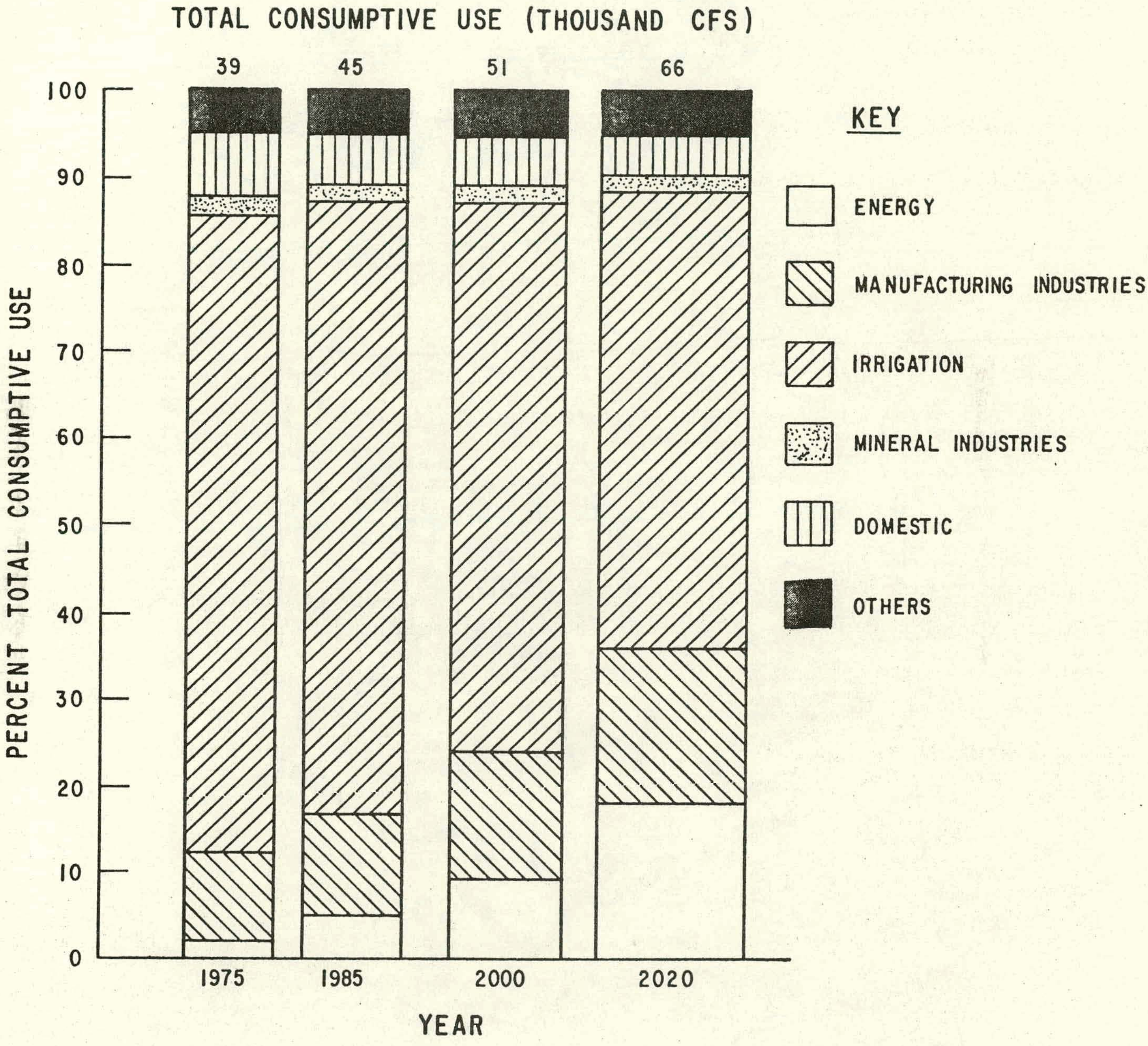



Fig. 2.5.3. Total Water Requirements for All Regional Consumptions (Recent Trends Scenario)

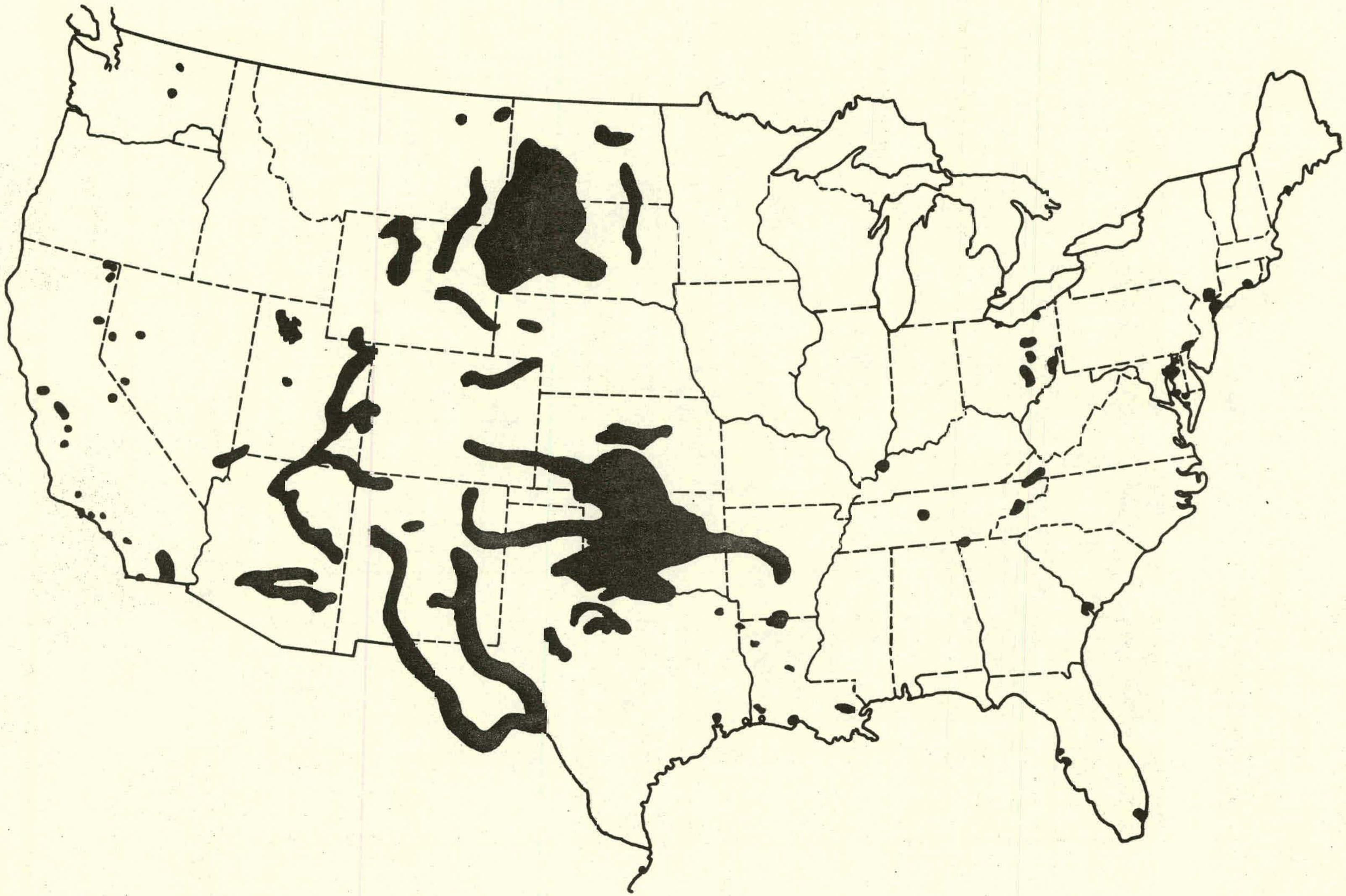


Figure 2.5.4. Areas with Potential Limitations to Energy Development due to High Salinity in Surface Waters (greater than 1000 ppm total dissolved solids)

## 2.6 COAL RESOURCES

*The regional share of total U.S. coal production declines slightly from the present 23%, but production increases in absolute terms from 140 million tons/year (mtpy) to 300 million tons/year in 2000. Constraints on coal production are not likely to impede coal production under the Recent Trends Scenario. However, problems may arise under more accelerated coal development.*

The various scenarios require the largest coal production since the immediate postwar era, requiring fairly modest to rapidly accelerated coal output. The region is expected to play a very important role in meeting these postulated increases. Production is expected to approach 200 million tons/year by 1985, an increase of about 50 million tons over 1975 levels and about 19% of expected U.S. production in 1985. This production is a slight decrease from the current proportion of U.S. coal output (23%). The region's share of total U.S. coal production is expected to continue to decline gradually after 1985. This share declines primarily because the generally high sulfur content of regional coal puts it at a competitive disadvantage relative to Montana/Wyoming coal and some Appalachian coal. After 1985, depletion in the region (except in North Dakota) can be expected to increase mining costs relative to those in the Montana/Wyoming area.

There are several potentially serious constraints on meeting the required levels of coal production in the region:

- Agricultural competition for inputs.
- Transportation system capacity.
- Reclaimability and cost associated with reclaiming mined land.
- Institutional constraints on opening new mines.
- Potentially high cost associated with mining deep reserves and low-sulfur coal.

These constraints probably will not prevent attainment of the production levels postulated in the Recent Trends Scenario but may, however, impact local areas or subsections of the region severely. Accelerated coal development under the High Coal Electric and High Synfuel Scenario increases the probability that these constraints, especially capacity of transportation systems, will limit future production.

## Level of Reserve Utilization

*Coal production in all states of the region except Kansas and North Dakota will become increasingly dependent on deep mining so that, by 2020, 45% of regional output will be supplied by deep mines in the Recent Trends Scenario. This is a sizable increase over 32% now supplied by deep mining. Except for Oklahoma, the levels of coal production considered here will not consume more than 36% of any state's reserves.*

Table 2.6.1 compares possible deep- and strip-mined production under the Recent Trends Scenario with actual 1974 figures. In the region, strip mining presently outproduces deep mining by a ratio of about 2:1. However, by 2020 this ratio decreases to about 1.2:1.0. The decrease in importance of strip mining would be even more pronounced if North Dakota's share of regional coal production did not increase so much over the period. Except for North Dakota and Kansas, all states in the region become much more dependent on deep mining. Levels of coal production increase most significantly in Illinois and North Dakota, from the current 60 and 70 mtpy to 115 and 130 mtpy in 2020.

In spite of this increasing deep mining, production by strip mining would consume more than 50% of the strippable reserve base in Ohio, Indiana, and Oklahoma under demand in Recent Trends. Yet, deep reserves are so abundant that overall reserves are not excessively consumed. Even under the Accelerated Synfuels and High Coal Electric Scenario, deep and strip production in each state is less than two-thirds of the state's reserves. In all states except Oklahoma, percentage consumption of reserves is 36% or less in this scenario. Table 2.6.2 and Fig. 2.6.1 illustrate the total consumption of reserves in each state under the Accelerated Synfuels and High Coal Electric Scenario.

## Differences in the Coal Development Options

*Coal production in Illinois and North Dakota changes most dramatically from the Recent Trends to the Accelerated Synfuels and High Coal Electric Scenario. Output in Indiana and Missouri also increases greatly under accelerated coal development, but production in the other states in the region change relatively little. Regional coal production in 2000 increases to 450 mtpy for the Accelerated Scenario and to 300 mtpy for the Recent Trends Scenario.*

Table 2.6.1. Coal Production by State and Mining Method ($10^6$ tons/year)

| | 1974 | | | 1985 | | | 2000 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Strip | Deep | Total | Strip | Deep | Total | Strip | Deep | Total | Strip | Deep | Total |
| Ohio | 31.0 | 14.4 | 45.4 | 26.5 | 24.5 | 51.0 | 34.6 | 35.9 | 70.5 | 35.9 | 45.1 | 81.0 |
| Indiana | 23.6 | 0.1 | 23.7 | 23.4 | 1.0 | 24.4 | 21.0 | 7.0 | 28.0 | 18.9 | 16.1 | 35.0 |
| Illinois | 27.0 | 31.3 | 58.3 | 24.9 | 48.3 | 73.2 | 32.5 | 75.5 | 108.0 | 43.7 | 131.3 | 175.0 |
| Missouri | 4.6 | -- | 4.6 | 7.0 | -- | 7.0 | 9.9 | 2.0 | 11.9 | 11.0 | 7.0 | 18.0 |
| Iowa | 0.2 | 0.4 | 0.6 | -- | 0.8 | 0.8 | -- | 1.1 | 1.1 | -- | 2.0 | 2.0 |
| Kansas | 0.7 | -- | 0.8 | 1.0 | -- | 1.0 | 1.0 | -- | 1.0 | 1.0 | -- | 1.0 |
| Arkansas | 0.5 | -- | 0.5 | 1.0 | -- | 1.0 | 1.5 | 0.5 | 2.0 | 3.0 | 1.0 | 4.0 |
| Oklahoma | 2.4 | -- | 2.4 | 5.0 | 2.0 | 7.0 | 6.5 | 3.5 | 10.0 | 9.1 | 4.9 | 14.0 |
| North Dakota | 7.5 | -- | 7.5 | 26.0 | -- | 26.0 | 62.0 | -- | 62.0 | 128.6 | -- | 128.6 |
| Regional Total | 97.5 | 46.2 | 143.7 | 114.8 | 76.6 | 191.4 | 169.0 | 125.5 | 294.5 | 251.2 | 107.4 | 458.6 |
| % of Total | 68 | 32 | 100 | 60 | 40 | 100 | 57 | 43 | 100 | 55 | 45 | 100 |

Table 2.6.2. State Production, 1975-2020, Relative to Reserves ($10^6$ tons)

| | Accelerated Synfuels and High Coal Electric Production | Reserves Available[a] | Percentage Depletion of Reserves |
|---|---|---|---|
| Ohio | 3,428 | 11,635 | 29 |
| Indiana | 2,108 | 5,814 | 36 |
| Illinois | 7,058 | 36,500 | 19 |
| Missouri | 1,282 | 5,768 | 22 |
| Iowa | 90 | 1,442 | 6 |
| Kansas | 76 | 1,110 | 7 |
| Arkansas | 138 | 454 | 30 |
| Oklahoma | 509 | 777 | 65 |
| North Dakota | 3,948 | 12,802 | 31 |
| Regional Total | 18,637 | 76,302 | 24 |

[a]Assumes strippable reserves are 80% recoverable and deep reserves are 50% recoverable.

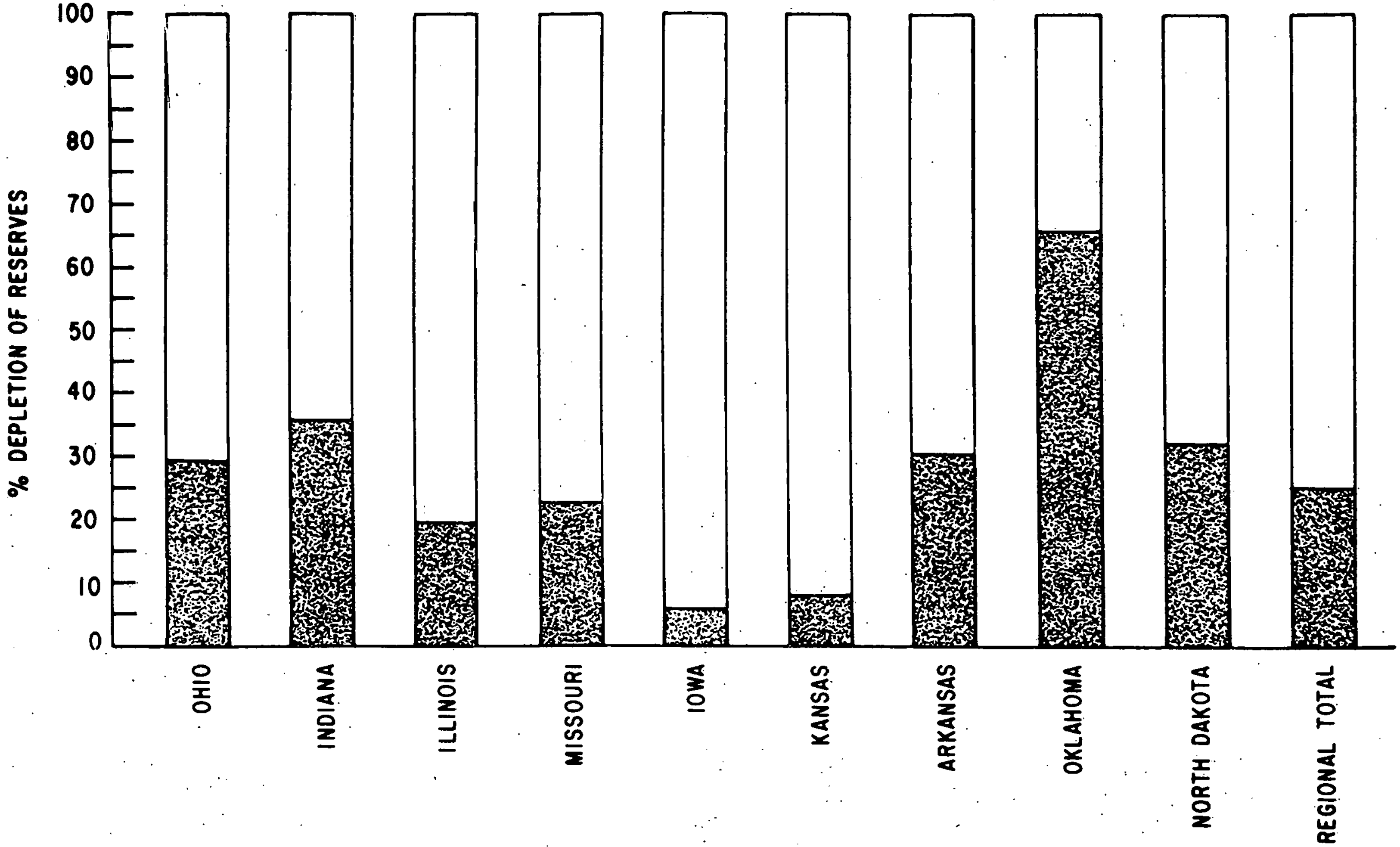



Fig. 2.6.1. Percentage Depletion of Reserves

Figure 2.6.2 shows that the divergence between regional production in the Recent Trends and the Accelerated Synfuels and High Coal Electric Scenarios increases over time. This increased divergence is due to the increasing importance of coal-based synthetic fuels as substitutes for gas and oil (under accelerated development of synfuels.) Table 2.6.3 illustrates state changes. The two leading state synfuel producers under Recent Trends conditions -- Illinois and North Dakota -- remain the leaders under accelerated conditions. Production in North Dakota increases much less than in Illinois on a percentage basis over the Recent Trends baseline because of its smaller reserve base and the likelihood of adverse reaction to the environmental effects of accelerated coal production. Ohio, Indiana, and Missouri follow in that order by 2020 as coal producers in both scenarios. Under accelerated development the differences in production among these three states narrow because synfuel production adds large increments of output to the totals in Indiana and Missouri, while output in Ohio grows less rapidly. The production levels of the other states in the region change little from the Recent Trends to the Accelerated Synfuels and High Coal Electric Scenarios.

Regional Overview

*Within the region two areas, North Dakota and Illinois, increase production significantly. These two areas account for 60% of production in 2000.**

North Dakota and Illinois will have the largest growth in absolute terms in coal production under Recent Trends conditions. One reason for this substantial increase is that both states contain abundant coal reserves that can be mined relatively cheaply and have adequate water resources nearby so that they become prime sites for synfuel conversion. Percentage growth in Arkansas and Oklahoma is rapid because of moderate interest by metallurgical industries and electric utilities. Coal production in the other states in the region increases less in percentage under the Recent Trends Scenario than in these four states because of poor coincidence between coal and water resources, the cost of mining the coal, or competition by other supply areas.

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*Other scenarios, which consider alternative levels of production for these areas, will be considered later.

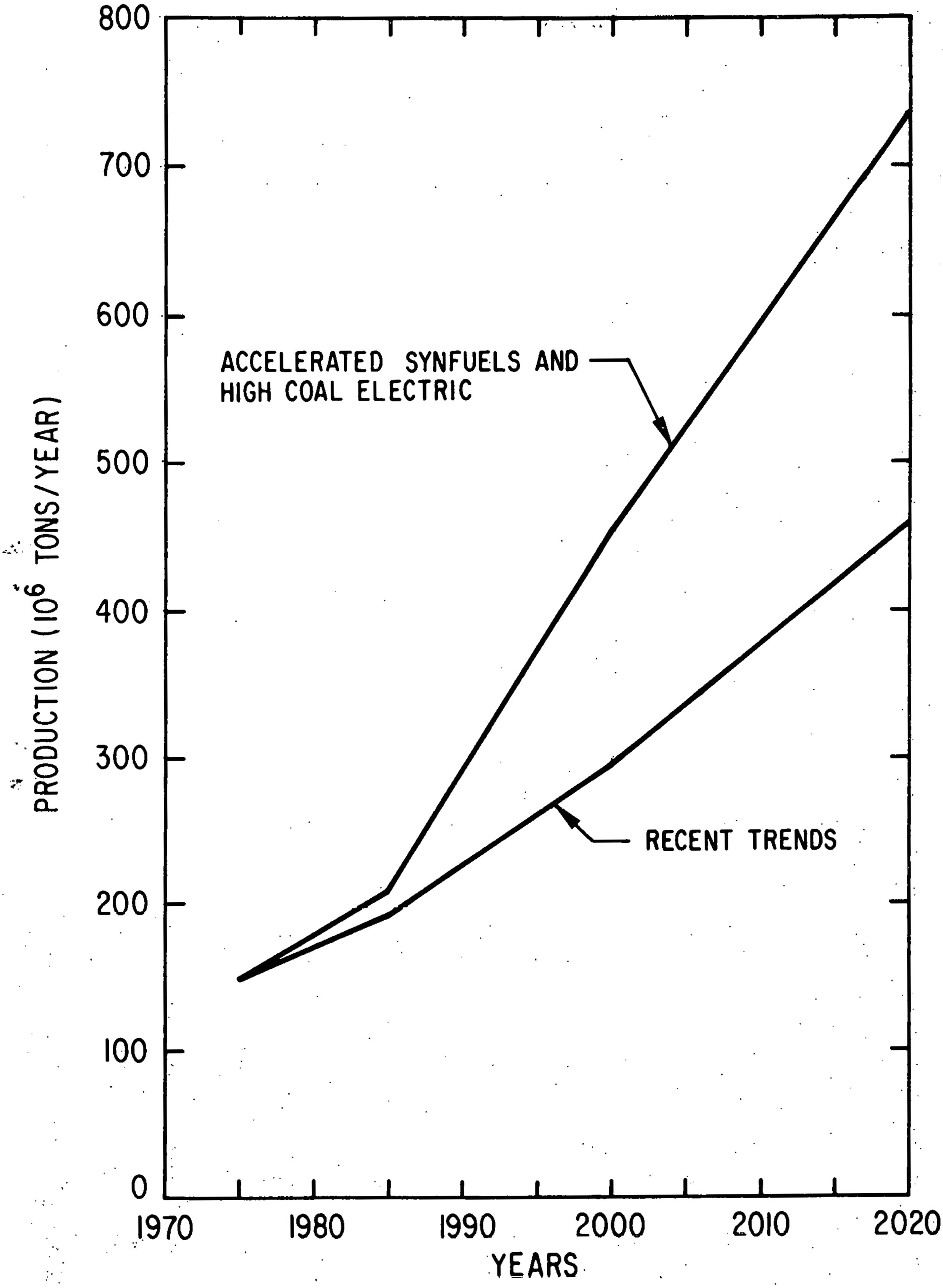


Fig. 2.6.2. Regional Coal Production Under Different Scenarios

Table 2.6.3. Production in the Region Relative to National Totals ($10^6$ tons per year)

| | 1975 | 1985 | | 2000 | | 2020 | |
|---|---|---|---|---|---|---|---|
| | Historical Data | Recent Trends | Accelerated Synfuels & High Coal Electric | Recent Trends | Accelerated Synfuels & High Coal Electric | Recent Trends | Accelerated Synfuels & High Coal Electric |
| Ohio | 46.2 | 51.0 | 51.0 | 70.5 | 84.0 | 81.0 | 109.0 |
| Indiana | 24.6 | 24.4 | 24.4 | 28.0 | 50.0 | 35.0 | 81.0 |
| Illinois | 59.5 | 73.2 | 80.2 | 108.0 | 161.0 | 175.0 | 294.0 |
| Missouri | 5.4 | 7.0 | 7.0 | 11.9 | 33.0 | 18.0 | 59.0 |
| Iowa | 0.7 | 0.8 | 0.8 | 1.1 | 2.1 | 2.0 | 4.0 |
| Kansas | 0.8 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 2.5 |
| Arkansas | 0.6 | 1.0 | 1.0 | 2.0 | 3.0 | 4.0 | 7.0 |
| Oklahoma | 2.4 | 7.0 | 7.0 | 10.0 | 12.0 | 14.0 | 20.0 |
| North Dakota | 8.5 | 26.0 | 36.0 | 62.0 | 106.0 | 128.6 | 160.0 |
| Regional Total | 148.7 | 191.4 | 208.4 | 294.5 | 453.1 | 458.6 | 736.5 |
| U.S. Total | 640.0 | 1,025.0 | 1,092.0 | 1,559.0 | 2,290.0 | 2,745.0 | 3,944.0 |
| Regional Percentage of U.S. Total | 23 | 19 | 19 | 19 | 20 | 17 | 19 |

## 2.7 LAND USE

TO BE DONE

## 2.8 AIR QUALITY

*The major issues related to regional air quality impacts and the constraints to coal utilization may be summarized as follows:*

- *National Ambient Air Quality Standards (NAAQS) (Table 2.8.1)*

  *In general, the increments in pollutant concentrations from coal utilization facilities alone are significantly less than the NAAQS. An exception is the 24-hr standard for sulfur dioxide, which will limit electrical generation capacity at a single site to about 3000 MW if existing New Source Performance Standards (NSPS) are assumed. If one assumes that this standard may be important in counties with more than 2000 MW of coal-fired capacity, a total of 36,600 MWe, or 24.6% of regional coal-fired capacity, will be affected in the year 2000.*

- *Background concentration (Figure 2.8.1)*

  *Siting of central station generation and synfuels conversion facilities is constrained because of existing or projected emissions from other sources, particularly if these sources are large enough to prevent meeting the NAAQS. If conflict occurs in areas of high emission density or where ambient standards are now violated, 70,000 MW, or 47.0% of regional coal-fired capacity, will be affected by the year 2000.*

- *Prevention of Significant Deterioration (PSD) (Table 2.8.2 and Fig. 2.8.2)*

  *The impact of the mandatory Class I areas designated in the Clean Air Act Amendments of 1977 should be minimal. Less than 1% of regional capacity will be within 50 miles of these areas in the year 2000. However, if expanded Class I designations are accepted in the future, the current allowable increment in 24-hour sulfur dioxide levels in these areas would severely constrain deployment of coal utilization technologies. If a 30-mile buffer zone is required, 45,7000 MW or 30.8% of regional capacity will be affected in the year 2000.**

*Based on location of Class I areas according to mandatory designations in the September 1975 U.S. Senate draft amendments to the Clean Air Act.

- *Sulfate and Long-Range Transport (Figure 2.8.3)*

  *A significant increase in exposure to sulfates in the central and eastern U.S., where levels are already high, is to be expected from increased use of coal in the Central Region if NSPS sulfur emission rates are assumed.*

Table 2.8.1 NAAQS and Estimated Maximum Concentrations from Coal Utilization

| Pollutant | Type of Standard | | | NAAQS | 3000 MW | HYGAS[a] Gasification $250 \times 10^6$ scf/day | Midwest Recent Trend Scenario (2020) |
|---|---|---|---|---|---|---|---|
| Sulfur dioxide | Primary | 24 hr | Annual Max.[b] | 365 | 250-450 | 21-25 | --- |
| | | 1 yr | Arith. Mean | 80 | 2.4 | 0.2 | 5.9 |
| Particulate matter | Secondary | 24 hr | Annual Max. | 150 | 21-41 | 1.8-2.1 | --- |
| | | 1 yr | Geom. Mean[c] | 60 | 0.2 | 0.02 | 0.5 |
| Nitrogen oxide | Secondary | 1 yr | Arith. Mean | 100 | 1.4 | 0.1 | 3.5 |
| Carbon monoxide | Primary | 1 hr | Annual Max. | 40,000 | 15-30 | 1.3-1.5 | --- |
| | Secondary | 8 hr | Annual Max. | 10,000 | 10-20 | 0.8-1.0 | --- |

[a] Ranges for short-term concentration reflect alternate windspeed and load factors. For the gasification alternate windspeeds are used with a constant load factor.

[b] Annual maximums are values not to be exceeded more than once per year.

[c] As a guide to be used in assessing implementation plans for achieving the annual maximum 24-hour standard. Computed concentrations for facilities are arithmetic mean.

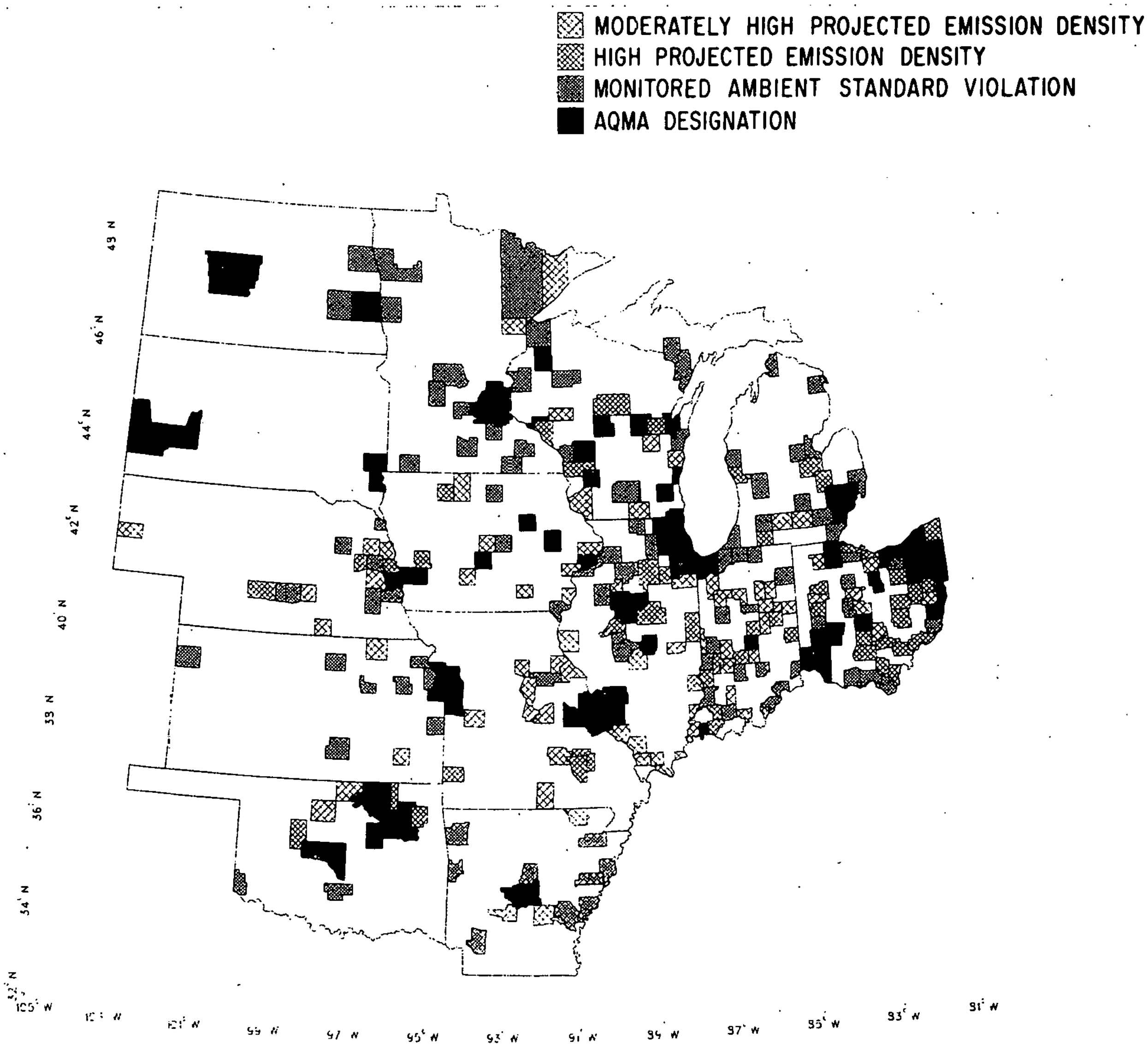


Fig. 2.8.1. County Classifications Based on Existing and Projected Emissions and Air Quality

Table 2.8.2 Proximity of Sited Coal Facilities to Mandatory Class I Areas and Expanded Class I Areas (2000)

Expanded Class I Areas [a]

| Distance Class I Area Miles | Cumulative Capacity within Given Distance, MW | |
|---|---|---|
| | Recent Trends | High Coal Electric |
| 10 | 14,272 | 17,314 |
| 20 | 34,665 | 39,431 |
| 30 | 45,670 | 54,240 |
| 40 | 60,181 | 69,146 |
| 50 | 75,499 | 79,174 |
| Total Regional Coal Capacity | 148,501 | 176,236 |

Mandatory Class I Areas

| Distance Class I Area Miles | Cumulative Capacity within Given Distance, MW | |
|---|---|---|
| | Recent Trends | High Coal Electric |
| 10 | 0 | 0 |
| 20 | 0 | 0 |
| 30 | 102 | 102 |
| 40 | 640 | 640 |
| 50 | 696 | 696 |
| Total Regional Coal Capacity | 148,501 | 176,236 |

[a] Includes International Parks, National Parks, National Wilderness Areas, National Wildlife Refuges, National Monuments, National Recreational Areas, Wild and Scenic Rivers, and National Lakeshores and Seashores.

[b] Includes International Parks, National Parks, National Wilderness Areas, and National Memorial Parks.

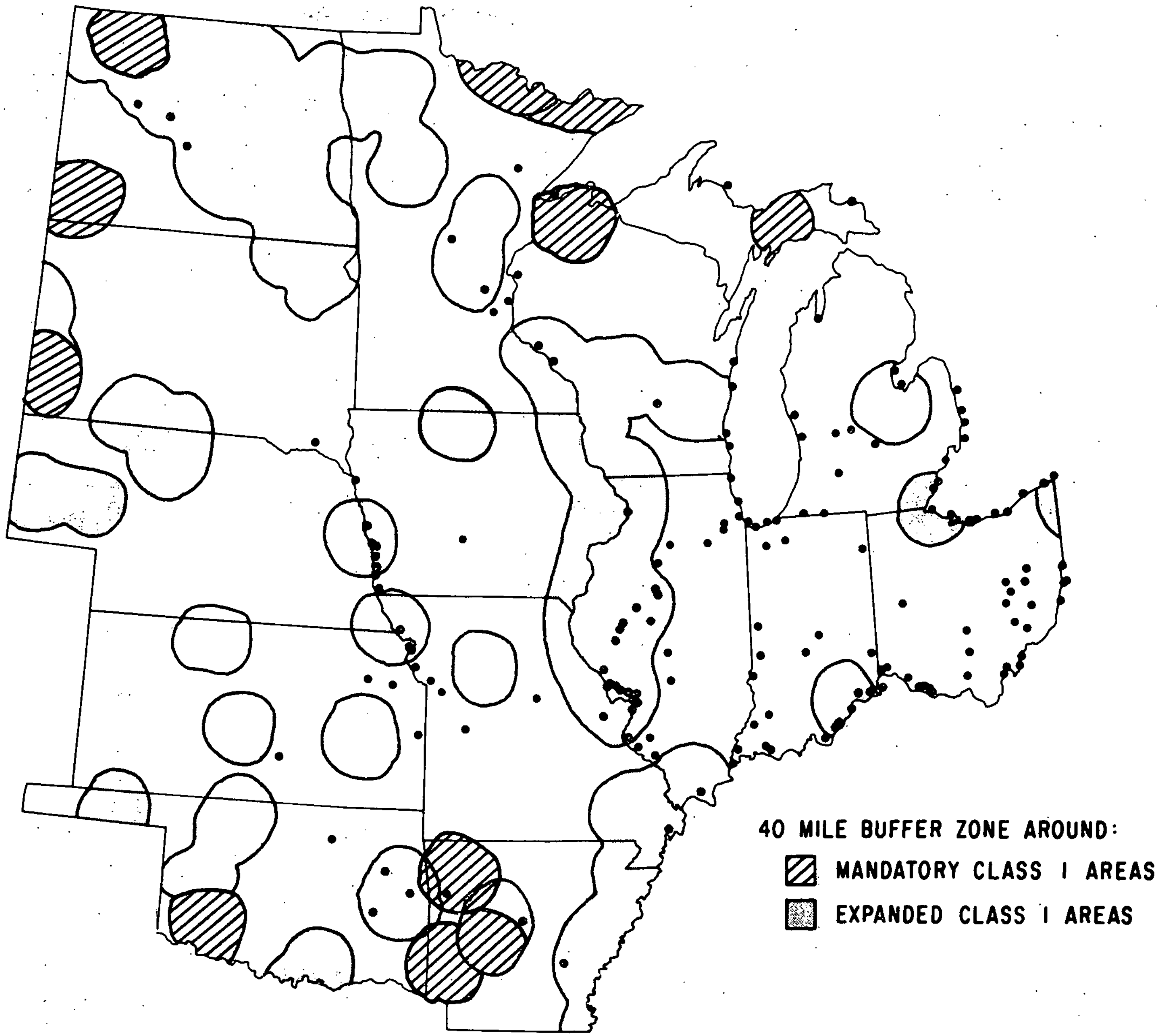


Fig. 2.8.2. 40-Mile Buffer Zone around Class I Areas Superimposed on Sites of Coal-Fired Generating Facilities above 500 MW (Recent Trends, 2020)

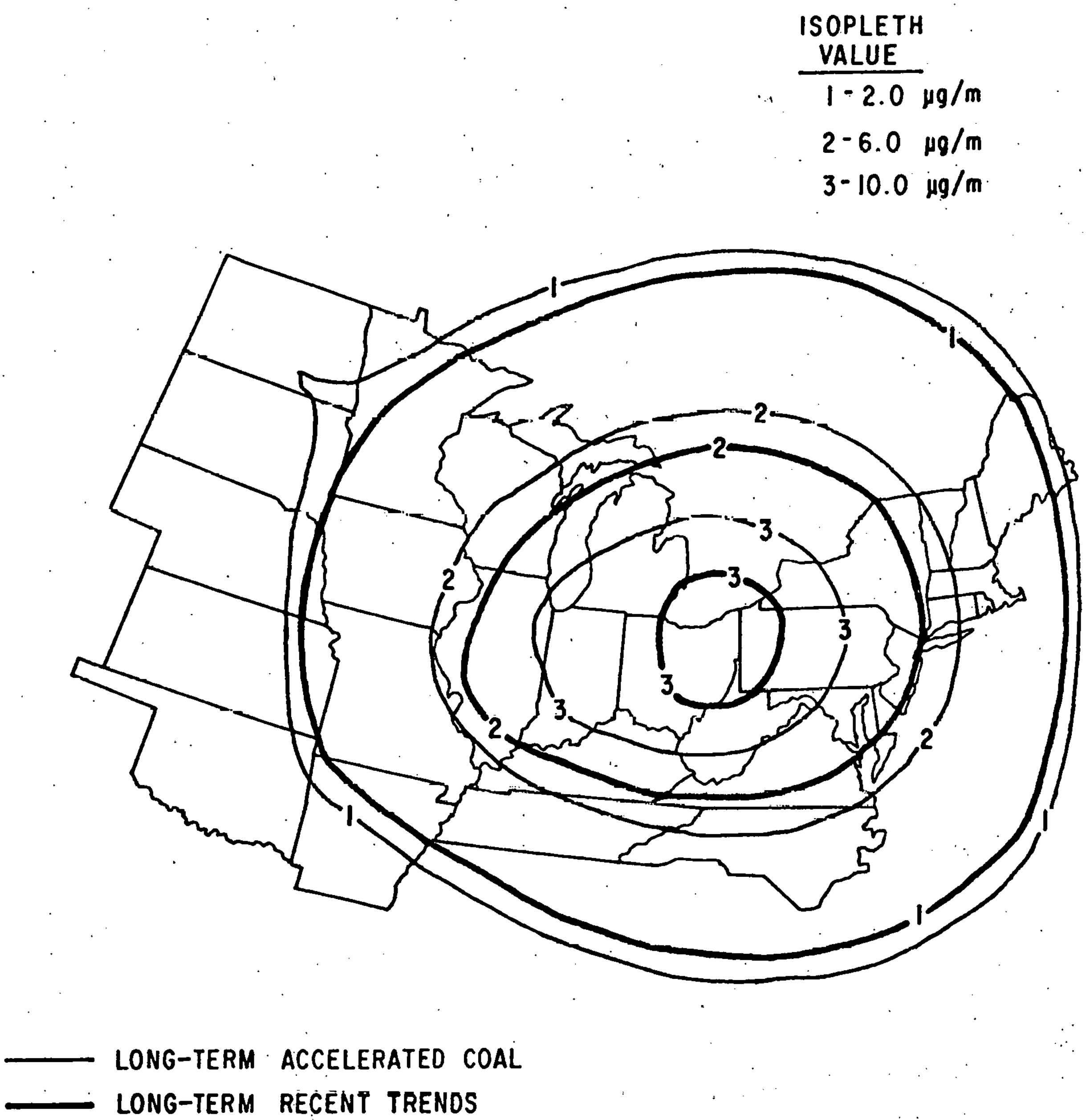


Figure 2.8.3 Annual Regional Sulfate Concentration Resulting from Recent Trends and Accelerated Coal Scenarios (2020)

The relative flatness of the area and favorable atmospheric conditions reduce pollution from coal facilities. This flatness prevents impact of plumes with high-level land, which leads to localized maximum levels of pollutants. Additionally, the region has, in general, good meteorological conditions for dispersion of pollutants. Good ventilation occurs throughout the region and stagnation conditions are rather infrequent.

Existing air quality throughout the region largely depends on locality and the proximity to major sources. The air quality in some areas may constrain the construction of new coal utilization facilities because high existing concentration levels reduce how much more pollution will result in standards being exceeded. In general, levels of total suspended particulates (TSP) are very high throughout the region. Whether this constrains coal development, to any large extent, is uncertain, since coal utilization facilities add little to the regional levels of TSP.

Sulfur emission is the major air pollutant that could limit future coal utilization. The increase in annual sulfur dioxide levels due to new facilities will probably not be sufficient to violate the National Ambient Air Quality Standards (NAAQS). However, the 24-hr $SO_2$ standard may be exceeded near large coal-fired power plants. In addition, proposed Prevention of Significant Deterioration (PSD) regulations could place major limits on siting. The regulations on $SO_2$ appear to be those most restrictive to future coal development.

Another regional air quality issue is the contribution of sulfur emissions to sulfate levels in the midwest and in the east, where levels are already high. Use of a regional model for sulfur transport and transformation suggests that incremental increases of several $\mu g/m^3$ can occur due to future coal utilization in the region. The magnitude of the impacts of sulfates from emissions appears to depend more on the total emissions of sulfur in the region than on how these emissions are distributed throughout the region.

All future air quality impacts and constraints on coal utilization cannot be predicted. Future impacts will depend to a large extent on new regulations on ambient air quality and emissions, which depend on future technologies and the demand for coal-fired generating capacity versus the demand for maintenance of good air quality. However, applying present regulations to future impacts of coal use indicates that air-quality constraints may arise and must be dealt with.

Differences in Coal Development Options

*The primary effects of increased coal development are an exacerbation of siting constraints relative to PSD areas and an increased exposure of the population to sulfates.* For the High Coal Electric Scenario, 95,000 MW of coal-fired generation capacity is sited within 30 miles of expanded mandatory Class I areas* in 2020 compared to 83,000 MW for the Recent Trends Scenario. Similarly, ilarly, the population exposure to sulfates in the central and eastern U.S. increases by 22% in the High Coal Electric Scenario. The maximum increment in annual average concentration for sulfur dioxide is less than 7.1 $\mu g/m^3$, (8.9% of the NAAQS) for the High Coal Electric Scenario and 6.7 $\mu g/m^3$ for the Recent Trends. The constraints due to 24-hour NAAQS for sulfur dioxide relate to impacts from individual sources, and thus are only indirect in related total regional coal development.

Impact of Coal Fuel Cycle Components

*The largest impact of the coal fuel cycle on concentrations of pollutants currently regulated is associated with direct combustion for electrical generation.* For this primary emission source, because of limits for maximum 24-hour sulfur dioxide concentration, a minimum distance of 30 miles will be required between Class I PSD areas and facility sites of 1000 MW at NSPS emission rates. NAAQS for 24-hour sulfur dioxide levels also either limit electrical generation by coal combustion at a single location to 2000 - 3000 MW or require advanced emission control below NSPS (see Table 2.8.1). The largest fraction of criteria pollutant emissions from synfuels conversion is also from direct combustion to product process energy; however, these energy requirements from combustion are typically about 20% of those for electrical generation per ton of coal consumed. The potential for emission of hazardous hydrocarbons from synfuels conversion requires further evaluation. Emissions in the coal fuel cycle also result from extraction, processing, and transportation of coal. However, these emissions total only a few percent of those from direct coal utilization and cause appreciable air quality problems only in localized areas.

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*Based on September 1975 U.S. Senate draft amendments to the Clean Air Act.

Regional Overview

*In general, the siting constraints due to existing air-quality problems are more prevalent in the industrialized eastern part of the region.* The existing air quality problems in the east are in many cases related to high particulate levels and photochemical oxidants, which, in comparison to sulfur dioxide, may have a more limited effect on coal development upon closer examination.

Because of proximity to major population centers, the resultant exposure to sulfates is greater for facilities located in the eastern part of the region. For example, the population exposure to sulfates from a unit emission in Ohio is approximately double the population exposure from a similar emission in North Dakota.

## 2.9 WATER QUALITY

*The impact of coal development on water quality is closely tied to the water availability, with impacts primarily restricted to areas with insufficient water. Coal mining will continue to have a significant impact on water quality in smaller streams draining the major coal regions unless strict control is maintained. Coal conversion plants may cause localized pollution; however, characteristics of effluents from these plants are not well known.*

### Differences in Coal Development Options

*The water-quality problems will be proportional to levels of coal development in the region, with more problems likely with the Accelerated Synfuel Scenario than with the High Coal Electric Scenario. This difference is due to the difference between estimated effluents from coal-conversion plants and those for electric power plants. The High Coal Electric and Accelerated Synfuel Scenario in 2020 may yield 20 to 50% greater increases in water pollution than the Recent Trend Scenario.*

### Impact of Coal Fuel Cycle Components

*The major impacts on water quality appear to be from acid or alkaline mine drainage and coal-conversion plants. Major uncertainties result from incomplete data on coal-conversion effluents, questions of degree of treatment applied to air and water pollutants, and indirect effects associated with urban development in an area of high coal production or conversion.*

Waste streams from coal-conversion processes differ widely in potential water pollutants and pollutant concentrations. Uncertainty remains as to the characteristics of the treated effluent from these conversion processes, including those now under experimentation. Figure 2.9.1 shows the assimilative capacity of several rivers in the region to support a number of coal gasification plants. The data are based on a preliminary estimate of the controlled discharge from these plants. Manganese, ammonia, selenium, cyanide, and phenols appear to be the limiting parameters for water quality, although several exotic organic and inorganic compounds, such as thiocyanate, may eventually prove to be more limiting. Mercury, although not shown in the figure, may exceed standards for water quality and be the most limiting trace element. If complete

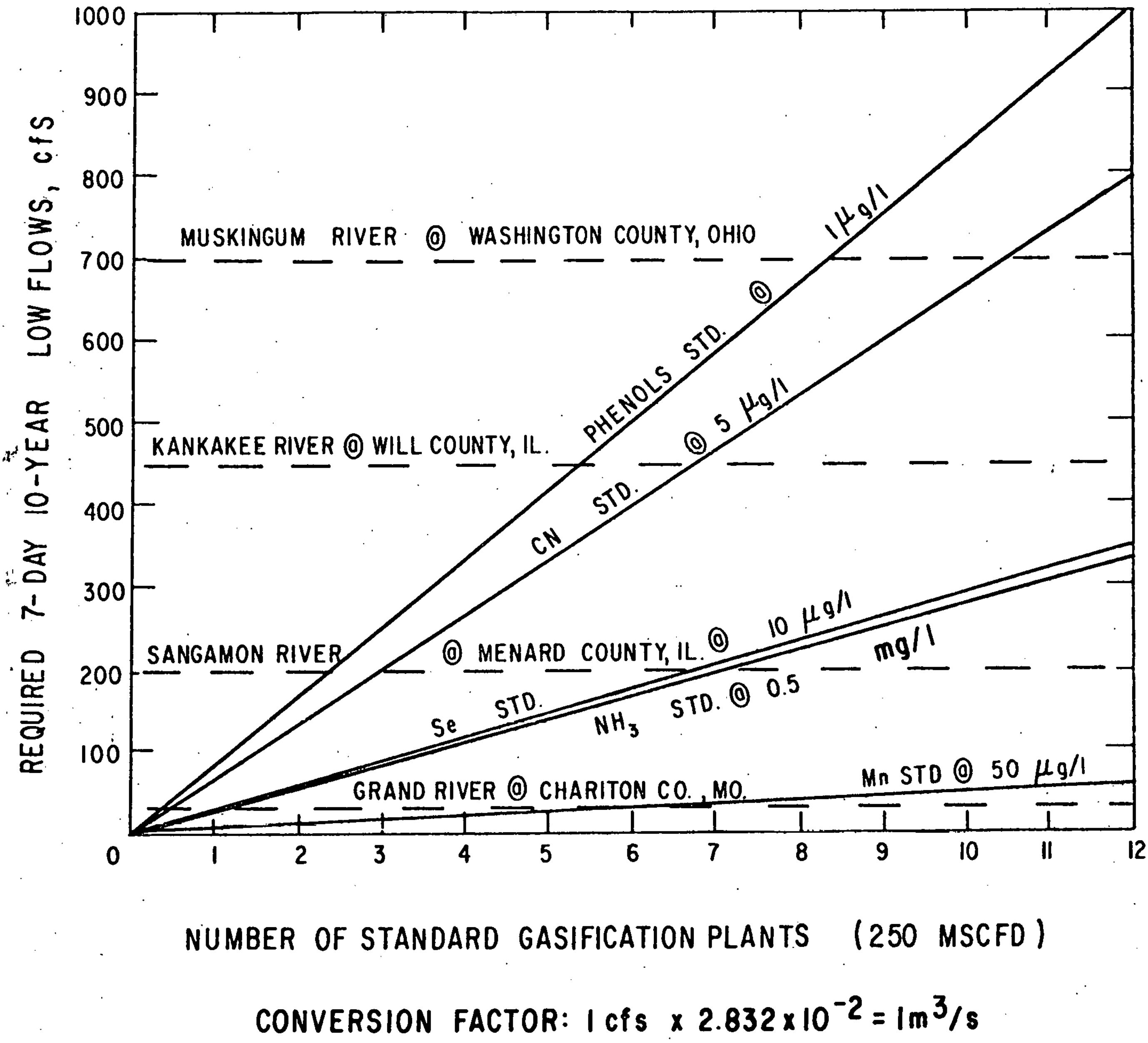



Fig. 2.9.1 Limitation on the Number of Coal Gasification Plants Based on Low-Flow Conditions and Water-Quality Standards

control of effluents is attained through zero discharge, the problems will be those of disposal of solid wastes, potential runoff, or groundwater pollution.

Power plants create uncertainty because of questions on the degree of pollution control that will be used. If closed-cycle cooling is used, thermal pollution will be minimized, but cooling tower blowdowns may create localized problems. Air-pollution control through flue-gas desulfurization would create problems in solid-waste handling, which could result in localized water-quality problems. Deposition of air pollutants, on the other hand, through dry or wet fallout can increase concentrations of trace elements in receiving waters. If the New Source Performance Standards are met, direct discharge of water pollutants from power plants will, under most conditions, be insignificant if the plants are sited on the larger streams in the region.

Effects of coal mining will be limited primarily to smaller streams draining the major coal fields. The study region already has areas of significant acid mine drainage in the east and alkaline mine drainage in the western states. These acid and alkaline conditions depend more on the chemical composition of the drainage than on the type of mining (surface or deep). Acid mine drainage is high in iron, sulfates, manganese, and dissolved materials. Ferric hydroxide deposits create the most significant effects on smaller streams. Alkaline mine drainage has lower iron concentrations and will have its most significant impact in increasing the salinity (dissolved solids) of some waters.

A major uncertainty for mine drainage, and particularly acid mine drainage, is whether the New Source Performance Standards for coal mining can be met for all future mining. Control of abandoned mines has been especially difficult. Table 2.9.1 shows the wide range of pollutant loadings possible for the Muskingum River Basin in Ohio; the amounts depend on whether control to achieve the standards is attained. Standards have been promulgated for pH, iron, manganese, and total suspended solids on the assumption that other parameters will decrease proportionally if these standards are maintained.

The indirect effects of urban development in areas of high coal activity are not well understood. The development, however, can be expected to increase levels of various pollutants such as nutrients, dissolved and total solids, and organic wastes. This effect might be the most significant water-quality impact of coal development; more studies are needed.*

*Analysis of urban or conjunctive development will be initiated in the near future.

Table 2.9.1 Estimated Loadings of Iron, Manganese, and Total Suspended Solids for the Muskingum River Basin in Ohio Based on Controlled and Uncontrolled Effluents[a]

| | Effluent Concentrations, mg/l | | | Loading, $lb \times 10^4/day$[b] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | uncontrolled[c] | | controlled[d] | 1985 | | 2000 | | 2020 | |
| | deep mines | surface mines | | uncontrolled | controlled | uncontrolled | controlled | uncontrolled | controlled |
| Iron | 352 | 52 | 3.0 | 10.8 | 0.43 | 19.2 | 0.72 | 25.2 | 0.91 |
| Manganese | 7.3 | 45.1 | 2.0 | 6.0 | 0.28 | 10.0 | 0.48 | 12.4 | 0.60 |
| Suspended Solids | 228 | 549 | 25.0 | 74 | 5.0 | 125 | 8.4 | 156 | 11 |

[a]based on Combined High Coal Electric-Accelerated Synfuel Scenario

[b]Conversion factor: $10^6$ lb/day = 5.25 kg/s

[c]EPA estimate (See Ref. 1 in Section 7.2)

[d]New Source Performance Standard

Regional Overview

Within the region, great differences exist in the location and quality of coal reserves and in the availability of water resources to assimilate wastes. An overall indexing system based on the dilution capacity of the watershed and the planned coal activity in 2020 is presented in Table 2.9.2. The greatest relative effects of coal development appears to be in the Missouri River Basin, where sufficient dilution water may not be available for assimilation of waste water from coal conversion facilities and mine drainage. The standards for iron, manganese, ammonia, sulfates, and total dissolved solids (salinity) will probably be exceeded more than now and in more locations in this river basin. High salinity is already a significant problem in this region. (See Water Availability in Sec. 2.5).

The Ohio River Basin will have increased problems, primarily with acid mine drainage, if strict adherence to federal guidelines for future development is not maintained. Deep coal mining is expected to increase by 350% by 2020 in this basin. For the Illinois River within the Upper Mississippi River Basin, coal activity will significantly increase. A case study in the region showed that standards for ammonia, sulfate, mercury, copper, and manganese will be exceeded more often than now. The same conditions that influence water availability, low-flow conditions, seasonable variability, and increasing demands by competing water users, will diminish the capacity of streams to assimilate these wastes.

A large increase, from 210 MW to about 17,000 MW, by 2020 is expected for the Arkansas-White-Red River Basins. However, these plants will probably be built on the main stems of the major rivers; thus the impacts on water quality will be minimal. Some impact of coal mining in this area is also expected. Little impact on water quality is expected in the Lower Mississippi, Red-Souris-Rainy, and Great Lakes River Basins. Large additions of power-plant capacity are expected in the Great Lakes Basin, but most of that will use the dilution capacity of the Great Lakes. Thus, impacts on water quality should be localized.

Table 2.9.2 Ratios of Impacts for Coal Power Plants and Coal Gasification in Major River Basins to the Year 2020[a]

| River Basin | 7-day, 10-yr Low Flow (cfs) | Power Plant Impact Index (MW/cfs) | Coal Conversion Impact Index (units/1000 cfs) |
|---|---|---|---|
| Ohio | 44,820 | 3.40[d] | 0.66[d] |
| Upper Mississippi | 47,810 | 1.38 | 0.46 |
| Lower Mississippi | 12,145[b] | 0.24[d] | - |
| Missouri | 10,225 | 4.36 | 1.76 |
| Arkansas-White-Red | 5,570[c] | 2.99 | - |

[a]Based on incremental changes to year 2020 and maximum coal development.

[b]Inflows from other river basins were subtracted.

[c]Includes the sum of Arkansas, White, and Red Rivers.

[d]Values doubled because coal development considered to be equal on the other side of Ohio and Lower Mississippi Rivers.

## 2.10 ECOSYSTEM IMPACTS AND CONSTRAINTS

*The major issues due to impacts on terrestrial or aquatic systems that may restrict coal use in the region are $SO_2$ fumigation, important recreational and endangered species, sequential siting along a water's edge, and maintenance of minimum stream flow.*

- Sulfur dioxide is the only primary gaseous effluent likely to reach concentrations that could cause acute visible injury to terrestrial biota. Potential 24-hr dose $SO_2$ levels from a 3000-MW plant are within the acute injury range for sensitive vegetation and approach the threshold injury level for plants of intermediate sensitivity (Fig. 2.10.1). Soybeans, grain, vegetables, and pasture and forage crops, which are sensitive to $SO_2$, are grown in the region. The total area in which visible $SO_2$ injury to sensitive vegetation may occur from a cluster of 12 model plants (three plants on each corner of a township) exceeds 22,000 acres. The frequency of occurrence of meteorological conditions leading to these conditions is being computed.

- Direct or indirect impacts from construction and operation of power plants to lake-run salmon and trout in the Great Lakes Drainage Basin or endangered aquatic biota (Table 2.10.1) may restrict coal development in areas defined as either spawning habitat for the salmon or critical habitat for the endangered species. Several Great Lake states have been actively stocking and managing salmonid populations since the fish were first introduced to the Lakes. These states will be sensitive to potential impacts from the construction and operation of power plants on Great Lakes basin tributary rivers. Any activities that could affect federally endangered species or their critical habitat would be prohibited.

- Two other factors resulting from power plant operation, sequential siting along a river or lake and the minimum stream flow necessary to maintain stream life, may constrain coal development. The combined effects of sequential power plant sitings is not well understood (e.g. Are the effects independent or synergistic?) The distance necessary between power plants to allow mobile aquatic organisms

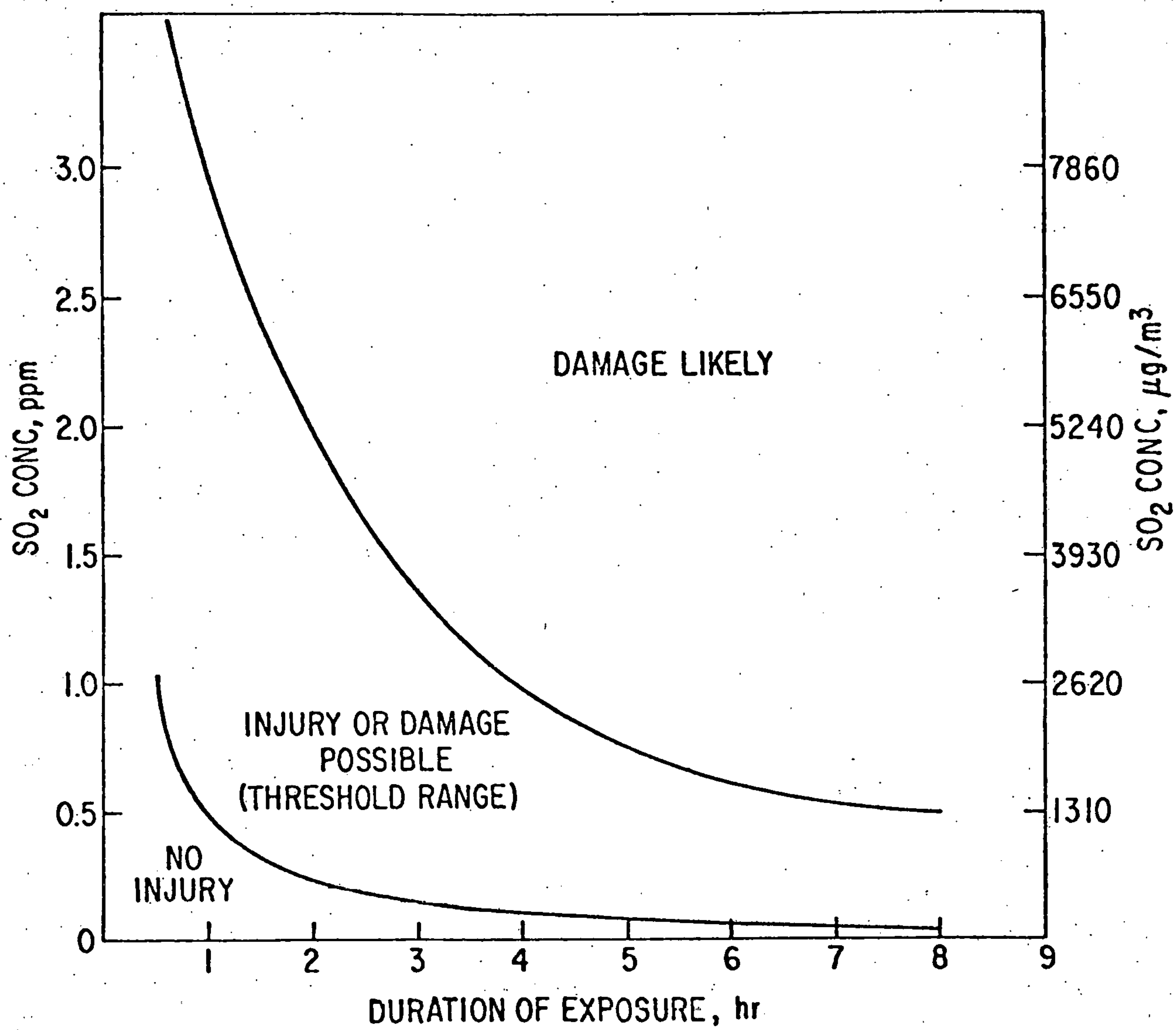



Fig. 2.10.1. $SO_2$ Dose-Injury Curves for Sensitive Plant Species.

Table 2.10.1. Endangered Aquatic Species and their Location within the Region

| Species | Location[a] |
|---|---|
| Curtis' Pearly Mussel | Black River, Missouri |
| Fat Pocketbook Pearly Mussel | White River, Arkansas<br>St. Francis River, Arkansas and Missouri |
| Higgin's Eye Pearly Mussel | Mississippi River, Minnesota and Wisconsin<br>Meramec River, Missouri<br>St. Croix River, Minnesota and Wisconsin |
| Sampson's Pearly Mussel | Wabash River, Indiana and Illinois |
| Tuberculated-Blossom Pearly Mussel | Lower Ohio River, Illinois |
| White Cat's Paw Mussel | Detroit River, Michigan<br>St. Joseph River, Michigan, Ohio, and Indiana |
| Pink Mucket Pearly Mussel | Muskingum River, Ohio |

[a]Federal Register Vol. 41, No. 115, p. 24064, June 14, 1976.

to recover from the impacts of impingement, entrainment, and effluent discharges may restrain siting along a water's edge to reduce impacts to an acceptable level. Changes in the flow regime of a river may affect critical components in the structure and function of the ecosystem. Such a change could reduce the amount of drifting invertebrates, which could reduce the food supply to a fish community. This reduction could ultimately reduce in number the high-order consumers by inter- and intraspecific competition for food.

## Differences in Coal Development Options

*The major issues of aquatic impact remain the same for different coal development options but the probability of* $SO_2$ *fumigation increases with the High Coal Electric Scenario.*

The major issues of aquatic impact remain about the same because siting patterns for electrical generating facilities and water consumption change very little with the coal-development options. The High Coal Electric Scenario results in a shift from nuclear power to coal, e.g., from no $SO_2$ emission to a point source of $SO_2$. The increase in $SO_2$ and consequent rise in potential of impacts to vegetation depend on the presence or absence of $SO_2$-sensitive species and the probability and frequency of a dose sufficient to result in plant injury; both of these conditions are site- and area-specific.

Two other aquatic issues, acid mine drainage (AMD) and acidic precipitation could increase under a High Coal Electric Scenario. Increased mining of some Midwestern coal deposits, particularly in Ohio, Illinois, and Missouri, which contain acid-forming pyrites, can result in the formation of AMD, with a consequent increase in acidity in receiving waters. Although water-treatment plants may control AMD, the chemical neutralization results in an increase in the total dissolved ion in receiving streams. The $SO_x$ and $NO_x$ from coal-fired electrical generating facilities have enhanced acidic precipitation in the Northeastern U.S. and Canada, and data exists on rain of below normal pH (<5.6) falling on most of the U.S. east of the Mississippi River.

## Regional Overview

The regional analysis on the potential effects of sulfur dioxide on agricultural crops and aquatic ecosystems, along with resultant constraints, continues. Figure 2.10.2 shows the selected river areas and watersheds in the region being assessed for future coal and power development. The distribution of $SO_2$-sensitive agricultural species, expressed as a percentage of the total county, is being graphically displayed. Overlaying these maps with isopleths showing short-term high concentrations, and probability and frequency of occurrence, will show areas within the region where impacts on agricultural species are possible; this analysis is being conducted.

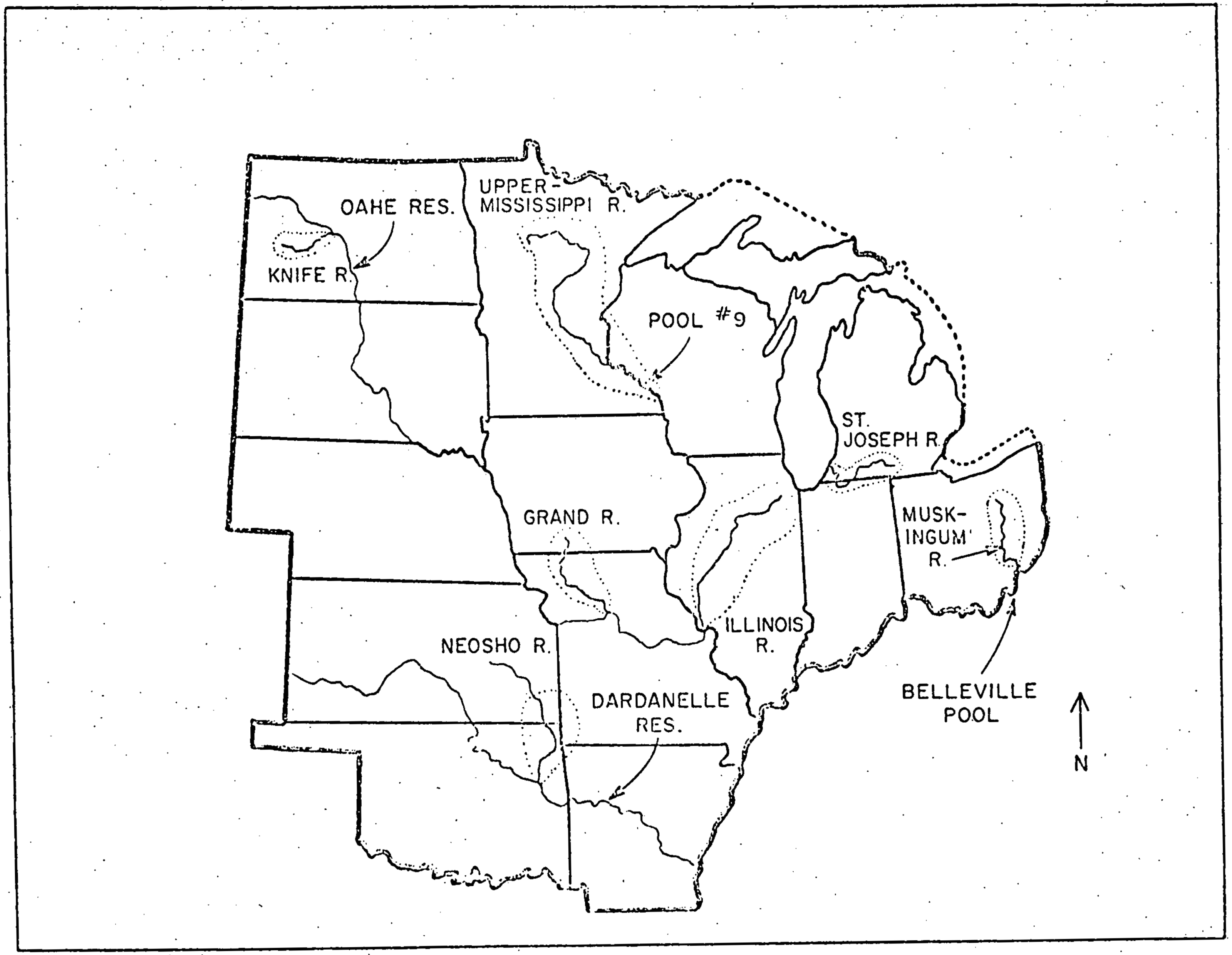



Fig. 2.10.2. Selected River Areas and Watersheds in the Region

## 2.11 TRACE ELEMENTS

*Trace element emissions from conventional coal combustion have been studied sufficiently to allow emission rates to be calculated; however, data on these emissions from coal gasification are inadequate. In general, because coal utilization contributes small amounts of trace elements for the cases examined, relative to background, problems are expected in areas with high existing levels. Conservative assumptions on projected trace element concentrations from the Recent Trends Scenario option in the Illinois River have resulted in concentrations exceeding Illinois Drinking Water Standards for arsenic, cadmium, copper, iron, lead, mercury, and manganese. Projections of air quality result in violations of suggested acceptable levels for lead and manganese. Arsenic emissions might adversely effect vegetation with a low tolerance, e.g., soybeans, and cadmium and selenium emissions might adversely affect animals. Impacts on aquatic systems may occur in smaller drainage basins, such as the Big Muddy and Kaskaskia, which lack sufficient dilution to prevent measurable increases in trace elements.*

### Direct Combustion

The increased trace-element concentrations on submicron particles during direct combustion is a problem because control devices for total suspended particulates are least efficient for particles less than one micron. A 1000-MW coal plant operating at 100% capacity and equipped with an electrostatic precipitator having a collection efficiency of 99.5% will emit 1.9 tons/day of fly ash using Illinois No. 5 coal or 3.0 tons/day using Wyoming coal. About 3% of the 1.9 tons/day is composed of arsenic, barium, cadmium, chromium, cobalt, lead, manganese, mercury, selenium, vanadium, and zinc.

### Gasification Facilities

The only data on emission of trace elements from gasification facilities were obtained from a limited-batch process rather than a continuous steady-state operation. Data obtained from the Synthane gasifier indicate that trace elements are concentrated in the residual char. Burning this char in the utility plant boiler might release trace elements to the atmosphere in concentrations a factor of 4-5 times over what would normally be released from a boiler of that size.

The waste water from an SNG plant contains trace elements that would require removal. To date, only iron, copper, zinc, and chromium concentrations are controlled in wastewater streams by electric utilities.

## Extraction

The level of trace element inputs to river systems from extraction depends upon: (1) effluent limits specified in the discharge permits issued to mining companies; (2) availability of water in the receiving body to dilute these effluents; and (3) compliance by mining companies with discharge permits. Water leached from collected fly ash, bottom ash and FGD sludge ponds can have concentrations of trace elements that could violate quality standards.

## REGIONAL OVERVIEW

*The assessment of trace elements is a continuing special study of the drainage basin of the Illinois River. Therefore, projections throughout the region have not been made. The amounts the human body would take up for exposure to trace elements in the atmosphere and in surface water are much less than in the diet.*

## 2.12 SOCIAL AND ECONOMIC IMPACTS

*A large amount of the coal development in 1975-2020 occurs in counties with susceptibility for much local socioeconomic impact. The amount of electrical generation from coal burning and the development of synthetic fuels in high-impact counties are shown below:*

- *High-Impact Areas 1975-1985*

  *37.7% of power addition, or 5,100 MW*
  *100% of high-Btu gasification additions*

- *High-Impact Areas 1985-2000*

  *31.6% of power addition, or 12,800 MW*
  *100% low-Btu gasification additions*
  *85.8% high-Btu gasification additions*
  *100% liquefaction additions*

- *High-Impact Areas 2000-2020*

  *45.2% of power addition, or 53,000 MW*
  *66.7% of low-Btu gasification additions*
  *88.9% of high-Btu gasification additions*
  *83.3% of liquefaction additions*

The timing and magnitude of such local impacts, and whether they will prove beneficial or detrimental, depend on both the host community and the coal technology to be sited there. The combination of the assimilative capacity (its ability to absorb major development) of the local area and the relative employment and capital requirements of the technology uniquely determine these impacts. Economic and demographic characteristics of the local area govern its assimilative capacity. Examples of these characteristics include:

- the size and age/sex composition of the community or county population;
- the density of settlement in the impact county and adjacent areas within commuting distance;
- the amount of secondary (i.e., retail, commercial, and service) employment relative to basic employment in the county; and
- the size and location of nearby regional trade centers.

While these impacts are primarily local, in some areas in the region they are likely to be severe because of economic and demographic conditions and the potential for coal development. For example, localized adverse impacts are likely in the Fort Union Coal Basin of North Dakota. Adverse impacts are far less likely in the southern portion of the region. However, our analysis indicates that within any subregion (e.g., the Northern Great Plains), different counties and communities will vary in their susceptibilities to adverse impacts because of differences in their economic and demographic characteristics.

Differences in Coal Development Options

*Many more counties will undergo a high degree of impact from the High Coal Electric and Accelerated Synfuels scenarios than from the Recent Trends scenario. The areas generally experiencing high impact do not differ significantly between the Recent Trends and the High Coal Electric and Accelerated scenarios.*

During 1985-2000, about 40 counties will be newly affected by coal conversion or combustion facilities under the Recent Trends scenario. Of these 40 counties, 15 are projected to experience adverse impacts. For the High Coal Electric and Accelerated Synfuels scenarios, the number of counties affected approaches 60, and the number experiencing adverse effects is 30. This large increase and the relative number of counties adversely affected suggest the potential severity of local socioeconomic problems likely under this scenario. Figure 2.12.1shows the areas of adverse impacts for 1985-2000 under the Recent Trends scenario and the High Coal Electric and Accelerated Synfuels scenarios. Although adversely impacted areas are fewer and smaller under the Recent Trends scenario, these areas seem to be concentrated along the Illinois, Missouri, and Ohio Rivers and in the Fort Union Coal Basin. One exception is the addition of such areas along the Mississippi River for the High Coal Electric and Accelerated Synfuels scenario.

Impact of Activities in Coal Fuel Cycle

*Dramatic differences in the impacts from coal development are observed among mining, combustion, and conversion and among counties having differing characteristics. The potential for impacts imposed by each technology from lowest to highest is:*

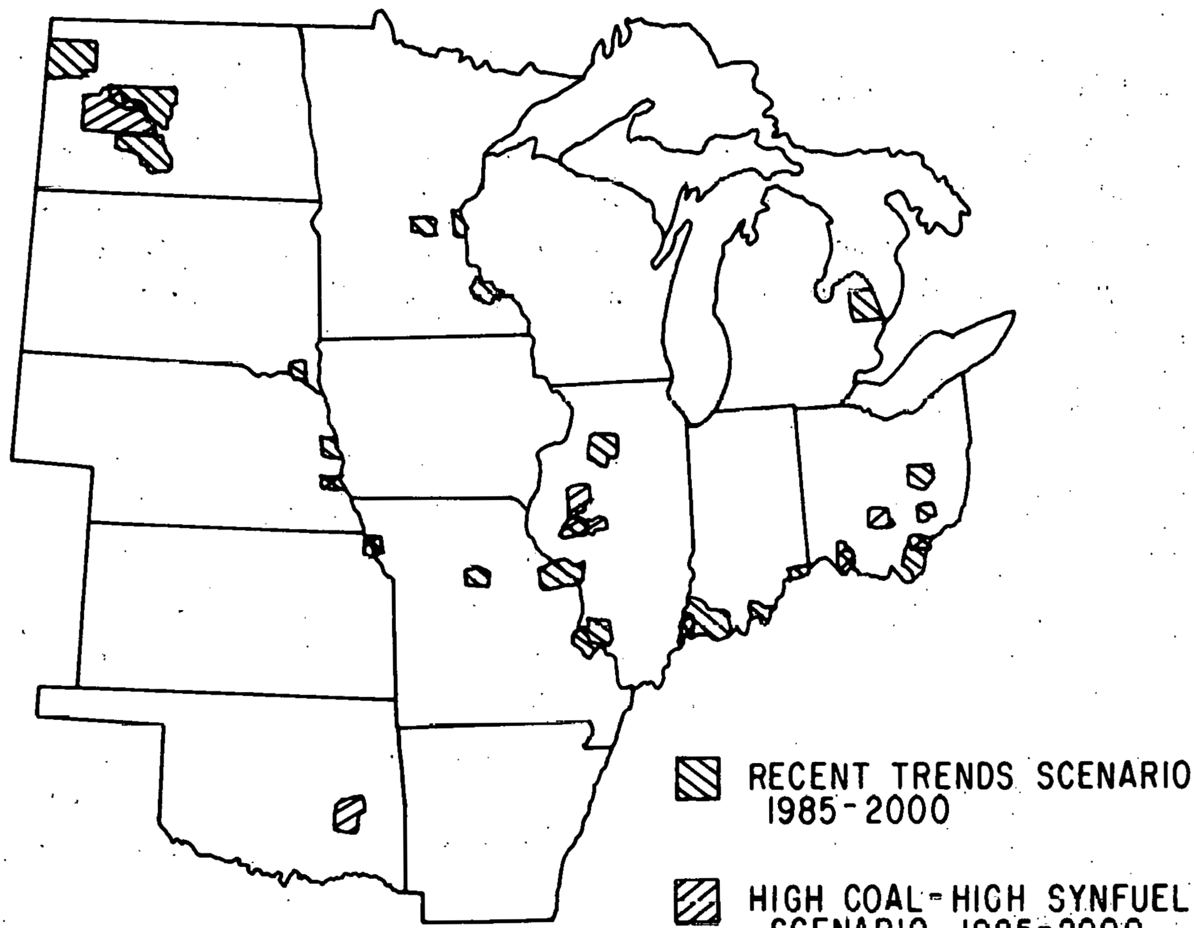



Fig. 2.12.1. Comparison of Areas of Adverse Impact

- *Coal mining (6MT/y)*

- *Low Btu gasification (2500 Mcfd)*
  - *800-MW electrical generation*
  - *1600-MW electrical generation*

- *High-Btu gasification (250 Mcfd)*

- *Coal liquefaction (50,000 bbl/day)*
  - *2500-MW electrical generation.*

Figure 2.12.2 shows the impacts associated with alternative coal technologies. It gives information on the percentage change in local population and the number of jobs filled locally for mining, electrical generation, and gasification.

The factors responsible for the differences within a given county from the various technologies are largely accounted for by the annual direct employment requirements of each technology (see Table 2.12.1).

Dramatic differences also occur in the susceptibility of various counties to local growth. Counties within the region are grouped into four categories according to their assimilative capacity for energy development:

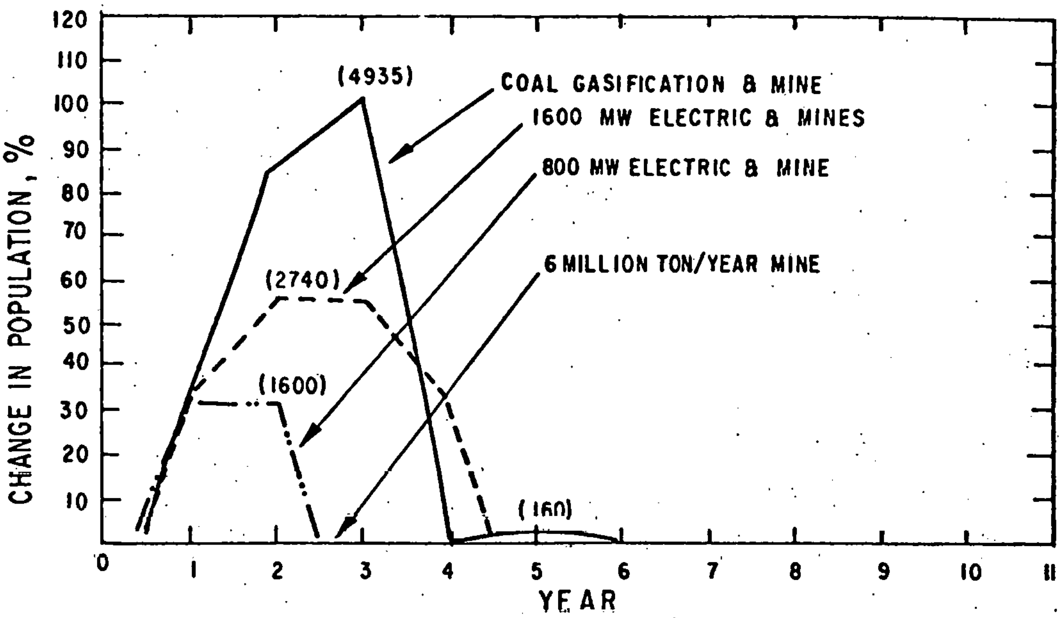
- Extremely high susceptibility to adverse impacts from new development (example, Dunn County, North Dakota).

- High susceptibility to adverse impacts (example, Morgan County, Ohio),

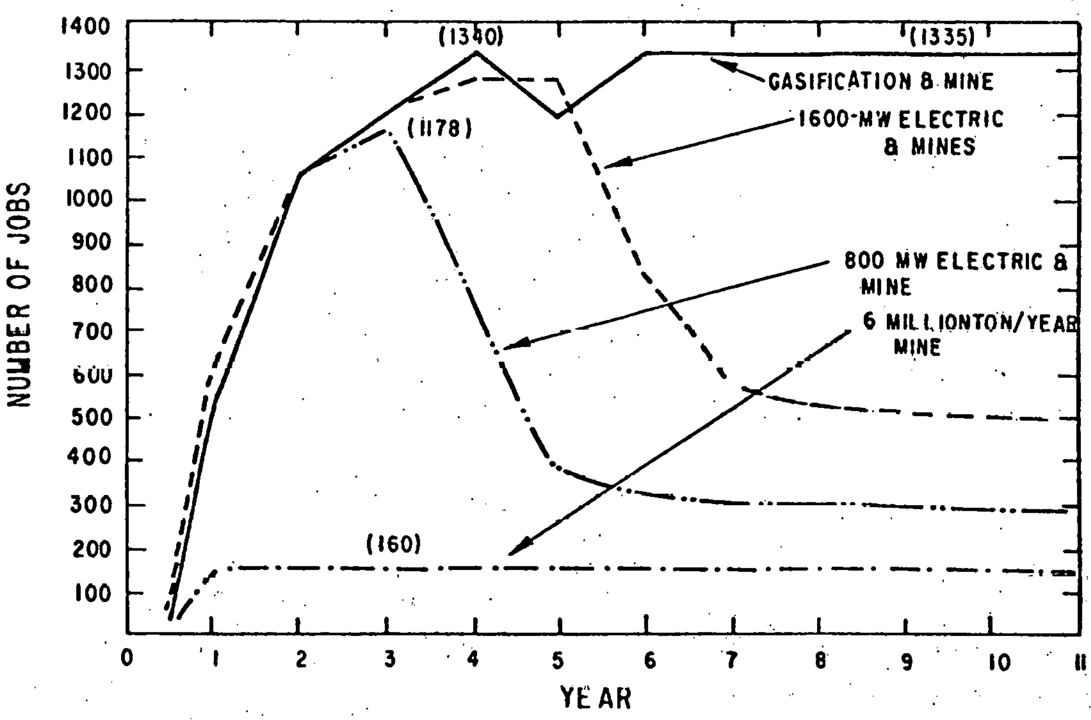
- Moderate susceptibility to adverse impacts (example, Morrison County, Minnesota),

- Low susceptibility to adverse impacts (example, Muskegon County, Ohio).

In Fig. 2.12.3 the assimilative capacity of each of these groups of counties is plotted. This figure presents information on the maximum percentage change in population resulting from in-migration required to fill the new direct and indirect jobs created by alternative levels and types of coal development. As is evidenced by this figure, ranges of development are required in the counties of every category to cause adverse socioeconomic impacts. Table 2.12.2 presents, by county type, the ranges of coal development required to cause adverse local socioeconomic impacts.




(a) Change in Total Population.




(b) Number of Jobs Filled Locally.

Fig. 2.12.2. Impacts Associated with Alternative Coal Technologies (Dunn County, North Dakota)

Table 2.12.1. Annual Employment Requirements by Technology

| Year | Mining | | | | | Coal-Fired Electric Generation | | | | Coal Gasification | | Coal Liquefaction |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Strip | | | Deep | | | | | | Hi-Btu | Lo-Btu | |
| | 2 MM | 4 MM | 6 MM | 2 MM | 6 MM | 400 MW | 800 MW | 1600 MW | 2400 MW | 250 MMCF/D | 2500 MMCF/D | 50,000 BBLS/D |
| 1 | 100 | 150 | 180 | 425 | 1260 | 420 | 420 | 420 | 420 | 355 | 68 | 200 |
| 2 | 100 | 150 | 180 | 425 | 1260 | 840 | 1260 | 1680 | 1680 | 1270 | 202 | 1200 |
| 3 | 100 | 150 | 180 | 425 | 1260 | 420 | 1260 | 2520 | 2940 | 2070 | 378 | 2100 |
| 4 | 100 | 150 | 180 | 425 | 1260 | 55 | 475 | 1735 | 2995 | 2320 | 181 | 2460 |
| 5 | 100 | 150 | 180 | 425 | 1260 | 55 | 110 | 585 | 1845 | 585 | 181 | 1838 |
| 6 | 100 | 150 | 180 | 425 | 1260 | 55 | 110 | 220 | 695 | 585 | 181 | 638 |
| 7 | 100 | 150 | 180 | 425 | 1260 | 55 | 110 | 220 | 330 | 585 | 181 | 638 |
| 8* | 100 | 150 | 180 | 425 | 1260 | 55 | 110 | 220 | 330 | 585 | 181 | 638 |

Sources: *Basic Estimated Capital Investment and Operating Costs for Underground Bituminous Mines*, U.S. Department of the Interior, Bureau of Mines, Information Circulars 8661 (1975) and 8682A (1976).

*Basic Estimated Capital Investment and Operating Costs for Coal Strip Mines*, U.S. Department of the Interior, Bureau of Mines, Information Circulars 8661 (1975) and 8703 (1976).

*Manpower Materials, Equipment, and Utilities Required to Operate and Maintain Energy Facilities*, Bechtel Corporation, March, 1975, U.S. Department of Commerce, NTIS PB-255 438.

*18th Steam Station Cost Survey*, Electrical World (Nov. 1, 1973).

*Socioeconomic Characterization and Assessment of the North Dakota Coal Gasification Project Area*, Woodward-Evicon, Inc., prepared for the Michigan-Wisconsin Pipeline Company (Sept. 1974).

*Interagency Task Force on Synthetic Fuels from Coal*, Federal Energy Administration Project Independence Blueprint, Final Task Force Report.

*Operating employment expected to remain stable over the remaining life of the facility.

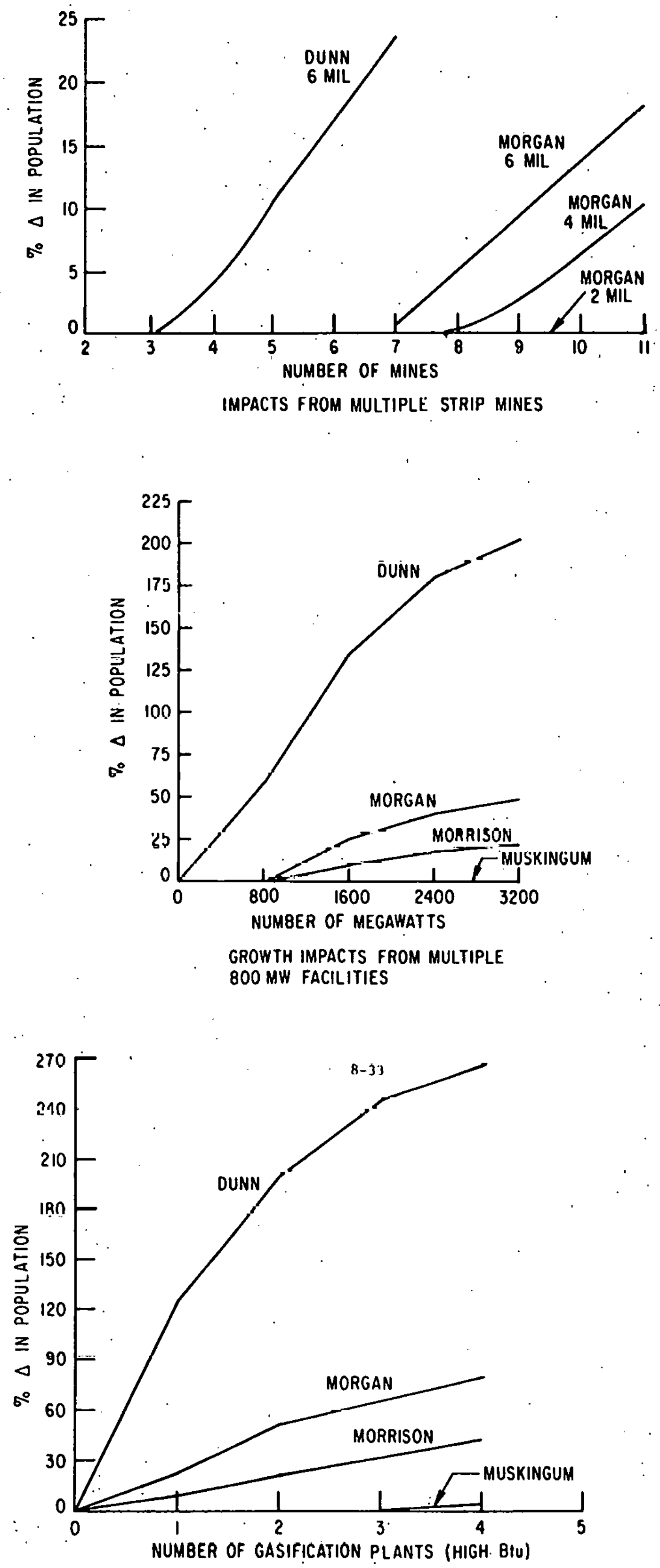



Fig. 2.12.3. Assimilative Capacity of Various Counties.

Table 2.12.2. Levels of Coal Development Creating Adverse Local Growth Impacts by County Type

| Technology Type | County Type | | | |
|---|---|---|---|---|
| | Extremely High | High | Medium | Low |
| High-Btu Gasification (No. of facilities) | 1 | 1 | 2 | 4 |
| Low-Btu Gasification (No. of facilities) | 2-3 | >4 | >4 | >4 |
| Liquefaction (No. of facilities) | 1 | 1 | 1-2 | >4 |
| Coal Electric Facilities (No. of Megawatts) | 800 | 800-1600 | 1600-2400 | >3200 |
| 6 MMT/Y Strip Mines (No. of mines) | 5-6 | 10-11 | -- | -- |

Regional Overview

*Some specific areas of intense coal development within the region will risk potentially adverse socioeconomic impacts. Coal resource counties in rural areas with only small populations within accessible commuting distances are particularly susceptible. These areas include major portions of North Dakota and limited areas in southern Illinois, Indiana, and Ohio.* Figure 2.12.4 indicates the areas of the region where adverse socioeconomic impacts are expected from the Recent Trends scenario.

From now to 1985, only six counties in the region are likely to experience adverse growth impacts. No discernable regional pattern is detecable, with the possible exception of North Dakota.

Between 1985 and 2000, 12 counties in the region may undergo adverse impact. The only discernable pattern here is that the high-impact areas are along the principal waterways of the region corresponding to where most new facilities are expected to be sited -- along the Missouri, Ohio, and Illinois Rivers. The percentage of adversely impacted areas is high in North Dakota and Nebraska, and low in Illinois, Indiana, Michigan and Ohio. The major industrial states of the region contain few adversely impacted counties relative to the growth of coal development expected in these states. This status, however, is expected given the greater assimilative capacity of the counties in these states.

Finally, between 2000 and 2020, 26 counties within the region will be potentially adversely affected by new coal developments. The impact on the North Dakota Fort Union Coal Basin is expected to be severe. In every North Dakota county selected for development during this period, adverse impacts are forecast. These impacts reflect both the low assimilative capacity of these sparsely populated, less developed counties and the increased coal development in this region. As with the earlier periods, adverse impacts are also expected to be scattered along the Ohio, Illinois, Missouri, and Mississippi Rivers. In Ohio, 13 counties can expect coal development activities during this period; 5 will be adversely impacted. Similarly, 13 Indiana counties will be sites of coal facilities, with only 4 being adversely effected. Only three of the ten Ohio counties scheduled for coal development are expected to be adversely effected, and only one in eight will experience problems in Michigan.

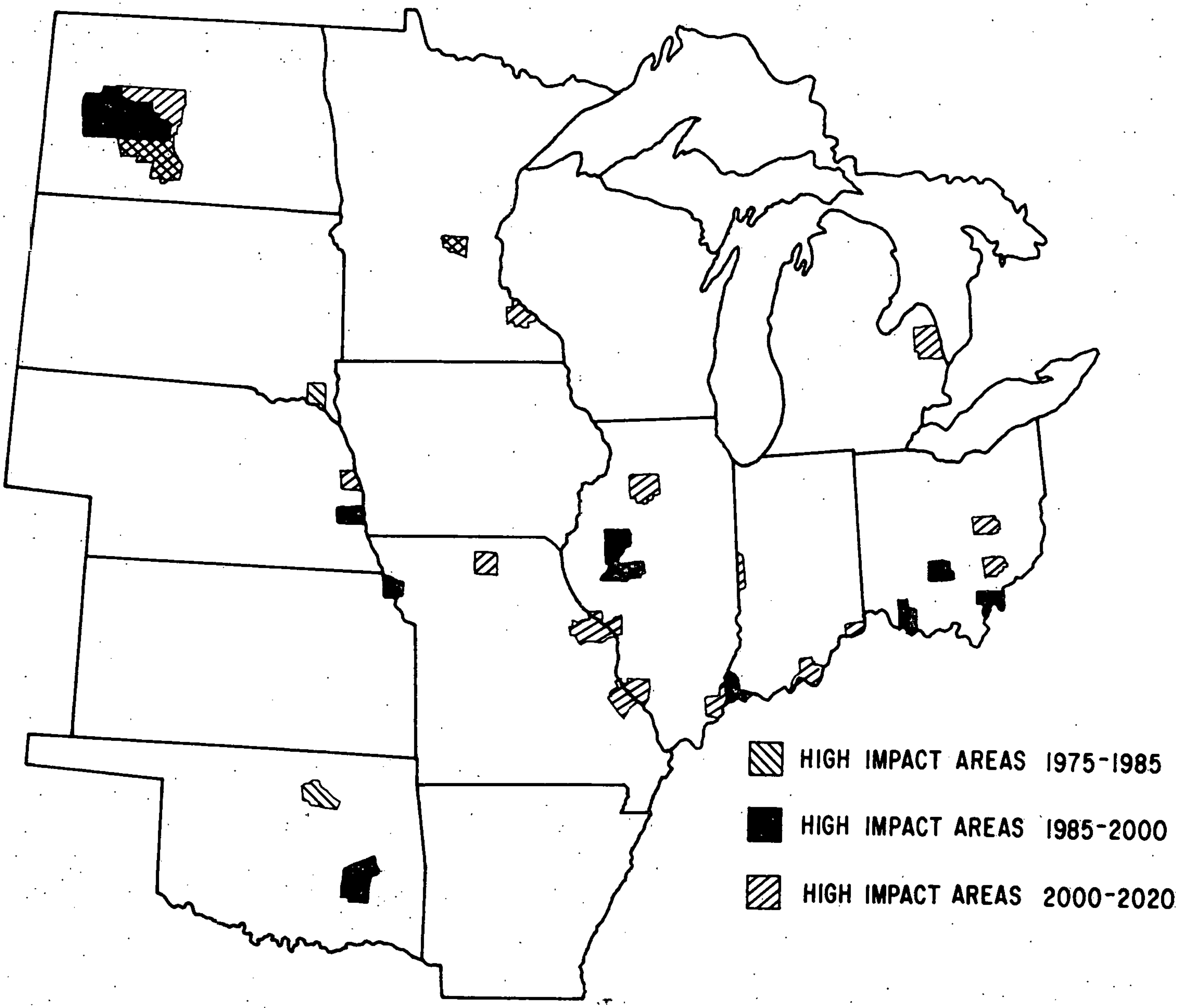



Fig. 2.12.4 High Impact Areas (Recent Trends Scenario)

Apart from the rather obvious broad distinctions between the industrialized and nonindustrialized areas of the region, only the Fort Union Basin appears as a well-defined subregion, in which the impacts of coal development will be consistently severe unless mitigation measures are taken.

## 2.13 Health and Safety Risks

*Although precise quantification is not now possible, indications are that significant public and occupational health risks could occur from increased coal utilization. On the order of 30-60 deaths per year are estimated to be related to the components of the coal fuel cycle for a 3000-MW electrical generation capacity, although the uncertainty in the estimate is a factor of 10 to 100. The major component in this estimate is public exposure from air pollutants; railroad accidents related to coal transport are the second largest effect, in particular if long transport distance for Western coal is required. Coal synfuel conversion reduces the atmospheric emissions considerably, but the level of occupational disease resulting from effects related to escape of the hazardous chemical constituents of the process stream is unknown.*

### Differences in Coal Development Options

*The currently quantifiable health and safety risks (Table 2.13.1) are greater by a factor of 5 or more for coal per unit energy produced for electrical generation (extraction through conversion) than for high-Btu gas. The estimated impacts from 3000 MW-electrical generation are greatest for exposure to atmospheric pollutants (20 deaths/year), followed in order by rail transport (12 deaths/year for 500-mile haulage), underground extraction (5-24 deaths/year) or surface extraction (1 death/year), and coal processing (0.2 death/year).*

The greater impacts of electrical generation are primarily due to the higher level of sulfur emissions and the high value for currently available estimates for effects of sulfates transported over long distances. However, definitive estimates of health effects from air pollutants are lacking as illustrated by the broad range in the 80% confidence limit, which ranges from zero to 4.6 times the expected value. A further limitation to these estimates is the unavailability of validated long-range models for air pollutants. In spite of the lack of good quantitative estimates, the overall qualitative conclusion remains that air-pollutant effects are a potentially serious problem needing further intensive study.

Table 2.13.1 Estimates of Unit Coal Health and Safety Effects[a]

| | Annual Effects per Conversion Facility (∿$2.5 \times 10^{11}$ Btu/day output) | |
|---|---|---|
| | Electrical Gen.[b] | Gasification[c] |
| **Surface Mining**[d] | | |
| Occupational Accidents | | |
| Deaths | 1 | 0.5 |
| Disabling Injuries | 49 | 27 |
| **Underground Mining**[d] | | |
| Occupational Accidents | | |
| Deaths | 4 | 2 |
| Disabling Injuries | 274 | 153 |
| Occupational Disease | | |
| Deaths | 1-20 | 0.5-11 |
| Coal Workers Pneumoconiosis Cases | 2 | 1 |
| **Coal Processing Plants** | | |
| Occupational Accidents | | |
| Deaths | 0.2 | 0.1 |
| Disabling Injuries | 13 | 7 |
| **Rail-Transport Public Accidents** | | |
| Interior Coal to Midwest (500 mi.) | | |
| Deaths | 12 | -- |
| Disabling Injuries | 59 | -- |
| Western Coal to Midwest (1500 mi.) | | |
| Deaths | 37 | -- |
| Disabling Injuries | 176 | -- |
| Western Coal to East (2000 mi) | | |
| Deaths | 49 | -- |
| Disabling Injuries | 235 | -- |
| **Conversion Plants** | | |
| Public Exposure to Sulfates | | |
| Deaths[e] | 20(0-92) | 4 (0-16) |

[a]Adapted from Brookhaven National Laboratory data

[b]3000 MWe at 100% load; 36.7% efficiency; 26,800 tons/day at $25 \times 10^6$ Btu/ton; 33,500 lb/hr $SO_2$ emissions (NSPS)

[c]$25 \times 10^6$ scf/day Synthane SNG; 1000 Btu/scf; 66.7% efficiency, 15,000 tons/day at $25 \times 10^6$ Btu/ton; 6,100 lb/hr $SO_2$ emissions. Mine-vicinity siting.

[d]Estimates of impacts of surface and underground mining assume all coal to supply facility is obtained from surface and deep mines, respectively.

[e]Adapted from Table 9.1. Numbers in parentheses are 80% confidence limits.

Additional information on health effects due to occupational exposure from synfuels by-products, waste-water effluents, and end use may alter the relative effects of synfuels vs. electrical generation. The process streams of synfuel processes contain substances known to be toxic, carcinogenic, and mutagenic, but lack of knowledge of control effectiveness prevents quantification of the level of impacts.

In addition to having reduced sulfur emissions, synfuels production also results in fewer transportation-related accidents than electrical generation since most conversion plants are expected to be located at or near the coal mines. For a given energy output from the plant, synfuels conversion requires less coal than does electrical generation and thus extraction health and safety impacts attributal to these facilities are smaller. Statistical records provide relatively good estimates of occupational hazards from past coal extraction activities; however, the uncertainty in the impact of recent regulations affecting mine conditions prevents precise projections of future risks.

The cumulative health and safety impacts in the year 2000 from coal utilization in the Midwest are illustrated in Table 2.13.2 for the Recent Trends and Accelerated Coal Electric Scenarios. Because of the linearity of risk factors, estimates of cumulative effects for the Accelerated Coal Scenario generally reflect the 20% increase in coal-derived energy generation.

## Regional Overview

*Based on the available estimates, location of electrical generation and synfuels conversion near sources of Western low-sulfur coal will potentially reduce cumulative health and safety risks of increased coal utilization.*

Estimation of impacts on public health from a given level of atmospheric emissions in alternative locations, as expected, shows that the further west the coal is burned, and hence the farther is the source from the large concentrations of population on the eastern seaboard, the less will be the total impact. An exception is noted, however, as a consequence of the combination of the location of the Chicago area and the general tendency for impacts to concentrate to the east of the source: moving the source from Illinois through Indiana and Ohio decreases the total impact. The impact on

Table 2.13.2 Cumulative Health and Safety Effects of Regional Coal Development Options in the year 2000.

| | Recent Trends Scenario | High Coal Electric Scenario |
|---|---|---|
| **Mining** | | |
| Occupational Accidents | | |
| Deaths | 63 | 72 |
| Disabling Injuries | 3970 | 4560 |
| Occupational Disease | | |
| Deaths | 17-350 | 20-400 |
| Coal Workers Pneumoconiosis Cases | 35 | 40 |
| **Coal Processing Plant** | | |
| Occupational Accidents | | |
| Deaths | 1 | 2 |
| Disabling Injuries | 84 | 98 |
| **Coal Rail Transport** | | |
| Public Accidents | | |
| Deaths | 153 | 181 |
| Disabling Injuries | 462 | 549 |
| **Air Pollutant Exposure** | | |
| Annual Death Rate Increase/$10^6$ Persons[a] | 147 (0-657) | 181 (0-809) |

[a] Based on population-weighted average increase in exposure in 30 northeastern states. Numbers in parenthesis indicate 80% confidence range.

the Chicago area, which is to the west of these areas, drops off far more rapidly than the impact to the east rises. In fact, concentrating combustion in Illinois maximizes the total impact, with the relative population-weighted exposure levels from a source in this state being greater by a factor of two than exposure from a source in North Dakota and 9% greater than the exposure from a similar source in Ohio. Lower sulfur levels in many Western coal resources could further lower the impact per unit of energy production.

Western coal also has less occupational hazard for extraction since these coals are primarily strip-mined. Transportation impacts could be minimized by use of Interior Province coal within the region, but this reduced risk is at least partially offset by higher sulfur content of the coal.