# League of Women Voters of Minnesota Records

# UPPER MISSISSIPPI RIVER...Comprehensive Basin Study


## APPENDIX-F
## MINERAL RESOURCES

DRAFT NO. 3

Prepared Under Supervision of
UMRB CO-ORDINATING COMMITTEE
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DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

# APPENDIX F

# MINERAL RESOURCES OF THE

# UPPER MISSISSIPPI RIVER COMPREHENSIVE BASIN STUDY (UMRCBS)

PRELIMINARY
NOT FOR PUBLIC RELEASE

Prepared by
Area III Mineral Resource Office
Minneapolis, Minnesota

APPENDIX F

MINERAL RESOURCES OF THE
UPPER MISSISSIPPI RIVER COMPREHENSIVE BASIN STUDY (UMRCBS)

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## APPENDIX F - MINERAL RESOURCES OF THE UPPER MISSISSIPPI RIVER COMPREHENSIVE BASIN STUDY (UMRCBS)

### PREFACE

A comprehensive study of the Upper Mississippi River Basin (UMRCBS), and for brevity herein expressed as the Basin, is being made by the several State and Federal agencies for planning and development of water and related land resources.

Representatives of the State and Federal agencies involved compose the Upper Mississippi Coordinating Committee, and the U. S. Army Corps of Engineers, North Central Division, is the sponsor of the study and through its representative is chairman of the Committee. The Corps designated the specific assignments of Basin's studies to each of the participating agencies and coordinated the efforts of this consortium. Accordingly, some of the studies of mutual interest to all agencies, including the Bureau of Mines, U.S. Department of Interior, are financed through contract with the Corps.

The authority for the UMRCBS devolves from a resolution by the U. S. Senate Committee on Public Works adopted May 21, 1962 and spelled out in the Congressional House Documents Number 669, Seventy-sixth Congress, and Number 66, Seventy-seventh Congress.1/

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1/ Letter, Statement of History and Coordination, Encl. 2; Subject, Coordinated Budget Estimate for Upper Mississippi River Comprehensive Basin Study, from U. S. Army Division, North Central to Chief of Engineers, Washington, D. C., Jan. 23, 1964.

Authorization of the Bureau of Mines, Area III Mineral Resource Office, Minneapolis, participation in the UMRCBS was made effective through an agreement between the Corps and the Bureau initiating the study on October 1, 1963.[2]

2/ Interservice Supply Support Agreement, October 1, 1963, Request Number NCD SA 64-3, U. S. Army Engineer Division, North Central Corps of Engineers, Chicago, Illinois.

This report was prepared by the Bureau of Mines to provide information to the participating agencies concerning the utilization, past, present, and future of water and related land resources by the mineral industry of the Upper Mississippi River Basin. This information is itemized individually on a plan area basis and collectively on a regional basis. Trends and conclusions are given on the future needs and availabilities of each mineral resource.

Subsequent reports continuing and extending the present study or accelerating work in any of the concerned areas would be welcomed by the Bureau if the need should develop and the funds become available.

SECTION I
INTRODUCTION

1. PURPOSE

The Bureau of Mines, U.S. Department of the Interior, has been commissioned by the Corps of Engineers to study mineral resources as one part of the comprehensive study of water development and land utilization being made of the Upper Mississippi River Basin. Specifically, the Bureau will estimate mineral resource potential, evaluate solid and liquid mineral fuel production, and relate these factors to water use, to water availability, and to water pollution, its causes, extent, and possible corrective measures. In addition, land utilization will also be a part of the study. All of these factors will be evaluated for present conditions and projections made for the future.

With the above-stated objectives in mind, purposeful and efficient planning may be effected for future development of water and land resources in the mineral industry, including the promulgation of intelligent and effective conservation procedures, in the comprehensive plans for the Upper Mississippi River Basin.

2. LIMITS OF THE UPPER MISSISSIPPI RIVER BASIN AND PLAN AREAS

a. Extent of Basin. The Upper Mississippi River Basin (UMRB) is located in the north-central part of the United States and includes the major portions of the States of Iowa, Illinois, Wisconsin, and Minnesota, a portion of Missouri, and minor portions of Indiana and South Dakota, all together involving a contiguous watershed area of 188,200 square miles shaped like a rough ellipse

750 miles long by 550 miles wide. In these States the Basin embraces the drainage areas of rivers, tributaries, and streams with the southern limit at the confluence of the Ohio and Mississippi Rivers at Cairo, Illinois, and the northern limit in Minnesota at a point 70 miles south of the ~~American~~ U.S.-Canadian border. The eastern limit is at a point near South Bend, Indiana, and the western limit at Big Stone Lake in South Dakota. The area involved on a county basis in the watershed is 191,407 square miles.

b. Plan Areas. To facilitate the accumulation of data in the UMRCBS, the Basin is subdivided into two types of small units or areas, defined by mutual agreement among members of the Economic Advisory Committee and established as the partition models to be followed rigidly by the participating agencies, including the Bureau of Mines. The first type of area subdivision is the economic subregion based on economic criteria and the second type is the Basin plan area or water drainage subbasin based on hydrologic criteria. The latter type of subdivision, the plan area based on water drainage behavior was designated for the mineral resources study by the Corps of Engineers and is followed in this report.

Plan areas outlined by natural water drainage are irregular and sometimes randomly overlap county lines, the latter of which are usually rather geometrically symmetrical and arbitrarily established. Again, for convenience to the resources study the peripheral limits of the established plan areas have been fixed along county lines, an action ~~which~~ that assists greatly the availability of data and records and causes little or no inconvenience nor a departure from accuracy. Thus, on the basis of county boundaries, 302 counties in the UMRCBS are grouped into 17 Basin planning areas (plan areas) as designated by the Corps of Engineers and are so used in this report. The other groupings involving a greater number of counties, some outside the UMRCBS and not used in this report, group 321 counties into 11 economic subregions.

3. SCOPE OF STUDY

All mineral commodities--with treatment of each limited to exploration, mining of ore deposits and beneficiation of minerals--produced in the Basin (UMRCBS) were considered in this study. Bureau records locally on file were the sources of some information on historical, quantity, production value, and employment in the Basin's mineral industry. Employment data were not available for some commodities. Data for petroleum and natural gas were taken from bulletins published by the State of Illinois.

Estimates of mineral reserves in the Basin were extracted from published and unpublished State and Federal Government reports and, of course, data in the Bureau of Mines files. No field examinations were made to determine quantity or quality of reserves. Accuracy and detail of the reserves depend on the information available. Several commodities, principally the construction materials--sand, gravel, crushed stone, and gypsum--were examined and enough data used only to assure adequate reserves to meet projected demands. In particular instances, where available data were not sufficiently detailed to assign quantities to small areas, estimates were made according to the best engineering judgement. Ore reserves are continually changing as new information obtained by exploration adds to the reserves while mineral production reduces them.

Before the comprehensive plan for the Basin is activated, detailed studies will be required on individual development projects for their effects on the mineral industry.

## 4. ACKNOWLEDGEMENTS

Direct assistance in the preparation of this report was given by various individuals, particularly the directors of State Surveys, who, through their cooperativeness and willing help, provided information and data. We would particularly like to thank Dr. John Frye, Chief, Illinois Geological Survey; Dr. John B. Patton, State Geologist, Indiana Department of Natural Resources; Dr. Garland Hershey, Director of the Iowa Geological Survey; Dr. Paul K. Sims, Director of the Minnesota Geological Survey; and Mr. George F. Hansen, Director and State Geologist, Wisconsin Geological Survey; and their staffs.

## SECTION II
## GENERAL REVIEW OF BASIN MINERAL RESOURCES AND PRODUCTION - PAST, PRESENT, AND PROJECTED

5. PRINCIPAL MINERAL RESOURCES

Mineral resources in the Basin, whose consumption, demand, and price are influenced by National or Regional demand, may be divided into two groups: export commodities, transported from their origins out of the region and possibly out of the Basin; and residentiary commodities, used locally or moved only small distances from their origins.

Export mineral commodities are coal, iron ore, lead concentrates, zinc concentrates, industrial sands, special dimension stone, natural gas, petroleum, natural abrasives, and some sand and gravel. Residentiary mineral commodities are sand and gravel, crushed stone, marl, clay, shale, and some dimension stone. It should be noted, however, that some special quality, high-valued dimension stone is exported out of the Basin, as well as some sand and gravel to areas of scarcity.

a. Distribution in the Basin and Mode of Occurrence. The general distribution in the Basin of each mineral resource depends on and reflects the individual characteristics of ore genesis, deposition, and concentration. Some mineral resources may be distributed regionally (e.g. sand and gravel), others only locally (e.g. barite, lead).

Large concentrations of coal are found in the south portion of the Basin, mainly in southern Illinois, and minor amounts in Iowa and Missouri. Large tonnages of iron ore and taconite are found concentrated in narrow belts in northern Minnesota with minor amounts in the south part of that State. Lead is found in the old lead belt and in the newly discovered Viburnum Trend in Missouri at the southwestern tip of the Basin and in southwestern Wisconsin (slight amounts). The principal source of zinc is in southwestern Wisconsin, with slight amounts in Missouri. Dimension stone is found spraddled in four separate areas of the Basin: Minnesota is the principal source, with granite in the St. Cloud area and dolomite in the Mankato area; slight amounts are found in southeastern Wisconsin; small production of some special granites occurs at the southern tip in Missouri; and slight production of marble occurs at the south tip of Illinois. Petroleum, natural gas, and natural gas liquids are found in the south portion of the Basin, confined entirely to southern Illinois. Sand and gravel is found almost everywhere in the Basin, except the southern tip; rock for crushed stone aggregates may be found nearly everywhere in the Basin, but overburden must usually be removed to expose it. Barite is produced only from the southwestern tip of the Basin in Missouri; and gypsum is found in the north central and southeastern portion of Iowa.

Other mineral resources of minor importance in the Basin, but having special qualities, are industrial sands, natural abrasives, clay, shale, and marl. Clays and shales of industrial importance are found in Illinois, Missouri, and Iowa; industrial sands in Illinois, Missouri, and Wisconsin; natural abrasives in Illinois; and marl in Minnesota and Wisconsin.

b. Coal. The principal coal deposits in the Basin are in Illinois and, of the 40 to 50 coalbeds in this State, only about four beds are main producers (62)[3/]. The beds occur in layers of

3/ Underlined numbers in parentheses refer to items in the Bibliography at the end of this appendix.

variable thickness, some at the surface slightly covered and others buried to depths of several hundreds of feet. Thus, the burial depth and bed thickness dictate the type of mining operation to be used. Strip mining methods mine surface coal layers, including very thin ones, and in the process destroy large areas of farmland; while underground mining methods, which require only small surface areas and mine layers not less than 28 inches thick, may be restricted by surface subsidence regulations, particularly near populated areas, or proximity to oilfields. Much of the coal mined in Illinois is consumed in the State for electric energy generation and the production of metallurgical coke.

c. Iron Ore. The major iron ore deposits occur in Minnesota, lesser ones in Wisconsin, some unimportant ones in Iowa, and some important high grade ones in Missouri. The ores may be classed roughly as (1) natural ores, (2) taconite (magnetic) ores, and (3) nonmagnetic taconite ores. The Mesabi range in Minnesota is no longer important in natural ores, since these ores are diminishing in quantity at a rapid rate, but this State is only beginning to exploit great reserves of taconite, which yield after a manufacturing process a high-iron product shaped like marbles (pellets), which is now prized as blast furnace feed. When pellets are used in a blast furnace its daily capacity may be doubled, besides allowing other furnace benefits. On the Cuyuna range, some miles south of the Mesabi, mining activity has lessened because most of the remaining material is a low-iron high-phosphorus natural ore and manganiferous protore now considered uncommercial. In southern Minnesota, in the Fillmore County area, small tonnages of low-grade limonitic ores (natural ores) are mined within a few feet of the surface (and the surface later rehabilitated and returned to farmland or made into recreational areas). Another classification of iron-containing material is nonmagnetic taconite, which occurs in great quantities in Minnesota, but awaits the development of an economic extraction (beneficiation) process.

The Wisconsin deposits of importance are taconitic and are now undergoing exploitation (Jackson County). The Iowa deposits of insignificant tonnage are shallow, quite low grade limonitic ores and are not now exploited.

In Missouri, high-grade, magnetic iron ores occur in significant tonnages. Except for one small surface deposit, the ore is deep in the ground as at Pea Ridge, and when mined and beneficiated, yields a very high grade commercially desirable pellet.

Iron ore is mined by two methods, open pit and underground. Where deposits are near the surface and are large enough, open pit methods may reach depths of about 600 feet and are desirable because of relatively lower mining costs and nearly 100 percent ore extraction.

Underground methods must be used where the ore occurs at greater depths but mining costs are higher and the ore extraction is only partial since part of the ore must be left to support the mine openings.

Open pit mining methods for both natural and taconite ores are used in all of the Minnesota operations; for the last remaining underground iron mines in the State were shut down in 1967. The taconite operations in Wisconsin will be open pit. In Missouri, however, because of the depths of the iron ore deposits, underground mining methods must be used.

Modern blast furnace operations now demand a furnace feed of both exacting chemical composition of high iron and low silica and mechanical requirements of particle shape, strength, and size distribution. Thus, nearly all crude ores, regardless of classification, must be beneficiated to yield an upgraded product, concentrating the desirable fraction while discarding the waste materials. The upgraded product secured, then, is but a fraction of the mined crude ore. Some beneficiation operations may be simple, as in screening out fine particles ("fines") or a simple wash operation, or they may be extensive and complex as in the processing of magnetic taconite.

d. <u>Sand and Gravel</u>. Sand and gravel are available in great quantities from the glacial drift that covers the northern three-fourths of the Basin. Pit site selection factors of primary consideration not directly related to the physical characteristics of the deposit are availability of land at a reasonable cost, zoning restrictions, and distance to principal markets. Sand and gravel are large bulk volume, low valued commodities, thus, transportation costs are a vital economic factor in sand and gravel operations.

e. Crushed Stone. Crushed stone, another large-bulk-volume, low-valued commodity, is available throughout most of the Basin, and several types of rock, granite, limestone, and traprock, are utilized in making crushed aggregate. These rock layers are usually overlain by glacial drift and other rocks, and the thickness of this overburden, which must be removed to expose the desired rock layer, is a significant factor in the selection of a quarry. Where specifications in construction work are particularly rigid, however, and local rock types cannot meet specifications, the rock, ~~then,~~ must be quarried at considerable distances from the market. I~~n the vicinity of~~ Near urban areas, particularly residential sections, zoning restrictions frequently prohibit quarrying operations, thus forcing quarry sites to be located ~~considerable distances~~ from the market.

f. Peat and Marl. Peat and marl are two mineral commodities of small development and economic value. Peat resources in the northern edge of the Basin in Minnesota are considerable; production is used locally except for small quantities exported. This export business is slowly growing. Marl is sporadically distributed in small deposits and where produced is used locally as a soil conditioner.

## 6. MINERAL COMMODITY PRODUCTION AND VALUE FOR 1960

Mineral commodities produced in the UMRCBS, and shown in table 1, increased in total dollar value in the decade 1950-1960. The commodities showing increases are portland cement, iron ore, petroleum, sand and gravel, and crushed stone; those showing decreases are coal, copper, lead, and silver. A few commodities showed a mixed behavior of lower production in 1960 but greater total dollar value; for example, barite and iron ore.

The peculiarities of each mineral commodity influence their effects on employment, water and land use, and operational activity; the latter may be either widespread or relatively local in the Basin. An example of this is iron ore mining which, with its well mechanized operations, is relatively local in the Basin and takes place only in several small areas. A large proportion of the iron ore produced in the Basin is smelted in blast furnaces concentrated in the Chicago and East St. Louis areas. Employment and water and land use for this commodity are thus concentrated in these areas. Coal production (and petroleum production) likewise is somewhat localized in southern Illinois and its effects in employment and land and water use are more dispersed. In contrast, sand and gravel is widespread in occurrence throughout the Basin, and its demands on employment, land and water use, are dispersed widely. The same may be said of crushed stone.

TABLE 1. - Upper Mississippi River Basin, mineral production, 1950 and 1960

| Mineral | 1950 Quantity | 1950 Value | 1960 Quantity | 1960 Value |
|---|---|---|---|---|
| Abrasives: Grinding pebbles..........short tons.. | 530 | $10,600 | W | W |
| Tube-mill liners................do.... | W | W | W | W |
| Barite..................................do.... | 209,311 | 1,890,292 | 180,702 | $2,587,820 |
| Cement: Masonry...............280-pound barrels. | (1/) | (1/) | 1,804,132 | 5,664,996 |
| Natural...............376-pound barrels. | W | W | ------- | --------- |
| Portland..........................do.... | 29,958,871 | 67,330,520 | 39,640,738 | 136,562,871 |
| Clays and shale 2/..................short tons.. | 3,282,922 | 4,799,120 | 4,503,135 | 12,759,604 |
| Clay produced for use in mfg. cement........do.... | NA | NA | 1,181,852 | 1,164,797 |
| Coal (bituminous).........................do.... | 54,736,582 | 218,187,673 | 40,703,487 | 174,622,865 |
| Cobalt...................................pounds.. | ------- | ------- | W | W |
| Copper.............................short tons.. | 2,982 | 1,240,512 | 1,087 | 697,854 |
| Gypsum....................................do.... | 981,647 | 2,507,651 | 1,282,817 | 5,427,529 |
| Iron ore 3/.........................long tons.. | 15,940,149 | 79,230,712 | 14,597,296 | 230,147,639 |
| Lead...............................short tons.. | 135,481 | 36,579,870 | 114,358 | 26,759,772 |
| Lime......................................do.... | 1,308,323 | 13,117,618 | 1,846,736 | 24,609,860 |
| Nickel...................................pounds.. | ------- | ------- | W | W |
| Peat...............................short tons.. | 10,853 | 98,553 | 23,829 | 260,775 |
| Petroleum.............thousand 42-gallon barrels.. | 22,862 | 63,328,767 | 32,916 | 97,435,441 |
| Sand and gravel....................short tons.. | 47,342,140 | 37,572,387 | 92,770,409 | 88,622,573 |
| Silver...................................ounces.. | 236,273 | 213,839 | 15,594 | 14,113 |
| Stone (crushed and broken) 4/.........short tons.. | 33,870,365 | 45,545,710 | 73,710,993 | 100,118,972 |
| Limestone for use in mfg. cement and lime...do.... | NA | NA | 11,044,626 | 10,555,795 |
| Stone (dimension).........................do.... | 145,366 | 8,108,302 | 211,493 | 10,627,672 |
| Zinc......................................do.... | 28,339 | 8,048,276 | 41,556 | 10,721,448 |
| Value of items that cannot be disclosed: Tripoli and values indicated by footnote W.............. | ------- | 666,489 | ------- | 1,982,628 |
| Total.................................... | ------- | 588,476,891 | ------- | 831,345,024 |

W Withheld to avoid disclosing individual company confidential data. NA Not available.
1/ Masonry cement not considered as "mineral production" in 1950.
2/ Excludes clay produced for use in manufacturing cement.
3/ Includes iron ore containing from 5 to 35 percent manganese, natural, which is ordinarily classified by the Bureau of Mines as manganiferous ore.
4/ Excludes limestone produced for use in manufacturing cement and lime.

Total water use in the Basin in 1960 demanded by the mineral commodities was about 31,000 million gallons of new water intake; of this water volume, about 28,000 million gallons ~~were~~ was discharged or dispersed by disposal of some form, while about 2300 million gallons ~~were~~ was consumed or lost from further use. Sand and gravel was the major user of water.

Water available in the Basin as runoff water, not including ground water, is reported at 65 billion gallons per day (bgd), due to an average runoff of ~~seven~~ 7 inches per year;[4] thus, demands

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4/ Corps of Engineer's Letter, July 10, 1967, p. 5, "Section VI, National Assessment for Upper Mississippi River Region, 1965."

for water by the Basin's mineral industry annually represents merely one-half day of this available water supply or on a daily basis slightly less than [redacted] a thousandth of this daily available water supply.

Total land use in the Basin in 1960 by the mineral commodities was 6,866 acres, or nearly 11 square miles, insignificant compared ~~to~~ with the 188,200 square miles of the Basin. Coal was the major user of land area.

7. <u>PROJECTED RATES OF MINERAL PRODUCTION AND EMPLOYMENT - GENERAL</u>

Projections of rates of mineral production and employment for each mineral commodity in the UMRCBS were made for the years 1970, 1980, 2000, and 2020. The future mineral needs, as expected, will be constantly increasing and, for some mineral commodities, the Basin will be able to meet these needs adequately, but for ~~some~~ others the Basin's reserves will be exhausted, or nearly exhausted, before the end of the projection period.

Each of the four mineral commodities, sand and gravel, crushed stone, dimension stone, and gypsum, will more than quadruple the 1970 production rates in the year 2020; at the same time employment rates will increase substantially, doubling for sand and gravel, and increasing 75 to 80 percent for each of the other three ~~remaining commodities.~~ Based on 1960 production rates, 2020 production rates for these commodities will increase fivefold to sevenfold. Largest sand and gravel and crushed stone areas of production (about 45 percent of the Basin) will be the Chicago area (Plan Area 5A) followed by Illinois, South (Plan Area 5B). Most of the finished dimension stone will be quarried in Minnesota (Plan Areas 1 and 16) and in Wisconsin (Plan Area 3); and all of the gypsum will be produced in Iowa (Plan Areas 11 and 12).

a. <u>Projected Production by Commodity</u>. Production rates for coal, a principal mineral commodity in the Basin, will increase more than half again (55 percent) the 1970 rate by the year 2000, then decline; employment however, will remain about constant for this period, then decline after 2000. The decline in coal production will be due to changing fuel demands rather than to inadequacy of reserves. Illinois will produce nearly all of the coal, with the major amount from the south tip of the State (Plan Area 7).

Iron ore, another principal mineral commodity of the Basin, will more than double (122 percent) its 1970 production rate by the year 2020; employment will also more than double during this period. Production will come from relatively small but widely separated areas, with about two-thirds of the total iron production from Minnesota (Plan Area 1) and about one-third from Missouri (Plan Area 8). A small tonnage of iron ore will also be produced in Jackson County, Wisconsin (Plan Area 2).

Petroleum production, presently important in the Basin, will decline rapidly to a near-vanishing point by the year 2000; employment likewise, will decline quickly. Oil production in the Basin will be confined to southern Illinois.

Lead production will more than double (124 percent) over the 1970 rate by the year 2020; simultaneously, employment will rise by 60 percent. Practically all of the lead production in the Basin will be from Missouri, with a small amount of byproduct zinc. Zinc rates of projected production will increase slowly, reaching 23.5 percent over the 1970 rate by the year 2020; employment, however will decline

22 percent off the 1970 rate. Nearly all of the zinc will be produced in the Wisconsin-Illinois zinc area (Plan Area 4) with a small amount of byproduct lead.

The byproduct metals, copper, silver, cobalt, and nickel are derived from lead and zinc processing, and no estimates of their reserves have been made nor projections evaluated. Compared ~~to~~ total value of Basin minerals produced in 1960, the value of these byproduct metals is less than ~~one-tenth of one percent~~ (0.1 percent). Their future value in produced quantities will remain relatively insignificant.

Barite is projected at a constant production rate only to 1980, ~~as~~ the presently treatable reserves will be exhausted soon after this date - unless improved beneficiating methods are developed to treat materials now considered uncommercial; employment will hold constant until the time of demise is reached.

Total employment for all mineral commodities in the UMRCBS will increase substantially (about 50 percent) for the study period, 1970 to 2020.

b. Water Requirements. Future new intake water use in the Basin's mineral industry is expected to increase, perhaps five-fold, with the anticipated growth of the industry. The greatest volume of water use by 2020 will be in Plan Area 8 (Missouri) followed by Plan Areas 5A and 5B (Illinois, North and Illinois, South).

The sand and gravel industry will require an increase of water for processing because of increasing demands for cleaner and better quality sand and gravel. The crushed stone industry will be similarly affected.

For coal, the anticipated new intake water use will double, ~~due~~ owing to cleaner coal requirements. Iron ore will require a great increase in new water in Plan Area 8 (Missouri) while in Plan Area 1 (Minnesota) the water demand will remain about the same as present use.

c. Land Used by the Mineral Industries. Annual land needs for future mineral production in the Basin will increase about sevenfold by 2020, and the cumulative area for the projection period will total more than ~~one~~ 1 million acres or more than 1500 square miles. However, most of the used area may be reclaimed and restored to useful purposes. Every plan area will require greater land area with Plan Area 5B (Illinois, South) requiring the greatest.

Commodities demanding the greatest land area for projected productions are coal, which will require about three-eighths or about 375,000 acres of the total cumulative mineral land area, and sand and gravel, which will require about one ~~quarter~~ fourth or about 250,000 acres of the total cumulative mineral land area. Petroleum operations will require very little land. Land area requirements for iron mining will be relatively small (less than 3 percent of Basin total); for open pit mining the land area will be much larger than for underground mining. Lead and zinc mining land requirements will be about 1.5 percent of Basin total. Crushed stone will need about 10 percent or about 100,000 acres of the cumulative mineral land area.

## SECTION III
## HISTORY OF THE MINERAL INDUSTRY IN THE BASIN

The following brief historical treatment of the Basin's mineral industries is not intended to be an exhaustive and rigorous treatment of the subject, ~~as~~ since such a lengthy study would be out of place in the UMRCBS, but ~~it~~ is merely a brief review of the highlights marking discovery and developments of some principal minerals to give the reader of this mineral study some depth of background and to give some satisfaction of reader-curiosity concerning the when and where of discovery. For facts on lead and zinc history, heavy dependence was made on the U.S.G.S. Professional Paper by Heyl et al. (49).

### 8. HISTORY OF BASIN'S MINERAL INDUSTRIES, PRE-1900

Minerals and mineral production have played an important part in the development of the Basin.

The early trappers and explorers who traversed the area reported numerous mineral occurrences~~, which were recognized one by one and from time to time~~. About the year 1690, a trading post for lead was established on the Mississippi River near the present site of Dubuque, Iowa (50), where the mineral, galena, a lead sulfide, was smelted, and the product, lead ingots, was shipped down the river as far south as New Orleans. During the middle 1800's some lead products, shot, sheet lead, and lead pipe, were also manufactured in this area; ~~and~~ lead production reached its peak in 1847, when 27,000 tons of metallic lead ~~were~~ was produced, but declining thereafter.

In Missouri, lead deposits were first reported in 1700. Mining started about 1720 in Madison County and in 1726 in Washington County within Plan Area 8. A shot tower and equipment for the manufacture of sheet lead were built in 1799.

Total lead production in the Basin in 1900 was 40,615 tons of metallic lead, of which the Wisconsin-Illinois-Iowa district produced 1300 tons.

Zinc mining in the Basin began in the 1860's, after having been noted in the Wisconsin-Illinois-Iowa district; some of the ore was processed locally in smelters already existing and the larger part of it was shipped to a smelter at La Salle, Illinois. Milling and smelting practices were improved lending impetus to the increasing mining activity. Early zinc production was confined to carbonate ores but was soon supplemented by production of sulfide ores and, by 1900, 45 ~~forty-five~~ mines were producing ore. In ~~the year~~ 1916, peak production of more than 3-1/3 million tons of zinc ore occurred.

In Missouri, little attention was given to the zinc ores, which occurred with the lead deposits, until a zinc smelter was erected at Potosi~~, Missouri,~~ in 1867. By 1900, the principal zinc production in Missouri came from the Joplin district (outside the Basin); however, in that year about 1,400 tons of zinc metal ~~were~~ produced from within the Basin area.

Coal was reported in Illinois in 1668 and in Iowa in 1673. In Illinois, coal was first mined in 1810 from outcroppings on the Big Muddy River in Jackson County and in that year a boatload was shipped to New Orleans. In Iowa one of the earliest commercial mines began operations in 1840 at Farmington in Van Buren County (86). In that year 17,000 tons of coal was mined in Illinois from 19 counties. Coal production was first recorded in Missouri in 1873 when 784,000 tons was produced.

In Illinois, shaft mining or underground mining of coal began in 1855, at Du Quoin, Perry County, coincident with the completion of a railroad, while commercial strip mining commenced much later in 1910, although there were some small operations earlier.

Excepting markets along waterways, coal mining was dependent on local markets; the coal was hauled by wagons from the mines to the consumers until railroads were built and completed in the area. Improved transportation systems helped the mining industry grow until it became one of the most important industries in the area. In 1900 coal production in Illinois, Iowa, and Missouri amounted to 25,800,000, 5,200,000, and 3,540,000 tons, respectively, with most of this production coming from the Basin.

The Basin's first iron ore production was in 1819 from Crawford County, Missouri (Plan Area 8). In Minnesota, iron ore was noted first in 1780 by French explorers at Gunflint Lake; in 1848 on the Vermillion range at Lake Vermillion by J. G. Norwood, a geologist; in 1866 at Embarrass Lake on the eastern Mesabi by Henry H. Eames, who reported "immense bodies of iron ore," and who in the same year, also reported iron ore near Grand Rapids; in 1903 on the Cuyuna range by Cuyler Adams who found ore by drilling to a lean ore formation; and in 1941 (first year of production) at Spring Valley in southern Minnesota. The first Minnesota iron ore production was from the Soudan mine near Tower in 1884, and from the Cuyuna range in 1911, from the Kennedy mine. In the Basin's section (30 miles long) of the Mesabi (Itasca County) the first ore shipment was in 1902 from the Hawkins mine at Nashwauk.

Gypsum was first reported in Iowa in 1849, as outcrops near Fort Dodge along the Des Moines River in Webster County, and in 1910 at Centerville at a depth of about 550 feet. Because Fort Dodge was the hub of good transportation, the first gypsum mill was built here in 1872. Growth of the industry in this area was slow during the area's early history but progressed more rapidly as the region developed and became settled. The Fort Dodge area at present is the most important gypsum center in the Basin, operating mostly open pit mines; Centerville, with underground mines, ceased all operations in 1934 after opening up in 1917; and a new underground operation at 600 feet has been placed in production in 1960 near Sperry in Des Moines County.

Petroleum, as early as 1865 was produced in small quantities until about 1888, when commercial production of oil began in the Illinois part of the Basin. Oil exploration increased during the 1880's and numerous wells were drilled near Pittsfield, Pike County; Litchfield, Montgomery County; and Sparta, Randolph County.

Exploration declined until after 1900, when production began to take an upturn and reached a peak in 1940, with the production of 148 million barrels of oil.

Stone was used by the early settlers for housing and other construction. As the demand developed, dimension stone replaced the use of rough field stone and was used extensively as a building material during the 19th century. Early production statistics on dimension stone are inadequate to trace its use in the Basin area. Many quarries were operated and the stone used locally. However, near the end of the 19th century, the use of dimension stone decreased, being replaced in construction to a great extent by reinforced concrete.

By the turn of the century in 1900, substantial quantities of minerals were being produced within the present Basin limits, and table 2 lists the principal minerals produced according to total dollar value in the five ~~main~~ States comprising the Basin. In early mineral production records in the Basin, detail is limited, and the records do not provide sufficient accuracy to the production figures of several minerals for use in any accurate studies. In the table, some additions and deductions were made to the State totals to approximate more closely the Basin production values. As can be seen, coal, stone, and lead were the most important minerals in 1900.

TABLE 2. - Estimated value of production for selected mineral commodities in 1900 for the Upper Mississippi River Basin 1/

| | | | |
|---|---|---|---|
| Gypsum | 2/ $ 561,588 | Natural gas | $ 2,247 |
| Iron ore 3/ | 2/ 126,922 | Lead | 4/ 3,709,886 |
| Coal | 38,362,854 | Zinc | 4/ 596,550 |
| Stone | 6,188,417 | Nickel | 3,886 |
| Clay | 341,779 | Cobalt | 6,471 |
| Petroleum | 5/ 1,000 | Barite | 65,696 |

1/ All figures are the sums of State totals except those of lead and zinc ~~which~~ exclude that portion of the Tri-State district in Missouri. States included are Illinois, Iowa, Minnesota, Missouri, and Wisconsin. Except where otherwise noted, all figures are taken from 1900 Mineral Resources of the United States.

2/ Iowa figures were obtained from 1900 Report of the State Geological Survey.

3/ Excludes Minnesota since all production was from St. Louis County. Wisconsin data excludes production from Iron and Florence Counties. Source of Wisconsin Data: Lake Superior Iron Ore Association, 1938.

4/ Upper Mississippi Valley district quantity figures were taken from Heyl's publication, "Zinc-Lead-Copper Resources and General Geology of the Upper Mississippi Valley District," U. S. Geol. Survey Bull. 1015-G, and multiplied by the average price to determine total value. Missouri figures exclude data from the Tri-State district. The southeastern Missouri total was computed by subtracting the southwestern Missouri total from the State total. Sources of data were BuMines Inf. Circ. 7383 and Missouri Div. of Geol. Survey and Water Resources Inf. Circ. No. 4.

5/ Does not include petroleum produced in Missouri, which was included with the Indian Territory in the 1900 Mineral Resources of the United States. State figures for that year were unavailable.

TABLE 3. - Upper Mississippi River Basin historical production of selected metals and coal, 1900-1960 1/

| Year | COPPER | | IRON ORE 2/ | | LEAD | | SILVER | | ZINC | | COAL | | Total value | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity Short tons | Value | Quantity Long tons | Value | Quantity Short tons | Value | Quantity Ounces | Value | Quantity Short tons | Value | Quantity Short tons | Value | | |
| 1900.. | NA | NA | (3/) | (3/) | 41,915 | $3,709,886 | - - - - | - - - - | 6,982 | $596,550 | 30,000,624 | $33,194,481 | $37,500,917 | ..1900 |
| 1905.. | NA | NA | 4/ 498,998 | 4/ $824,075 | 76,104 | 7,245,149 | 12,900 | $7,869 | 12,042 | 1,313,662 | 44,044,490 | 51,008,864 | 60,399,619 | ..1905 |
| 1910.. | 47 | $11,955 | 3,145,542 | 8,359,869 | 135,938 | 11,963,232 | 33,096 | 17,872 | 29,915 | 3,230,412 | 50,168,565 | 62,976,669 | 86,560,009 | ..1910 |
| 1915.. | 201 | 70,378 | 5,779,521 | 10,536,523 | 186,667 | 17,546,698 | 57,756 | 29,282 | 47,309 | 11,732,632 | 61,021,485 | 73,014,514 | 112,930,027 | ..1915 |
| 1920.. | 756 | 278,307 | 8,989,518 | 35,091,851 | 164,642 | 26,342,280 | 111,128 | 121,130 | 32,022 | 5,187,564 | 88,903,881 | 283,119,000 | 350,140,132 | ..1920 |
| 1925.. | 6 | 1,718 | 9,645,423 | 23,638,510 | 211,270 | 36,760,980 | 83,340 | 57,838 | 22,587 | 3,433,224 | 64,298,502 | 145,294,000 | 209,186,270 | ..1925 |
| 1930.. | 88 | 22,958 | 9,630,915 | 24,715,530 | 200,159 | 20,015,900 | 170,210 | 65,531 | 16,874 | 1,619,904 | 51,342,936 | 92,218,000 | 138,657,823 | ..1930 |
| 1935.. | 34 | 5,616 | 6,833,272 | 16,706,616 | 97,227 | 7,778,160 | 110,551 | 79,459 | 8,923 | 785,224 | 43,679,953 | 70,593,000 | 95,948,075 | ..1935 |
| 1940.. | 685 | 154,810 | 12,327,278 | 31,607,130 | 170,347 | 17,034,700 | 147,306 | 105,000 | 5,776 | 727,776 | 48,478,705 | 83,747,197 | 133,376,613 | ..1940 |
| 1945.. | 3,399 | 917,730 | 15,411,904 | 39,886,424 | 175,266 | 30,145,752 | 94,022 | 67,429 | 19,888 | 4,574,240 | 69,438,624 | 162,710,613 | 238,302,188 | ..1945 |
| 1950.. | 2,982 | 1,240,512 | 15,940,149 | 79,230,712 | 135,481 | 36,579,870 | 236,273 | 213,839 | 28,339 | 8,048,276 | 54,736,582 | 218,187,673 | 343,500,882 | ..1950 |
| 1955.. | 1,722 | 1,284,612 | 20,057,082 | 141,737,469 | 129,166 | 38,491,468 | 268,620 | 243,115 | 35,345 | 8,694,870 | 44,139,806 | 161,063,717 | 351,515,251 | ..1955 |
| 1960.. | 1,087 | 697,854 | 14,597,296 | 120,147,639 | 114,358 | 26,759,772 | 15,594 | 14,113 | 41,556 | 10,721,448 | 40,703,487 | 174,622,865 | 332,963,691 | ..1960 |

1/ Excludes data for cobalt, nickel, and synthetic manganese ore.
2/ Includes iron ore containing from 5 to 35 percent manganese, natural, which is ordinarily classified by the Bureau of Mines as manganiferous ore.
3/ No production in the Minnesota portion of the Upper Mississippi Basin, and Missouri data are not available.
4/ Incomplete total. Excludes data for Missouri which are not available.

## 9. DEVELOPMENTS IN THE MINERAL INDUSTRY IN THE UMRCBS, 1900-1960

a. General. After the turn of the century the mineral industry in the Basin expanded with the general industrial growth of the Nation. It is difficult to extract mineral production data for all commodities in the Basin area from historical records, because they exist principally on a statewide basis. Table 3 shows the quantity and value of production for principal metallic minerals and coal for the area included in the economic subregions of the Basin for the period 1900 to 1960. The value of these mineral commodities increased from $37.5 million in 1900 to $333.0 million in 1960, an average increase of 3.7 percent per year. Early petroleum, sand and gravel, and crushed stone production statistics for the Basin area are not sufficiently detailed to assign accurate quantity and value data. Significant developments for each commodity are discussed separately.

b. Coal. Illinois and Iowa at the turn of the century had considerable coal mining activity. However, as the area developed because of improvements in transportation, the Iowa coals became less competitive because of their lower quality and the less continuous nature of the beds.

In 1900, Illinois produced over 25.1 million tons of coal from 920 mines employing 39,351 men. Of this, 23.4 million tons valued at $24.5 million was produced from within the Basin planning area. Coal production in Illinois increased until about 1920 when 80.1 million tons was produced from 1,035 mines employing

95,763 men. In that year, 88.3 million tons valued at $283.1 million ~~were~~ was produced within the Basin. Production continued at approximately this rate until about 1925 when it began to decline.

Some of the earliest coal production (on a small scale) was from outcrops. The first recorded production of strip coal for shipment by rail was in 1910. Steam shovels were introduced in 1910 for removing overburden, and soon after, coal also was loaded by this means (58). As methods for drilling and blasting overburden were developed, strip-mined coal assumed an increasingly larger share of the market. By 1920, specially designed equipment was able to handle overburden to depths of 50 feet. In 1926, a shovel with a 95-foot boom and 12-cubic-yard bucket powered by electricity was built and immediately showed tremendous advantages. In 1946, the Kolbe Wheel Excavator was introduced. This machine employed excavating buckets mounted on a wheel and discharged overburden onto a conveyor belt for disposal at some distance from the excavation. Production of strip coal in Illinois increased from 0.6 percent of the total in 1900 to 49.3 percent in 1960.

Reclamation of strip-mined areas in Illinois was first tried in 1930 with tree planting on the spoil banks of the piled-up, stripped overburden. In 1939, more than a million trees were planted and experimental plantings of grasses and legumes were made (58). Research in reclamation of strip lands has been conducted vigorously by several mining companies and governmental agencies. Lakes resulting from strip mining have created many recreational areas. Through 1964, coal mining activities in Illinois have disturbed about 141,000 acres and, of this, about 84,000 acres have been partly or wholly reclaimed.

Coal was beneficiated by washing in Illinois as early as 1906, and the first statistics on coal washing plants were collected in that year when over two million tons were washed in jig plants. Since that time another coal beneficiation method,mechanical cleaning, usually requiring water has become increasingly common. Since 1955, the percentage of coal cleaned dry by pneumatic means, considered mechanical cleaning,in the United States has remained at about 7 percent of the total coal cleaned, and it is assumed that this ratio will remain at about this level in the future. Both the washing and mechanical methods have their particular advantages, and the method selected depends on characteristics of the coal, availability of water, and market demands in terms of moisture content. In 1960, about four billion gallons of new water were required for coal cleaning and more than four times this amount was recirculated.

In Iowa, coal production by 1900 had reached 5.2 million tons with 388 mines operating and 13,041 men employed in the mines. Of this, 4.3 million tons valued at $5.8 million were produced from within the Basin planning area. Iowa's peak production was reached in 1917 when 246 mines employing 15,464 men produced 9.0 million tons of coal. In 1920 coal production from the Iowa part of the Basin was 6.2 million tons valued at $23.5 million. Since that year, there has been a declining trend in the amount of coal produced. Mechanical cleaning of coal has not been practiced to any great extent in Iowa, it is not done ~~at the present time~~, and it is doubtful if it will be in the future.

In Missouri, coal production in 1900 was 3.5 million tons valued at $4.3 million, of which 1.6 million tons valued at $1.7 million were produced in the Basin. In 1920, over 2.0 million tons valued at $7.6 million were produced in the Basin; but after this date, there was a general decline in coal production, and in 1960, only 0.7 million tons valued at $3.1 million were produced from the Basin. Of the total coal produced in Missouri in 1960, 96.9 percent was strip mined, and 66.5 percent was mechanically cleaned.

c. Petroleum. Although records of petroleum production in Illinois exist from 1900, early statistics are not sufficiently detailed to assign quantities to the Basin area. Statewide production figures are available, and growth of the industry within the Basin is closely related to the growth of production in the State. Oil production is obtained from depths of several hundreds to more than several thousands of feet. Shallow groundwater strata are unaffected because of protection by lining and sealing the well bore with steel casing.

In Illinois, in 1900, 200 barrels of petroleum valued at $1,000 were produced. By 1910, production increased to 33.1 million barrels of crude petroleum valued at $18.7 million, but after 1910, there was a general decline in production until the year 1935, when only 4.3 million barrels valued at $4.8 million were produced. Discovery of the large Louden and Clay City Consolidated oilfields in 1936 and 1937 resulted in a 1940 peak output of 147.6 million barrels of crude valued at $156.5 million. In 1940, the first year data were sufficiently detailed to prepare a Basin total, 114.9 barrels of crude valued at $121.8 million were produced within the Basin area. By 1960, production for the State had decreased to 77.3 million barrels valued at $228.9 million and production within the Basin had decreased to 32.9 million barrels of crude valued at $97.4 million.

Secondary recovery of oil by waterflooding, an operation requiring substantial quantities of water (about three billion gallons in 1960), mostly saline for this area, began in Illinois in 1944. Waterflooding is a method of recovering oil by which injection of water into the oil bearing formation displaces petroleum. By 1954, 23 percent of the oil production for the State was by this process and in 1960, 63.2 percent. The saline water produced in the oilfields cannot be used for farm or domestic purposes because of its high salinity.

d. Iron Ore. Available data for Missouri does not permit an evaluation of tons of iron ore produced within the Basin in 1900, but most of the production of 88,791 tons of ore valued at $134,962 probably came from the area included in the Basin.

In Minnesota, in the Basin's part (30 miles long) of the Mesabi range in Itasca County, the first year of iron ore production took place in 1902 with the shipment of 5,892 tons of ore from the Hawkins Mine at Nashwauk. By 1905, production of iron ore from Itasca County was 498,995 tons valued at $824,075. Since 1905, production of iron ore from within the Basin in Minnesota exceeded that from Missouri in quantity and value. The first year that iron ore was shipped from the Cuyuna range in Crow Wing County, Minnesota, was 1911, with the production of 181,224 tons. Production of iron ore from the Spring Valley district, in Fillmore and Olmsted Counties, Minnesota, began with 59,000 tons in 1941 and reached 575,000 tons in 1958, the year of maximum production.

Total production of iron ore within the Basin in 1955 was 20.0 million tons valued at $141.7 million of which ~~0.2 million~~ tons valued at $2.2 million was from Missouri. In 1960, corresponding production was 14.6 million tons valued at $120.1 million with 0.2 ~~million~~ tons valued at $2.9 million from Missouri.

Iron ore production in the Basin is only a small part of the total Minnesota production and factors affecting Minnesota iron ore production also apply to the Basin's production. Minnesota, the leading iron ore producing State in 1964, supplied 59 percent of the total usable ore shipped in the United States. In 1942, Minnesota's share of the total United States iron ore production reached a high of 70 percent. Before 1946, the United States was an iron ore export Nation but since 1960, the United States imported more iron ore than it exported. Depletion of the once great Mesabi direct shipping ore reserves during World War II encouraged an extensive worldwide program of iron ore exploration and, as a result, large-scale iron ore mining operations were developed by American companies in Canada, Africa, and South America to supplement the dwindling Mesabi direct shipping iron ore reserves.

Meanwhile, research efforts in Minnesota, spanning more than three decades, resulted in development of economic mining and metallurgical methods for utilizing the 6-billion-ton reserve of magnetic taconite on the Mesabi range.

The development of the taconite process with its capability of producing high-grade pellets of uniform structure and quality created a new, higher industry standard for iron ore. The natural ores and concentrates, both domestic and foreign, which in past years were considered marketable, now are used only as required to supplement supplies of high-grade pellets. The wide acceptance of iron ore pellets also has resulted in large reserves of poorer grade natural iron ores being relegated to the lower category of an iron resource, no longer an ore. Mining of taconite is by open pit.

e. Lead and Zinc. By 1900, the Upper Mississippi Valley district (Wisconsin, Illinois, and Iowa) was firmly established as a zinc producing area with a significant byproduct, lead production. In that year, 5,583 tons of recoverable zinc (metal) valued at $473,438 and 1,300 tons of recoverable lead (metal) valued at $114,660 were produced. At this time, the southeast Missouri district had become firmly established as a major lead producing area. In 1900, it produced 40,615 tons of recoverable lead (metal) valued at $3,595,226 as well as 1,399 tons of recoverable zinc (metal) worth $123,112.

Production in both mining districts continued strong until 1930 when there was a drastic decline due to the depression. The Upper Mississippi Valley district was more seriously affected than was the southeast Missouri district. During the 1930's, only one company operated in the Upper Mississippi Valley district. The establishment of premium prices for lead and zinc during World War II stimulated mining and the retreatment of old jig tailings by flotation. Much of the production in the war years came from small independent operators. The decline in metal prices and cancellation of the bonus system after the war forced many of the smaller operations to close. Since about 1950, most of the production has come from a few relatively large companies.

f. Sand and Gravel. Sand and gravel has been used for road and fill material since the first roads were constructed and in most cases is a local commodity. Its production was more a result of settlement and industrial development. As concrete construction became more common, sand and gravel specifications were higher. This resulted in the practice of screening and washing, requiring the use of water. Statistics on the early production of sand and gravel are limited largely to State totals, and probably much of the production from small operations is not included in the totals. Sand and gravel for construction is governed principally by local demand, availability of water, and permission to despoil land area. Industrial sands, however, are shipped considerable distances and the demand is related to industrial activity.

g. Stone. The general decline in the use of dimension stone, starting near the close of the 19th century, has continued to the present time. Only those quarries which produced dimension stone having a market beyond the local community have survived. Such markets depend on a superior quality stone with pleasing visual properties having wide public acceptance. Production of crushed stone for use as construction aggregates has increased. Abandoned quarries are unreclaimed as they are presently unamenable to contouring, restoration, or used for other useful purposes.

h. Gypsum. In 1900, all of the gypsum production within the Basin came from Webster County, Iowa. That year, production, mostly by underground methods, was 184,600 tons of gypsum valued at $561,588. Production of gypsum from Webster County has been continuous to the present time. Gypsum was mined in Appanoose County between 1912 and 1934.

The first gypsum mining in Webster County was from outcrops along the Des Moines River prior to 1872, but by 1900, most of the gypsum mined in the Basin was by underground methods. In 1927, one of the producers began stripping the overburden and quarrying the gypsum. Because the mining costs were lower and recoveries by this method were better, other companies started this practice, but it was not until 1945 that the last underground mine was closed. Much of the surface disturbed land has been unreclaimed.

In 1912, a shaft was sunk to the gypsum deposits in Appanoose County, but the influx of water encountered forced the closing of operations until 1917 when pumps were installed to handle the water and a gypsum mill was constructed. The deposits were worked intermittently until 1934.

The gypsum deposits in Des Moines County, Iowa, were first exploited in 1960 with the completion of a 600-foot shaft near Sperry, Iowa. The mine is now in production mining a 10-foot thick gypsum strata.

i. Miscellaneous Minerals. In addition to the mineral commodities discussed above, other minerals of lesser importance were produced in small quantities or as byproducts. Because production rates of these minerals will not have a substantial effect on water needs or land use in the Basin, they have not been discussed as separate items.

Barite has been produced from the Basin area in southeast Missouri since 1872. These deposits are in residual clays and were derived from the weathering of dolomites, in which the primary barite occurs. Mining is by open pit methods followed by recovery of barite in simple plants utilizing log washers and gravity separation.

Copper, cobalt, nickel, silver, and zinc are produced as byproducts of lead production in Missouri. As these metals do not influence the use of water or land, they have not been treated separately from lead in this report. Their principal significance is the added value they impart to the lead ores, thus permitting the exploitation of lower grade lead ores. Similarly, lead production in Wisconsin and Illinois is a byproduct of zinc production.

## SECTION IV
## WATER USE IN THE MINERAL INDUSTRIES

Water is a vital need for most mineral industry operations. Mining, quarrying, and subsequent processing are essentially concentrating operations aiming for the highest recovery of the mineral in a deposit. The ability of water to dissolve, suspend, and transport makes it an essential tool of the mineral industry. The basic objective in the processing of minerals is the separation of dissimilar particles. This can be accomplished in a number of ways and water is the principal agent of separation. Washing is probably the simplest, most common, and oldest processing method. The differential specific gravity of minerals and the ability of water to suspend and transport are characteristics most used in the processing of minerals. A wide range of gravity methods of separation and concentration have been developed over the years. Water is used as a solvent in leaching and chemical extracting. In the flotation process, water with chemical additives separates the mineral from the waste.

Increased demand for metal products and improved methods of mineral dressing techniques, have resulted in the mining of lower grade deposits. Processing of lower grade ore requires the treatment of greater tonnages of material, thus increasing the demand for water. Increasing demand for higher quality mineral products, such as aggregate material for concrete mixtures, has resulted in steady increase in water use.

Though large quantities of water is needed by the mineral industry, individual water requirements vary in quality and quantity. In many operations, such as the flotation process, higher quality water is required than for other operations.

Some mining operations use no water in processing, while others would be unable to operate without water. Scarcity of water, economy measures, and antipollution practices at many mining operations make it necessary to recycle water after some treatment that renders effluent water clean enough for repeated use. The degree of reuse is an important factor in determining water requirements at most mineral processing plants. In general, the total water recirculated per ton of product is greater than new water intake in the mineral industries in the Upper Mississippi River Basin.

## SECTION V
## PRESENT STATUS AND FUTURE PROJECTIONS OF THE BASIN'S MINERAL INDUSTRIES, 1960 AND POST-1960

### 10. INTRODUCTION

The end effects of the geological processes of wind, water, ice, earthquakes, vulcanism, temperature changes, and others formed the mineral deposits or mineral commodities as presently found in the Basin; the processes removed some of the mineral materials from one area (source rock) and redistributed them to other areas, usually concentrating commercially desirable minerals in small regions (ore bodies) or earth layers (strata), or with other minerals dispersing them widely, some buried deeply below the earth's surface while others lay exposed on top of the land.

The peculiar and unique distribution of mineral commodities as presently found in the Basin, then, is a result of the geologic forces acting to create them. Two of the principal creative forces act through water and ice, and these two are selected from many, merely to give a general idea how a geological process may act to bring about changes in the earth's surface.

Some of the general ways water and ice may act in geologic processes are as follows: water, surface and subterranean, both hot and cold through both mechanical and chemical actions, may act as an erosion agent; as a transportation medium; as a segregator and concentrator of various mineral grains when the water is moving or motionless; as a solvent (leaching), dissolving minerals and metals, transporting them in solution to other regions, then depositing (precipitating) the minerals and metals from solution and concentrating them in localized regions; as a bursting force or disruptive agent when water freezes in the cracks of rocks; and others. Ice, in the form of glaciers covering parts of a continent, acts as a giant scraper, plowing the land deeply, transporting enormous quantities of earth debris, and distributing and redistributing the debris (glacial drift) widely.

Thus, through the actions of these natural agencies, the mineral commodity of sand and gravel is found everywhere in the Basin with the exception of the southern tip; rock, for crushed stone, is found nearly everywhere in the Basin but it must be uncovered by stripping overburden; iron ore is found concentrated principally in small regions, widely separated, one in Minnesota and Wisconsin, the other in Missouri; zinc (with some lead) is found principally in the Wisconsin, Illinois, and Iowa zinc region; lead (with some zinc) is found only in Missouri; gypsum is found in beds (mostly flat) in Iowa, with some at the surface and some deeply buried; coal is found principally in Illinois and some in Missouri and Iowa.

Dimension stone may be found at the surface in a number of Basin locations, but the principal source is in Minnesota, with a minor amount in Missouri. Petroleum is found only in southern Illinois, produced from depths of only a few hundred feet to depths of some thousands of feet; and barite is found in Missouri.

## 11. GENERAL GEOLOGY

The Upper Mississippi River Basin, encompassing a watershed area of 188,200 square miles, is located geographically in the north central part of the United States and is called a lowland (part of the Central Lowlands) because it is marked by a visible contrast of topography with the surrounding specific regions of greater elevations; those contrasting regions east and west are far outside the Basin while those north and south are partly within. The term, "lowland," is a generalization to distinguish between regions of differing elevations, e.g., lowlands versus uplands. The great size of the Central Lowlands area, of which the Basin's part is less than one-third, suggests widespread uniformity in surface features; some parts are even monotonous, and the Basin's lack of major distinctions is due in part to its nearly flat-lying rocks (39, 109).

Glaciation dominates most of the Basin's landscape and it created considerable variety. Wherever the glacier went, and there were at least four major advances and retreats, the landscape is in large part the product of ice work or of water working under conditions imposed by glaciation. Thus, glacial drift covers nearly all of the Basin, masking the features of the underlying foundation rocks, and bears on its surface, not everywhere, many lakes and swamps, characteristic of some glaciation. The thickness and character of the drift differs across the Basin, being more than 300 feet deep in northern Minnesota while in the major portion of the Basin the depth varies from less than 10 feet to some tens of feet. The southern tip of Illinois is without drift as well as one area in southwestern Wisconsin (The Driftless Area).

The Basin, then has no sharply contrasting features of topography. The terrain consists principally of rolling land, with elevations ranging between 280 and 1940 feet above sea level. The only regions with rugged topography are the sub-mountainous Ozark area drained by the Meramec River on the Basin's southwestern edge and the steep-sloped unglaciated area of southwestern Wisconsin and northwestern Illinois.

a. Bedrock of the Basin. The surface of the bedrock beneath the glacial drift in the Basin is relatively flat with some broad undulations of low relief. The geological structure of this bedrock is largely determined by the major uplifted area of very old rocks (The Laurentian Uplift) to the north of the Basin, around which rocks of younger age outcrop in successive belts, with the outcrops of the youngest rocks farthest away from the uplifted center. From their truncated outcrops the bedrock formations in general dip very gently southwardly and, despite their faint dip, the structure formed by them determines which formation shall constitute the substratum in any one locality.

Within, and surrounding the Basin's edges without, minor structures of broad domes, low anticlinal arches, and broad saucer-like basins of varying areal extent, some occupying nearly an entire state, modify the prevailing geological structure and dip of the bedrock. There are three principal examples of these features. The largest, the Illinois Basin, a spoon-like depression of considerable magnitude, occupies most of the State of Illinois, and modifies the general dip of the bedrock at the Basin's south end; the Wisconsin dome (uplift) and arch covers the greater part of Wisconsin; and a basinal structure, similar to the Illinois Basin, crosses Missouri and extends well into Iowa and Oklahoma. An uplift (the Ozark uplift), exposing Precambrian rocks, modifies the geology on the southwestern edge of the Basin with encircling sedimentary rocks of younger age (109).

The geological ages of the Basin's underlying bedrock are among the oldest. The oldest rocks, the Precambrian, occur in two relatively small diverse areas, one in northern Minnesota and one in southeastern Missouri, while the next younger rocks, the Paleozoic, mainly fill the remainder of the Basin, with some Cretaceous rocks, the youngest, located in southwestern Minnesota. The Paleozoic rocks, subdivided into smaller geologic units, consist of sandstones, limestones, conglomerates, shales, and coal, and these beds extend in nearly horizontal positions westward from the Appalachian area to the eastern margin of the Rocky Mountains (5).

The Mississippi River and its tributaries flow through and drain the Basin, with the main course of the river, particularly along some stretches (e.g. Minneapolis) channeling through the drift and deeply into the bedrock to form gorges with vertical exposures of the bedrock. The ancient streambed in places (e.g. St. Louis, Missouri) was cut much deeper and wider than its present dimensions, but the old channel is now nearly filled to the present streambed with sand and gravel of reworked glacial deposits and modern sands and gravels. Thus, water action in the overall drainage system has more or less everywhere in the Basin modified the surface land features.

b. Distribution of Mineral Commodities in the Basin's Bedrock. Minerals associated with the regional bedrock structures in the Basin are of economic importance in the UMRCBS planning area; the Paleozoic rocks are important since many of the minerals of the Basin occur in them and these rocks may be subdivided from the younger shallower to the older deeper into Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, and Cambrian. Rocks older than the Paleozoic are grouped together as the Precambrian.

## 12. RESERVES, EXPLOITATION, WATER AND LAND USE BY COMMODITY

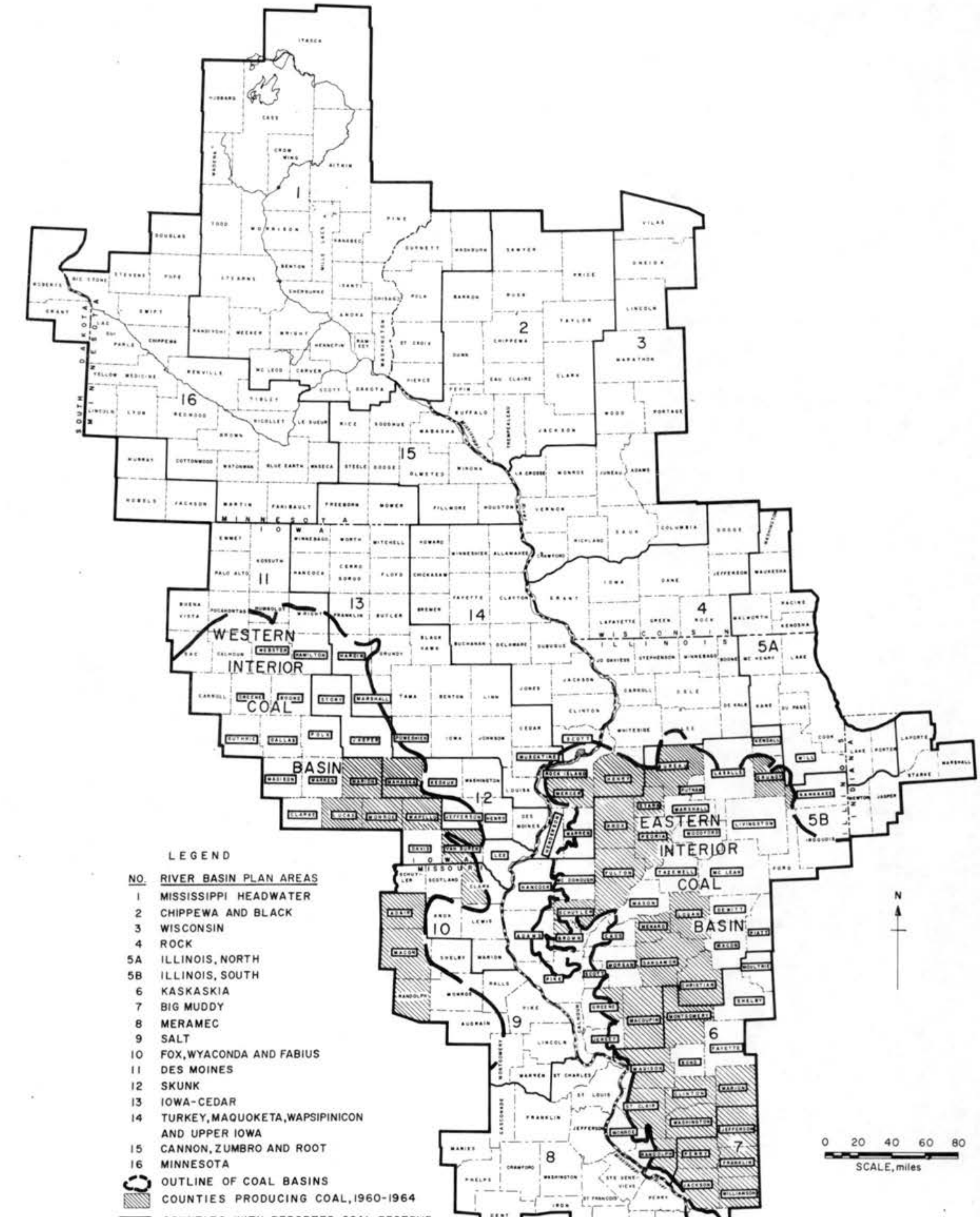
a. Coal. Coal is found in the sedimentary rocks of Pennsylvanian age, the youngest of importance in the Basin, and these strata under the glacial drift extend across the southern part of the Basin into southwestern Indiana, western Kentucky, parts of Iowa, northwestern Missouri, and cover most of the State of Illinois where the bulk of the Basin's coal is produced. The extent of the coal beds or Pennsylvanian strata in the Basin is shown in plate 1.

Glacial deposits cover most of these rocks, except where streams have cut through and exposed the bedrock. The sedimentary rock formations were deposited originally as relatively flat-lying beds but later there was some downfolding which left a large spoon-shaped basin in southeastern Illinois. The deepest part of the major downfold is found along the center of the spoon-shaped basin. Folding has not affected the coal deposits, adversely.

The Pennsylvanian System is about 2,600 feet thick in southern Illinois, and it contains 30 to 40 coalbeds or horizons throughout the System ranging in thickness from a thin streak to more than 12 feet. Only those lying in the middle portion of the System are considered economic and included in the reserve estimates.

In general the coalbeds in Iowa are discontinuous and appear to be lenticular in shape. Data are so meager in places that the extent of the reserves cannot be fully determined. It is estimated that possibly 2,018 square miles are underlain by coal that has not been explored.

In the Missouri portion of the Upper Mississippi River Basin, the rocks of the Pennsylvanian System are nearly horizontal except in northern Missouri where there is a low-angle monoclinal dip. Erosion has removed most of the Pennsylvanian rocks in this part of




UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
COAL

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

Midwestern Coal-Associated Mineral Occurrences and Markets, Part 5, West Virginia University, 1965, by O.B. Bucklen, et al.

the Basin. The coal reserves remaining are minor in importance and occur mostly in Adair and Macon Counties. Other counties may have intermittent production as small bodies of coal are discovered.

Coal reserves were based on information obtained from the Illinois, Iowa, and Missouri State Geological Surveys (24, 72, 91, 99, 100). All reserve figures represent coal in place without deductions for losses in the mining operation. Only those coalbeds known to have minable thickness and reasonable uniformity are included in the reserves. Coalbeds underlying populated areas and in the vicinity of oilfields were excluded from the reserves. This does not mean that all reserves included have economic value at the present time, but through changing mining technology they will have possibilities for the future.

In making reserve estimates, 1,800 tons per acre for each foot of coal was used. Assuming this density for coal, it is estimated that ~~there are~~ 98.1 billion tons of coal reserves lie in the Basin. This tonnage represents coal in place. Figure 1 shows the counties that have coal reserves.

In Illinois, a 28-inch coalbed is considered the minimum thickness for underground mining methods. Earlier estimates for strip mining considered 24 inches to be minimum thickness for beds that had less than 100 feet of cover, and the most recent reports consider 18 inches the minimum thickness with less than 150 feet of cover. ~~Due~~ Owing to recent developments in stripping technology the Illinois Geological Survey is recalculating ~~their~~ its strip coal reserves, using 18 inches as minimum thickness. These calculations are in progress and when finished will probably result in larger total reserves for the Basin. The total used in this report includes the presently available reserve data for Illinois. A 28-inch coal thickness was used for underground methods and 24-inch coal for strip mining except in areas where reserves using 18-inches have not been recalculated.

The Iowa Geological Survey used 14 inches as the minimum coal-bed thickness for all depths of overburden in estimating ~~their~~ Iowa reserves. However, 14 inches probably is too thin for underground mining. T~~wenty-five percent~~ of Iowa's 1.3 billion tons of the Basin's reserves is in beds having thicknesses of 14 to 28 inches.

Available information indicates the reserves in Missouri within the Basin are of relatively minor importance. Macon and Adair Counties are estimated to have 70 million tons of coal reserves with beds ranging from 26 to 42 inches in thickness. Other counties have produced coal in the past, and probably will produce intermittently in the future. Data are too limited to estimate reserves.

(1) Operations. There are two basic types of coal mining operations in the Basin: surface stripping and underground mining. Both are highly mechanized. Electrical power generation is the principal use for the Basin's coal. It is shipped from the mines to the market via truck, railroad, and barge.

Figure 1 shows the counties that had coal production of 1,000 tons or more in at least one year between 1960 and 1964. Other counties produced coal in smaller quantities but could well become large producers in the future. In 1960, 38 counties with 118 active mines produced 40,703,487 tons of coal. Coal quality was upgraded by wet and dry mechanical cleaning methods. Of the total production, 84.7 percent was cleaned by one or both methods. The most widely used method is wet cleaning which includes one or more of the following operations: jig washing, riffle launders, and wet tables. Dry cleaning methods consist of dedusting facilities and airflow tables.

Only in the wet washing plants is a supply of water essential. In Illinois, three-fourths of the water requirements are met by recirculated water. (See table 7 for water volumes). All washing plants have settling ponds for clarifying the water before any discharge reaches the local drainage.

Land requirements vary from mine to mine, depending on size and the type of mining methods used. Land is used for such items as mine buildings, railroads, roadways, cleaning plants, refuse disposal areas, settling basins, strip areas, and mine shafts or slopes.

(a) Strip Mining Practices. Strip mining is the oldest type of mining in the Basin and it dates back to the early history of mining. It has made its greatest progress since 1910 through improved design and development of large efficient earth-moving equipment. The strip mining cycle consists of removing the overburden for an area about 200 feet wide for the length of the pit and casting it to one side. The exposed coal is removed and overburden from the next strip is deposited in the mined area, figure 1.

A study of ~~ten~~ 10 strip mines in Illinois, of which nine were in the Basin, showed the coal recovery to range from 65 to 81 percent; the remainder is lost in mining and processing. From a mineral conservation standpoint the strip mining method achieves the highest coal recovery.

Land use is greater at strip mines than at underground mines. In the mining area, the entire surface is affected by the stripping cycle. The affected area, in acres, is inversely proportional to the coalbed thickness for a fixed percent recovery and tonnage; i.e., producing from thicker beds destroys less land per ton of production.

In 1960, strip mining accounted for 47.7 percent of the Basin's total coal production. The overburden and coalbed thicknesses ranged from 24 feet to 86 feet and 1-3/4 feet to 8 feet, respectively. Thin coal seams can be mined economically by strip methods.

Land reclamation in some form has been attempted since the beginning of strip mining in the Basin. By 1961, approximately 55 percent of the mined lands had been successfully reclaimed in Illinois (33). In Illinois, mining operators own about 62 percent of the acreage mined, 28 percent is held by private ownership, and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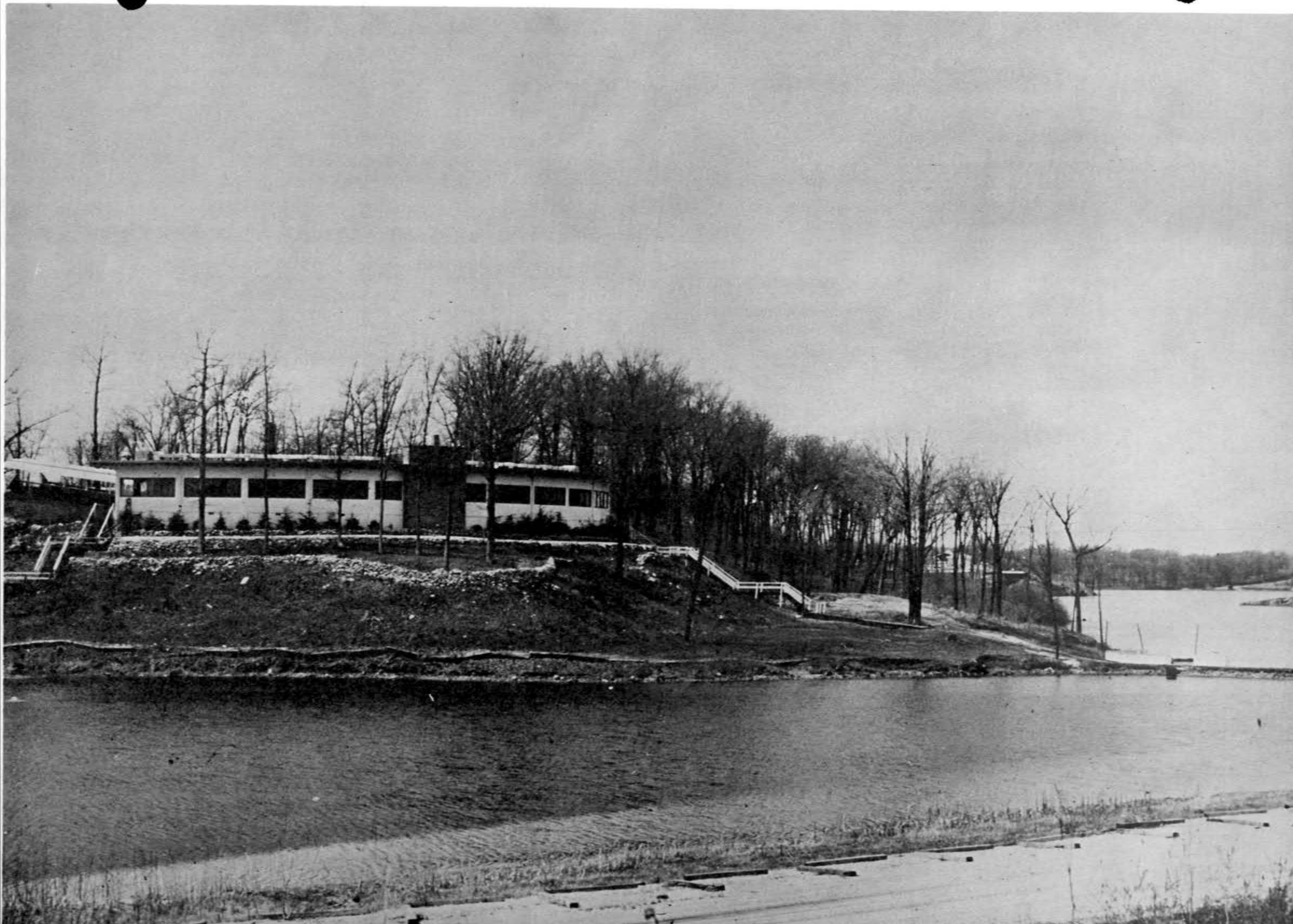
10 percent by public holdings. Reclamation operations are carried out principally by the coal operators, a 1962 requirement on their lands owned in fee and usually voluntarily on leased land.5/ (See table 8 for acreages). The most widely used reclamation programs have been tree planting, forage grasses, and an improvement of wildlife habitat. Other programs include land rehabilitation for recreational areas, building sites, and agriculture, figure 2.

5/ Report privately prepared by Paul N. Seastrom, Land Manager, The United Electric Coal Companies, February 8, 1964.

(b) Underground Mining Practices. Underground mining may be defined as a method used to extract minerals from the earth's crust through shafts or slopes. It is the most widely used type of mining in the Basin, but in recent years has been declining in importance due to increasing strip mining activity. Underground mining methods employed in the Basin include room and pillar, room and pillar with partial pillar recovery, and longwall. The latter is used where surface subsidence is permitted and yields the highest recovery.

In 1960 underground mining methods accounted for 52.3 percent of the Basin's total coal production. The cover ranged from 81 feet to 800 feet and coal bed thickness from 4 feet to 10 feet.

From a mineral conservation standpoint, underground mining methods yield a lower recovery than strip mining methods. A study of 16 underground mines in Illinois, of which 15 were in the Basin, showed coal recovery to range from 38 percent to 68 percent. The



lowest recovery was at mines where control of surface subsidence was necessary.

No reliable data were available on the amount of land used for underground mining. Land usage depends on the size of the operation, the arrangement of surface facilities, the amount of mine rejects, and whether surface subsidence is permitted. Whether there will be subsidence is difficult to predict because subsidence varies with thickness and nature of cover and mining method used. Underground mining requires less land than strip mining regardless of the underground method used.

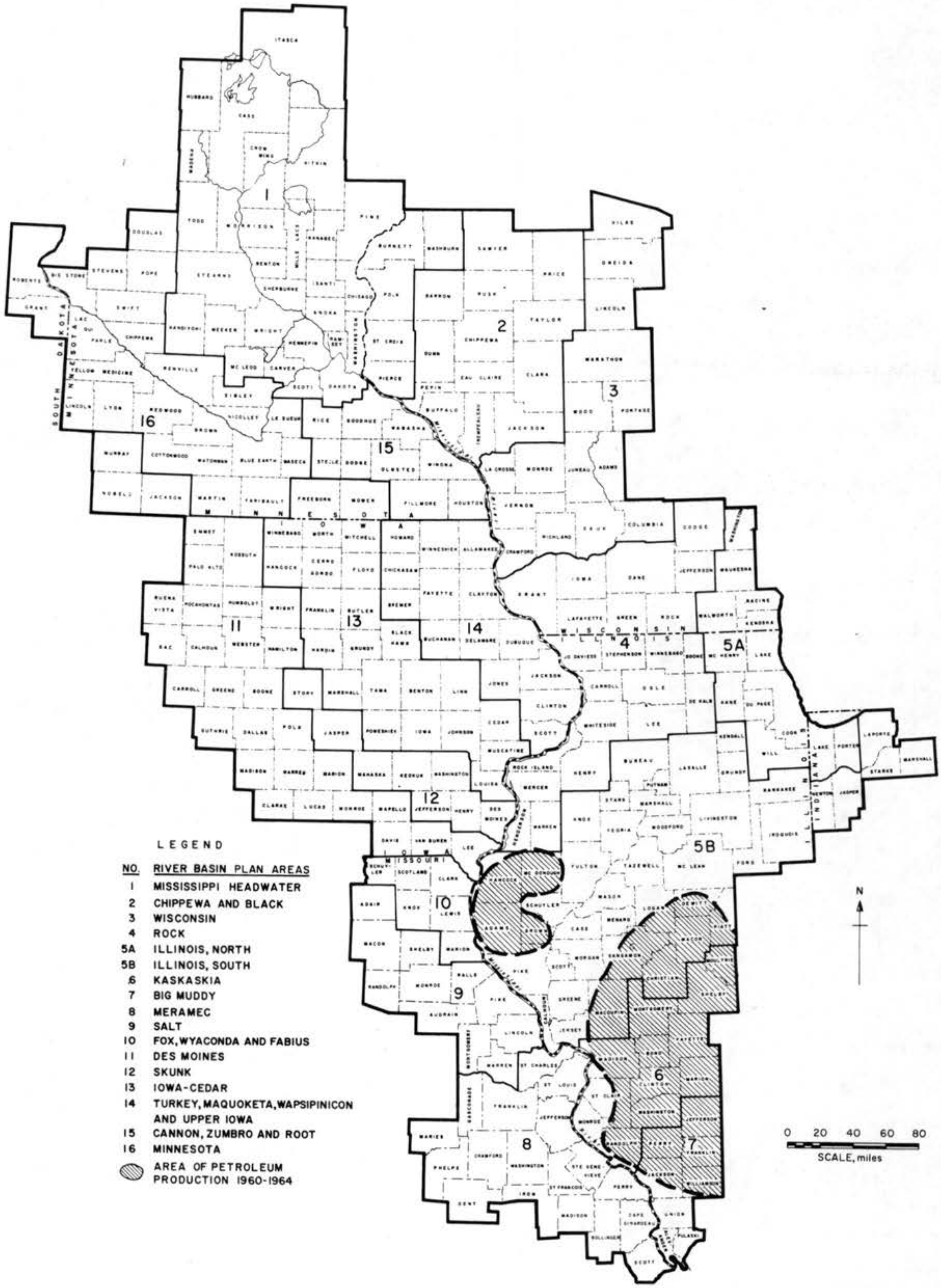
b. Petroleum and Natural Gas.

(1) Geology. Oil and gas in the Basin occur exclusively in southern Illinois in nearly all of the Paleozoic strata, from the Pennsylvanian down into the Ordovician, from about 57 different pay zones at different depths (some hundreds to some thousands of feet) in the Illinois Basin (61).

The mechanical arrangement of the strata in Illinois is like a layer cake of many layers, each deeper layer of increasing geological age, nearly horizontal and slightly distorted with small local bends, folds, and faults. The oil and gas found in each strata occur in areas insignificantly small compared to the Illinois Basin, but each has a geological feature that creates a trap that confines and holds the oil and gas captive. The nature of the trap has prevented the oil and gas from escaping--at least the part found--with geologic time.

(2) Reserves. All petroleum and natural gas reserves in the Upper Mississippi River Comprehensive Basin Study area are in the State of Illinois, although all of the Illinois reserves are not within the Basin, plate 2. On January 1, 1960, proven crude oil reserves in Illinois were reported at 596.1 million barrels (60). Natural gas reserves, both associated and nonassociated with crude oil, were estimated at 175 billion cubic feet; the natural gas contained an estimated 10.8 million barrels of natural gas liquids, principally natural gasoline (87). A detailed breakdown of reserves has not been made part of the public record. For the purpose of this study reserves have been prorated on the basis of crude oil production (data available by county), which is an estimate to be used with caution, particularly where natural gas and natural gas liquids are concerned. On the basis of 1960 crude oil production, therefore, reserves in the Upper Mississippi Comprehensive Basin Study area at the beginning of 1960 were placed at 248 million barrels of crude oil, 73 billion cubic feet of natural gas, and 4.5 million barrels of natural gas liquids.

(3) Operations. Oilfield operations require water in well drilling and in secondary oil production where waterflooding is practiced. Waterflooding within the Basin required 3.1 billion gallons of water, mostly saline produced from oil wells and cycled back to the injection wells, during 1960 as compared to only 48 million gallons (about 150 acre-feet per year) of potable water used for oil well drilling. Waterflooding requires a continuing

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supply of water for the duration of secondary recovery, which generally extends over a period of several years. Most of this water is supplied by the oil-producing wells, and the saline water produced with the oil is cycled back into the water injection wells.

A brief review of waterflood operations shows how water is used. Production of oil by primary methods expends, and eventually depletes, the natural energies of the reservoir. Eventually, further oil pumping is uneconomic. Although the oil reservoir still contains large quantities of oil, the remnant oil in the pores of the rock does not move of its own accord to the well, and it cannot be pumped to the surface.

Application of secondary methods of oil production permits an additional extraction of oil from the reservoir. This is done by pumping water or gas under pressure into the reservoir bed through strategically located input wells, so that the injected fluid displaces the oil from the reservoir's pores and pushes it toward the production wells. The injected water displaces the oil because of its immiscibility with oil, greater density, and greater surface tension. Gas also is used as the driving or displacing medium, but is much less efficient than water. In a method of secondary recovery known as pressure maintenance, the natural energy of the oil reservoir is not allowed to become depleted. Instead gas is introduced under pressure early in the life of the oilfield to maintain reservoir pressure, and the maintained pressure increases ultimate recovery.

In the Basin, either fresh water or saline water or both are injected into the oil bearing reservoir to displace the oil from the pores of the rock. The sources of such waters are surface streams, sewage plants, potable water wells, saline water wells, and producing oil wells. Indigenous water in the reservoir--and pumped-in water-- is produced with oil. Water produced with the oil varies from little at the beginning of waterflood operations to large quantities toward the time of abandonment. Produced water is slightly to strongly saline. Generally, saline water is re-injected into the oil reservoir, after filtering and some chemical treatment, and removal of iron compounds, so that often, no potable water is used. In other instances, when the volume is in excess, the saline water is disposed of by injection into a natural underground aquifer, with the approval of State regulatory agencies. Potable underground aquifers are unaffected by oil-field operations because of the use of well bore casing which passes through the aquifer and protects it against contamination by the well fluids.

Net water requirements for waterflood operations as used in this study represent the difference between the volume of water injected into the oil reservoir and the volume of water produced from it. Therefore, the difference between the injected and the produced volumes of water represents the so-called "makeup" water required to conduct waterflood or secondary oil recovery operations. In most cases little or no makeup water is required as saline water with the oil is produced in excess amounts and some must be disposed.

Waterflood production accounted for 75 percent of the Basin's production of 32,222,000 barrels of crude oil in 1960.

In well drilling, water is required in both rotary and percussion (cable tool) drilling procedures. In rotary drilling potable water is circulated into and out of the well to remove rock debris or cuttings from the hole, to cool the bit, to help support the walls of the hole, to prevent blowouts, and to control gas, oil, and water pressures in the geological formation being penetrated. Rotary drilling is the most common method used in drilling deep wells because of its greater speed. With such equipment water, or water mixed with bentonite and barite to form a drilling mud, is pumped into the hole through the drill pipe, the drilling mud emerges through the bit at the bottom of the hole and then, laden with cuttings from the bit, returns to the surface through the annular space between the drill pipe and the walls of the hole. At the surface the drilling mud is screened to remove rock fragments, treated to restore original fluid properties, and then recirculated. Losses of drilling water consist of seepage into the walls of the hole and evaporation at the surface. Such losses are restored with potable "makeup" water.

Estimates of the water required in oil well drilling were based on annual number of wells and footage drilled, listed by counties for each State as published in the Annual Statistical Issue of the Oil and Gas Journal. These data in conjunction with the Bureau of Mines water canvass of the mineral industry in 1962 indicated an average use of 33.6 gallons of water per foot (<u>23</u>) of hole drilled or a total use of 52 million gallons of water in the well drilling operations of the Basin's petroleum industry in 1960.

Land requirements for petroleum operations are small and of relatively short duration. During drilling operations, which normally last only a few months, a maximum of one to two acres are required for equipment storage and sludge pits. If drilling is successful and production is established, a very small plot is required for well head equipment and storage tanks or pipelines during the life of the field. The life ranges from a few years to several decades. Other land uses in the vicinity of a producing field are seldom affected to a significant degree by petroleum production operations.

(4) Legal Considerations. Illinois State regulations pertaining to petroleum operations ensure that proper protective casing procedures are followed to guard against salt water, oil, gas, or other wastes escaping from wells and entering surface or underground fresh water supplies. Regulations also govern construction and operation of salt water pits or oilfield refuse pits ("burn out pits") so that waste liquids and oilfield refuse may not escape in any manner, except by evaporation or by burning. Moreover, all operators are required to restore the disturbed surface land surrounding all wells to its original condition before drilling upon abandonment of operations.

c. Iron Ore.

(1) Geology. Iron ore occurs in Precambrian rocks in diverse locations in the Basin, in Minnesota, Wisconsin, and Missouri.

In Minnesota the Mesabi range, about 100 miles long, consists of sedimentary strata hundreds of feet thick known as the Biwabik iron formation, which dip gently southward from their wide outcrops under the drift, less so in the western part of the Mesabi within the Basin study area (30 miles long) where the iron formations are more flat lying (45). In the host rock, the Biwabik formation, the enriched ore bodies occur along the outcrop like plums in a plumcake, but those ore bodies in the Basin's study area are lower grade and consist of softer ores, a type referred to as "wash-ores" which are amenable to beneficiation, an upgrading process.

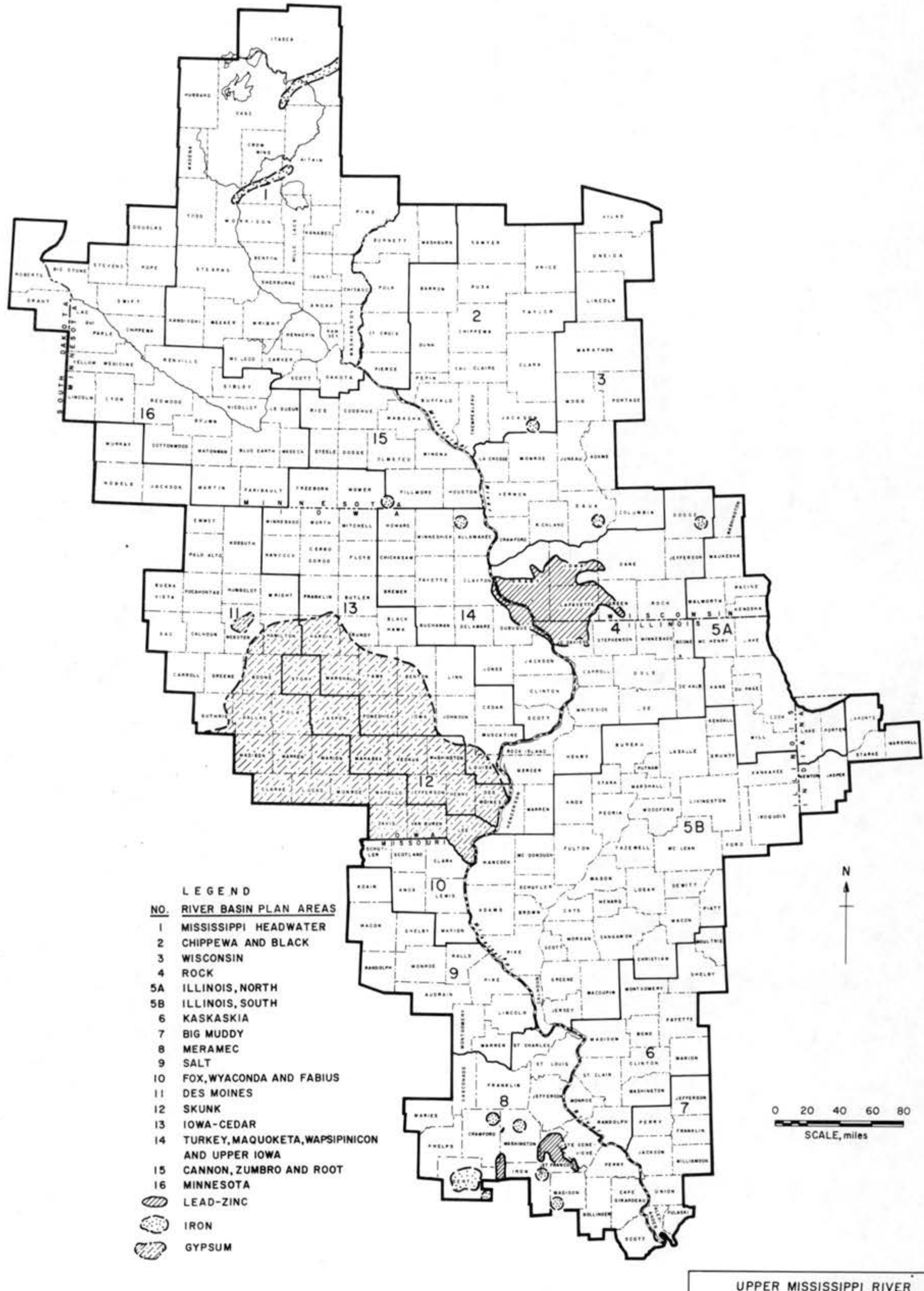
The host rock is called taconite. Those parts rich in magnetite provide a material with about 20-30 percent iron content, now exploited by the burgeoning taconite industry.

The Cuyuna range, about 65 miles southwest of the Mesabi range, is believed to be stratigraphically equivalent to the Biwabik iron formation of the Mesabi. The strata, however, are highly folded into a series of steeply pitching and truncated folds in which the ore bodies occur. These ores are characterized by an unusual manganese content (96).

In Missouri, isolated high-grade iron ore deposits occur in the Precambrian rocks in the Ozark Uplift. The most important ore body is at Pea Ridge; ~~and~~ consists mostly of magnetite and some hematite of high iron grade (about 64 percent) in a near-vertical ore body beneath 1300 feet of nearly horizontal beds of Paleozoic rocks.

(2) Reserves. The principal iron ore deposits in the Basin are in the Mesabi, Cuyuna, and the Spring Valley districts in Minnesota and in southeast Missouri, plate 3. Minor deposits are located in Wisconsin and Iowa (table 4). These minor iron ore occurrences, with the exception of the Black River Falls area in Wisconsin, do not appear to have sufficient known or inferred reserves to be of future importance. In Jackson County, Wisconsin, the Black River Falls magnetite deposits, although small, are metallurgically attractive as they could be beneficiated by magnetic methods to a high-grade product. A plant to treat these ores will be constructed by the Inland Steel Corp. The largest and most important iron ore reserves in the Basin are found in Itasca County, Minnesota.

Iron ore reserves in the Basin area are adequate to meet estimates of future production needs for the next century. The iron ore reserves of Itasca County (Mesabi range) are comprised of four major ore types--natural ore, nonmagnetic taconite, magnetic taconite, and semi-taconite. Natural ore operations will decline to near-extinction over the next two decades, and will be replaced




UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
IRON, LEAD-ZINC, AND GYPSUM

U.S. DEPARTMENT OF THE INTERIOR
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Geological Survey Bulletin 1082-C, 1955, by Martha S. Carr and Carl E. Sutton

Geological Survey Professional Paper 309, 1959, by Allen V. Heyl, et al.

Iowa Geological Survey, Gypsum Resources of Iowa, 1966, by Fred H. Dorheim

TABLE 4. - Iron ore reserves, Upper Mississippi River Basin 1/

| Area or deposit | Type of ore | Approx. iron content percent | Estimated reserves Crude ore, millions of tons | | | |
|---|---|---|---|---|---|---|
| | | | Measured | Indicated and inferred | Inferred | Potential ore unclassified |
| | | | MINNESOTA | | | |
| Cuyuna range | Limonite-hematite | 43 | 2/ 28 | - | 50 | 4,400 |
| Fillmore County | Limonite | 48 | 0.65 | - | - | - |
| Mesabi range, Itasca County | Limonite-hematite | 50 | 2/ 72 | - | 2 | - |
| Do | Magnetic taconite | 22 | - | 3/ 2,000 | - | - |
| Do | Nonmagnetic taconite | 30 | - | 3/ 15,000 | - | - |
| | | | WISCONSIN | | | |
| Baraboo range | Hematite | 35 | - | - | - | 4/ Large |
| Black River Falls | Magnetite-hematite | 30 | - | - | - | 4/ Large |
| Mayville-Iron Ridge | Hematite | 45 | - | - | 0.5 | 4/ Large |
| | | | IOWA | | | |
| Waukon | Limonite | 37 | - | - | - | - |
| | | | MISSOURI | | | |
| Bourbon-Sullivan | Magnetite-hematite | 44 | - | - | 3/ 100 | - |
| Iron Mountain | Specular hematite | 50 | - | 10 | - | - |
| Pea Ridge | Magnetite-hematite | 55-58 | - | - | - | 4/ Large |
| Southeastern Missouri | Limonite | 41-50 | 0.09 | 1.3 | - | - |

1/ Carr, Martha S., Carl Dutton, Iron Ore Resources of the United States, including Alaska and Puerto Rico, 1955. U. S. Geol. Survey Bull. 1082C, 1959.
2/ Minnesota Department of Taxation, 1965.
3/ U. S. Bureau of Mines.
4/ More than 10 million long tons.

with production from a multi-billion-ton reserve of magnetic taconite processed at large scale beneficiation plants. The output of these plants will be similar to the currently preferred pelletized product with a content of about 65 percent iron.

In addition to magnetic taconite, an even larger reserve of nonmagnetic taconite awaits development of an economic process for exploitation. Processes to beneficiate nonmagnetic taconite are already technically feasible but at a higher cost than magnetic taconites. Development of the nonmagnetic taconite reserves will be dependent on overall production requirements and the particular raw material needs of the iron ore merchant or steel company controlling the reserve.

The semi-taconite classification is specifically a legal classification for the purposes of taxation. A portion of the iron ore classed as semi-taconite could be treated at existing natural ore beneficiation plants, but the major portion would require treatment similar to that required for the nonmagnetic taconites.

Cuyuna range reserves of easily beneficiated ores are small but an extensive reserve of nonmagnetic low-grade ores requiring intensive beneficiation techniques are available for exploitation. The problems encountered in the development of processes to treat these ores are not unsurmountable. The main deterrent to the commercial development of these low-grade ores is readily available, tremendous tonnages of more easily treated Mesabi range magnetic taconite deposits.

The Spring Valley District, Minnesota, iron ores consist of small ore bodies formed on the uneven surfaces of limestone. The reserves are small. Operations ceased in 1967.

Total iron ore reserves of Missouri are unknown. Until recently Missouri iron ores supplied a localized market only. The recent development of high-grade pellet facilities at Pilot Knob and Pea Ridge have increased Missouri's share of the midwestern steel center iron ore market. It replaced part of the iron ore supplied previously by Minnesota's Spring Valley District.

Missouri's future iron ore production will be from deep Precambrian deposits. Deposits of iron ore are known to occur at Bourbon, in Crawford County; in the Boss Bixby area at the junction of Iron, Crawford, and Dent Counties; in the Katz Springs area, north of Sullivan in Franklin County; and at Potosi, Washington County. Exploration has been conducted for iron ore in Audrain and St. Charles Counties, Missouri.

(3) Operations. The method of mining iron ore is dictated by its occurrence. Deep deposits are mined by underground methods. Shallow deposits are mined by open pit methods.

The most prevalent method of iron ore mining in Minnesota, the major iron ore producing State in the Basin, is by open pit methods. Future production in Missouri will be principally by underground stoping methods because the deposits are at great depth.

In open pit mining there are four main methods of transportation or haulage of material from the mine; namely, truck haulage, rail haulage, conveyor, and skip hoisting. All methods, with the exception of rail haulage, are used in the Basin area. Rail haulage is used in a few mines on the Mesabi range but outside the Basin area. Conveyors and skip haulage are used in the deep open pits to eliminate excessive stripping of overburden that would be required to maintain a 10-percent grade on trade haul roads.

After the ore body is exposed by removal of overburden material, open pit mining consists of repeated cycles of drilling, blasting, loading, and haulage. The equipment used is large: drills capable of drilling blastholes 6 to 12 inches in diameter and 50 feet deep, shovels with 5- to 12-cubic-yard bucket capacity, and trucks with capacities of 34 to 100 tons are common in Cuyuna and Mesabi iron mining operations.

Open pit iron mining operations outside of the Mesabi and Cuyuna districts are small. The equipment used in these operations consist generally of 2½-yard shovels or draglines, 4- to 5-ton dump trucks, and churn drills for blasthole drilling.

Iron ores when mined are classed either as direct shipping or crude ore for concentration. The direct shipping ores, after crushing and screening, are transported directly to the blast furnaces but at present are generally used in blending ores. In the future, all iron ores will require beneficiation and concentration because grade requirements are becoming more stringent.

Most of the concentration of natural ores is by simple washing in which the fine siliceous material is removed with water. (See table 7 for water volumes). The 1962 water canvass made by the Bureau of Mines indicates that about 12 billion gallons of new water ~~were~~ was required to beneficiate natural iron ore concentrates in 1962 in the Basin portion of the Mesabi range. Recirculated water was about ~~three~~ 3 times this amount and discharged water about ~~three quarters~~. Crude ore which requires treatment in addition to washing is called a "retreat" type. "Retreat" ore in addition to having fine material that can be washed away, also contains chunks of siliceous waste of about the same size as ore particles. The "retreat" ores are introduced into a heavy-media cone containing ground ferrosilicon or magnetite suspended in water which gives the liquid a specific gravity between that of the silica waste and iron ore. The iron ore fraction sinks because it is heavier than the suspended solids and the lighter silica waste fraction (pure sand specific gravity is 2.6) floats away much the same as wood chips floating upon water. The magnetite or ferrosilicon suspension is washed from the ore and recovered by magnetic rolls and returned to the circuit.

Spoil material resulting from open pit operations consists of overburden, rock stripping, and lean ore. Wastes produced in upgrading low-grade ore to shipping grade consist of fine and coarse material known as tailings.

In the development of open pits, large quantities of glacial material, soil, rock from rock-seams and bedrock, and lean ore must be moved to uncover the minable ore. The lean ore which may be of value at some future time, is placed in dumps segregated as to type and iron content. The waste material, glacial material and soil is placed in large piles or dumps on land that will not be needed for future mining operations. Waste piles range in size from those containing only several thousand tons to multi-million ton dumps. Concentrator wastes resulting from beneficiating the low-grade ores to shipping grade consist of fine and coarse tailings. The tailings in the form of a slurry of water and waste are pumped to tailings pond areas adjacent to the concentrator. These tailings ponds range in area from several square miles to several acres only according to the size of the mill.

Land use requirements for mining are dependent mainly upon the size of the operation. Total lands disturbed in the Basin area of Minnesota ~~due~~ to iron mining are estimated at 67,720 acres. Lands are required for the pit, shop facilities, office, transportation (roads, railroad beds), beneficiation plant, stockpiles, waste material dumps, tailings ponds, and buffer zone. Figure 3 shows the Butler Taconite Plant of the Hanna Mining Company Agent at Cooley, Minnesota.

A major consideration in construction of facilities to service an open pit operation is their placement on lands that will not be affected by future mining operations. Dumps, plants, and shops are located on lands, if available, off the iron formation or at

a location that would not be affected by mining for many years. Railroad rights-of-way and roads are placed in the most advantageous location to facilitate mining operations and are relocated as the need arises.

The land requirements for a buffer zone to protect the public from blasting damage, noise, etc., are more extensive for an open pit mine than for an underground mine.

The problems concerned with strip mining operations include those of aesthetics, noise, and pollution of lands and waters.

The end product of unregulated strip mining is a landscape scarred by huge excavations, extensive dumps, and tailings areas. Land scars can be minimized by intelligent planning.

In the Spring Valley District of Minnesota recent practice was to reclaim the land after mining by replacing the overburden in the open pits. Under the overburden, the ore occurs as a thin layer over the underlying limestone. After rehabilitation the land is usable for agriculture. In the early years of mining, no rehabilitation was done. In these areas the depressions and ridges resulting from strip mining remain and are easily distinguished from adjacent farm lands. The mining and milling operations have not caused any particular water pollution problems as the tailings areas are small and confined.

Iron mining in Itasca County, Minnesota, presents a different type of problem because of the continuous nature of the ore. Mining in this area will continue into the next century. Inactive pits fill with water quickly after operations cease. Over a period of years the dumps develop a natural cover of trees and brush and on some plantings have been made. To minimize dust problems mining companies are currently seeding abandoned mine tailings areas with grasses with successful results.

The Armour Mine, Cuyuna range, and the Iron Mountain Mine, St. Francois County, Missouri, were the only operating underground iron mines in the Basin area in 1960. One underground mine at Pea Ridge in Missouri started production in 1964, and the Pilot Knob Mine also in Missouri is expected to be in production in 1967. When completed the Pilot Knob operation will replace production from the Iron Mountain Mine which will be phased out. The Armour Mine will exhaust its reserves before the end of the decade. (The mine was shut down in 1967).

Underground mining methods are dictated by the character and strength of the ore and surrounding rock, and the distribution and extent of the deposit. As a number of mining methods or variations could be used in mining most deposits, the choice of a method is dependent on safety, cost, and recovery.

The Armour Mine's ore is soft and incapable of supporting mine openings without artificial support. The Iron Mountain ore body has the required strength to support stope openings without artificial support.

Water pollution caused by iron mining operations and beneficiation plants is at a minimum because plant water is continuously reused by reclaiming from the tailings pond areas. The major source of water pollution is during periods of excessive rain during which holding areas may overflow and carry fine suspended iron minerals into streams.

Noise problems occur only in specific areas where mines are located close to urban areas. In most areas the mines are located at a sufficient distance that noise from operations (including blasting) is not a problem.

d. Lead and Zinc Ore.

(1) Geology. Lead and zinc occur in two principal areas of the Basin: (1) the Upper Mississippi Valley District (Tri-State) of southwestern Wisconsin, northwestern Illinois, and a fringe part of northeastern Iowa, and (2) Missouri, the Viburnum Trend, Old Lead Belt, and others.

The Upper Mississippi Valley District lies in a 4000-square mile area located mainly in the southwest part of Wisconsin, and the area is described in detail by Heyl et al (49). It lies primarily in the Driftless Area with glacial deposits occurring only on the fringes. The age of rock outcrops range from late Cambrian through middle Silurian with most mineralization occurring in the middle Ordovician strata.

The mineralization includes the primary minerals quartz, dolomite, sphalerite, marcasite, pyrite, galena, barite, calcite, and chalcopyrite; the secondary minerals are smithsonite, limonite, and cerussite.

The Upper Mississippi Valley District is on the western limb of the northward trending, anticlinal Wisconsin Arch. In the district, the sedimentary formations have regional strike of N 85° W through most of the district, and the formations dip gently 18 feet per mile southwardly. Superimposed on this major regional structure is a complex fault and crossfold system including three major anticlines, two orders of smaller folds, a few major reverse and shear faults, numerous small faults, and a well-defined system of joints.

There is a definite relationship between the commercial zinc and lead deposits and the regional and local structures. Most of the zinc deposits contain small amounts of lead sulfide and occur in the upper part of the Platteville Formation, the Decorah Formation and the lower part of the Galena Dolomite. Nearly all of these deposits lie along the limbs of larger synclines, along definite trends, and are controlled locally by smaller folds. Lead sulfide deposits have little or no zinc associated with them and are generally found in vertical joints occurring principally in the Galena Dolomite. Ore deposits are referred to as gash-vein, pitch-and-flat, and placer. Some ore occurs in porous, vuggy areas, and banded veins.

The present mining activity lies within an area of approximately 650 square miles. Zinc and lead are the primary commodities produced; the tailings, principally limestone, are used for agricultural lime, road material, and railroad ballast. Iron sulfides also occur with the ores but are not recovered. Minor amounts of barite and copper minerals occasionally occur with the ores. No attempt is made to recover the barite, but in a few cases copper has been recovered.

Southeastern Missouri is part of a broad, flat dome known as the Ozark Dome located on the Ozark Plateau. The Dome's structural center lies, in the area of lead mining activity, and Precambrian outcrops are surrounded by Cambrian sediments on the flanks of the Dome. Precambrian erosion produced a surface characterized by knobs and ridges with relief up to several hundred feet. The primary ore-bearing formation is the Cambrian Bonneterre dolomite, and the lead deposits in it are associated with small domes, arches, and anticlines which occur in sedimentary rocks. The subsequent Cambrian strata reflect differential settlement during and following Cambrian deposition which caused zones of weakness and, later, fractures at the crests of the structures. Mineralization precipitating from ore-bearing solutions was deposited within the fracture zones, along bedding planes and as disseminations in favorable beds. The mineral deposits are generally found in the bottom half of the Bonneterre Formation. They are generally several thousand feet long, a few hundred feet wide, and up to 200 feet thick. While zinc and copper minerals occur with the lead deposits, the copper mineralization is usually found below the lead mineralization and the zinc minerals are located above. Therefore, the minerals may be separated in mining.

(2) Reserves. During the past several decades the estimated ore reserves in the district have remained substantially the same. As ore is mined and ore bodies are depleted the mining companies have,through exploration, added reserves equivalent to those being mined. It has been the practice of the operators to maintain reserves approximately sufficient to maintain their current rate of production for 10 to 15 years.

There are within the district, numerous areas which have not been explored that quite possibly could contain substantial reserves. Around the periphery of the district are a number of places where extensions of ore trends might be expected. Because of these factors, continuous development of new reserves is anticipated. Therefore, it is assumed that the district will continue to produce lead and zinc at substantially the present rate to the year 2020. A moderate increase in production is predicted for the first 20 years with a leveling off after that.

Over the past 100 years, the old southeast Missouri Lead Belt has produced approximately 300 million tons of ore containing nearly eight million tons of lead metal. The future of this area appeared limited until 1958 when the first new discoveries of extensive new lead ore deposits were announced. The most important of these is known as the Viburnum Trend. Weigel (1965) estimates the potential of this new district at one billion tons of ore with 30 million tons of lead metal and considerable quantities of zinc and copper (119). The Viburnum Trend mineralization lies at greater depths than the old lead belt, but the geologic setting is otherwise similar and typical of the area.

(3) Operations. Zinc is mined in the Upper Mississippi Valley lead-zinc district entirely by underground methods. The mines range from 100 to as much as 350 feet deep. Access to the ore bodies is by vertical shafts employing skip or bucket hoisting or by inclines using truck haulage. Mining is by room and pillar method with random pillars. Loading is by end loaders but power shovels have been used in some of the mines with higher stopes.

Ore is processed to recover lead and zinc sulfides in plants ~~using~~ jigs and flotation. Waste products from the processing plants are usually jig tails consisting of coarse limestone minus ~~one-fourth~~ inch plus 8 mesh and flotation tails, principally finely ground limestone mostly minus 100 mesh. Both types of tailings contain some iron sulfides.

All mines in the district are relatively wet and require pumping of substantial quantities of water (of unknown mineral quality). Larger quantities of water are usually encountered during the early years of mining and development. As mines are developed, the continued pumping may lower the ground water table over a considerable area. With the lowering of the ground water table, the amount of water pumped decreases. In extending the mine openings, the operation may encounter cavities or underground reservoirs containing large quantities of water ~~which~~ may increase the influx of water into the mine for a short period ~~of time~~.

Water for the beneficiation plants is commonly supplied in sufficient quantity by water being pumped from the mines. The quantity of water from the mines is usually in excess of the needs for the beneficiation plants. Consequently, there is little incentive for the operator to conserve water or recirculate it. In some cases, wells have been drilled to supply plant water.

Jig and flotation tails from processing plants are usually discharged separately. Jig tails are usually stacked in large piles and the flotation tails discharged into tailings basins. The piles and tailings basins are situated so that all discharge water is collected in ponds permitting solids to settle out before the effluent enters the surface drainage system. The effluent contains little to no solids and only minor concentrations of processing chemicals from the flotation plants. The quantity and type of chemicals will vary from plant to plant depending on individual practices and characteristics of the ore being treated. The array of chemicals used is quite large but fall into three general classifications: conditioners, frothers, and collectors.

Mining and beneficiation practices in the lead district of Missouri are similar to those in the Upper Mississippi valley district. The mines range in depth from 400 to 1,000 feet with access by vertical shafts. Room and pillar methods of mining are used. Beneficiation is by jigging and flotation. Galena (lead sulfide) is the principal ore mineral but minor amounts of zinc, copper, and silver are also recovered.

e. Sand and Gravel.

(1) Reserves. Sand and gravel occurs in the Upper Mississippi River Basin in several types of deposits. The most important of these are associated with the glacial drift. These include the unsorted, unstratified till of terminal, marginal, and ground moraines and more important economically the stratified glaciofluvial outwash plains, valley outwash, and the local stratified features, eskers, and kames. Other deposits include recent alluvium and sand from friable early Paleozoic sandstone formations.

For sand and gravel deposits to be of practical value for construction purposes, they must contain sufficient tonnage of material with a relatively high ratio of coarse to fine material to warrant the erection of a recovery or treatment plant (108).

The distribution of sand and gravel in the Upper Mississippi River Basin is such that deposits usually can be found where the projections indicate they will be needed. Except for a few local operations, there are insufficient data available to assign numerical quantities to the total reserves. For the purpose of this study, available data were examined to determine whether or not reserves are adequate to fulfill future needs.

All estimates are based on geological inference. The thickness and lateral dimensions of many glacial and alluvial formations have been described or mapped in various State Geological Survey bulletins, U. S. Geological Survey reports, State University publications, and State resource maps. Projected accumulated demand for the year 2020 was pro-rated for each county on basis of production in 1960. The available data were examined to determine whether or not there is sufficient supply to meet this demand. The investigation indicated that sand and gravel reserves are ten times the projected demand in most counties and in all planning plan areas. The reserve estimates, therefore, are simply stated as greater than the 2020 projected accumulated demand of ~~18,900,000,000~~ tons ~~and~~ probably ~~are~~ extremely conservative.

(2) Operations. Sand and gravel deposits are mined by two basically different methods: surface excavation and dredging. Surface excavation may necessitate stripping of overburden prior to removal.

Processing includes all of the operations necessary to convert the crude sand and gravel to usable products. The amount of processing required depends on the quality of the raw material, and the specifications that govern its usage. In some instances, sand and gravel is utilized direct from the source with little or no beneficiation. Beneficiation may consist only of crushing and sizing. Frequently, this is complemented by some combination of jigging, washing, or scrubbing operations to remove deleterious materials such as organic substances, clay, and shale (18).

Simple dry screening and air separation are two methods which do not use water to remove deleterious material from sand and gravel. Other methods use water in various ways to wash the aggregate and to carry away the deleterious materials. These methods include wet screening, screw washing, log washing, scrubbing, and classification.

Changes in construction material technology have tended to upgrade the quality specifications for sand and gravel. This has greatly increased the need for water for washing and classifying operations. These processes constitute the largest use of water in sand and gravel operations. The overflow from washing and classifying contains a great quantity of very fine sand, silt, and clay.

In most sand and gravel operations, the discharge is directed to settling ponds which will trap the solid waste and ideally provide clear water for discharge into the stream or for recycling back into the washing operation.

In many sand and gravel operations, the proportion of sand to gravel is such that sand is produced in excess of the demand for it, and the excess sand constitutes a waste product. Often it is returned to the excavation in a manner that it can be recovered if some future demand warrants it.

Local and State laws governing land reclamation, after sand and gravel operations, range widely throughout the area of the Upper Mississippi River Basin. In some States or local areas, laws may require some degree of rehabilitation. In other areas, there may be no such requirements. It is in the interest of the sand and gravel producers to generate favorable publicity from their restoration programs, for it is logical that this can lead to more favorable laws governing sand and gravel mining activity especially in close proximity to urban areas. Consideration of the final disposition of the pit in planning an operation can enhance the area and community and often result in substantial revenue to the operator. Often a large pond or even a small lake may have been formed by excavation below the water table and later converted to local recreational areas. Where large operations have existed for several years or even decades, land restoration may present complicated problems.

f. Crushed Stone.

(1) Reserves. Rock formations which can be utilized for crushed stone occur over most of the Upper Mississippi River Basin. The principal characteristics affecting exploitation of suitable rock are the thickness of the overburden and workable depth of the rock formation. Other important factors are proximity to the market and related transportation facilities.

Crushed stone is produced from sedimentary, metamorphic, and igneous rocks. Economic availability and physical characteristics dictate which type of stone is crushed in a particular locality. Generally, sedimentary rocks are easier and less costly to crush than igneous or metamorphic rocks ~~due~~ to their lower strength and abrasiveness. In the Upper Mississippi River Basin, sedimentary rocks are much more widespread than the other two rock types. Most of the rock mined for crushed rock in the Basin is limestone and dolomite. Other rocks which are crushed include granite, traprock, quartzite, and marble.

All reserve estimates in this report are based on geological inference. The thickness and lateral dimensions of many stone formations have been described or mapped in various State Geological Survey bulletins, U. S. Geological Survey reports, State University publications, and State resource maps. Projected accumulated demand for the year 2020 was pro-rated for each county on the basis of production in 1960. The available data were examined to determine whether or not there is sufficient supply to meet this demand. The investigation indicated that stone reserves are generally greater than 10 times the projected demand in most counties and in all plan areas. The reserve estimates, therefore, are simply stated as greater than the 2020 projected accumulated demand of 16,900,000,000 tons. The estimates are probably conservative.

(2) Operations. Crushed stone operations consist of quarrying and processing. Quarrying includes stripping the overburden, breaking the stone, and hauling it to a processing area.

Stripping is done by a variety of methods, depending upon the depth and nature of the overburden. Economy of removal governs the methods and selection of equipment and procedures for stripping. One of the most costly operations is the drilling and blasting of rocks.

Processing includes crushing, screening, washing, storage, and reclaiming of water to produce uniformly graded products to meet specifications. Washing crushed stone aggregate is becoming more widespread as specifications become more rigid. The removal of dust particles is a common requirement in specifications for concrete aggregate. In some operations the removal of clay from crushed stone is necessary and is done with log washers or scrubbers, although the industry is not a large consumer of water.

g. Gypsum.

(1) Reserves. Gypsum reserves of the Upper Mississippi River Basin are located principally in Iowa, and are geologically associated with the Wapsipinicon Formation of Devonian age, Fort Dodge Formation of Permian age, and the Meramec Series of Mississippian age. The reserves are estimated by geological inference to be present in sufficient quantities to more than satisfy the projected demands through year 2020.

The bulk of crude gypsum production is obtained from the nearly horizontal Fort Dodge Formation in Webster County, Iowa, (figure 5). The area containing gypsum reserves is oval-shaped, approximately 6½ miles in an east-west direction and 5½ miles in a north-south direction. The thickness of the gypsum deposits ranges from 2 to 30 feet, depending upon the extent of erosion prior to Pleistocene deposition. The average thickness is indicated to be about 20 feet. Overburden consists of varying thicknesses of glacial drift and alluvium including sand, gravel, and gumbotil ranging in total thickness from 30 to 85 feet and averaging approximately 55 feet (82, 121).

Crude gypsum is now produced from the deep Wapsipinicon Formation in Des Moines County, Iowa, a mining activity recently initiated in this area. The gypsum mined from this formation is associated geologically with a dome structure ~~six~~ 6 miles long and ~~two~~ 2 miles wide. The gypsum strata are estimated to average ~~ten~~ 10 feet thick and lie at a depth of approximately 600 feet.

During the period ~~from~~ 1917 – ~~until~~ 1934, mining was conducted intermittently from gypsum deposits found in the Meramec Series of rocks of Mississippian age, located in Appanoose County, Iowa. Gypsum reserves occurring in the Meramec Series have a widespread occurrence and have been identified in well borings over parts of 14 counties. The gypsum strata, where encountered in well borings, were of various thicknesses, ranging from 5 feet to 20 feet, and lie at depths averaging approximately 500 feet.

(2) Operations. Gypsum produced in the Upper Mississippi River Basin is mined by both underground and strip mining methods.

In the Webster County, Iowa, area, which accounts for the bulk of the Basin's gypsum production, strip mining is used exclusively. Usually the working areas at these strip mines are laid out in adjoining parallel cuts, the length or width of the property. Individual cuts range in length from 500 to 1,000 feet and in width from 100 to 150 feet. Overburden up to 100 feet thick is removed by draglines or scrapers. Most of the spoil material is cast back into exhausted parts of the quarry. The exposed gypsum is drilled, blasted, and loaded into trucks for haulage to the processing plants.

Water from the mining operation is directed by drainage ditches to strategically located sumps, where it is collected, pumped out of the quarry, and discharged into natural surface drainage features.

Spoils and waste dumps, consisting of overburden material from strip mining activities occur in a relatively limited area of approximately 640 acres near Fort Dodge.

Gypsum mining by underground methods is conducted at one location in Des Moines County, Iowa. Mining is by room and pillar method with underground haulage by diesel powered vehicles. Crude gypsum is hoisted to the surface in a 600-foot vertical shaft and conveyed to the adjoining processing plant. Surface land requirements, aside from that occupied by the processing plant complex, are negligible as little waste accumulations are generated.

## 13. MINERAL INDUSTRY IN THE BASIN, 1960

a. General Considerations and Assumptions. Data on minerals and employment shown in the following tables were collected by canvass and compiled by the Bureau of Mines, U. S. Department of Interior.

Mineral productions by commodities for 1950 and 1960 in the Upper Mississippi River Basin are tabulated in table 5, and included in each plan area, for the year 1960 only. Included in the tables are several mineral commodities for which production projections and employment have not been made, namely cement, clay, and lime, which are shown under manufacturing in Part II, Appendix P - General Economic and Demographic Change. Because production of cobalt, copper, nickel, and silver are byproducts of lead mining in Missouri while production of lead is a byproduct of zinc mining in Illinois and Wisconsin, water and labor requirements for these byproducts are included in lead production for the Missouri region and in zinc production for the Illinois-Wisconsin region. Data are not included on employment in and production of abrasive stone, peat, and tripoli (rottenstone, a weathered rock used as an abrasive and polishing powder) as they are either confidential or not available.

To facilitate comparison, mineral production is defined as production measured by mine shipments and sales or marketable production and, in addition, includes consumption by the producers themselves; employment data is based primarily on man-hours worked by production workers. Number of employees is calculated for each mineral commodity by using an equivalent man-year factor determined for that industry as, for example, in the iron ore industry a man-year is equated to 2,000 man-hours; for the sand and gravel industry a man-year is equivalent to 1,800 man-hours; and reflects the seasonal nature of that industry. In the coal industry, in contrast, the number of employees is the average number of men working based on the total days the mines are active per year.

b. Water Data. The uses of water in this report are classified according to U. S. Bureau of Mines, Information Circular 8285 (63):

New Water - water introduced from external source for the first time.

Discharged Water - that portion of the plant's total water that is not recirculated or consumed.

Recirculated Water - water reused in the plant to conserve new water.

Consumed Water - water lost in the product by evaporation or other means, whereby it is lost for future use at that location.

(1) Source of Data. Throughout the Upper Mississippi River Comprehensive Basin Study, the year 1960 has been used as a base year for data and projections. The best data available on water use in the mineral industries were developed by a Bureau of Mines canvass for the year 1962. Estimates of the water use for 1960 were prepared based on the 1962 water canvass.

Water intake, water discharged, water consumed, and water recirculated in gallons per ton of product was tabulated and ratios developed for the firms canvassed. This included the sand and gravel, crushed limestone, coal, dimension limestone, crushed sandstone and quartz, lead and zinc, iron ore, barite, and natural abrasive mineral industries. Water data were not available for every producer; therefore each water ratio developed was adjusted to reflect a water ratio for total production in 1960 of each mineral commodity in each of the plan areas. Similarly, water used in gallons per barrel of petroleum produced, and gallons of water per foot of oil well drilling also was determined. Tables containing the results of the water requirement calculations are included in each plan area discussion.

c. <u>Basin Production - 1960</u>. The total dollar value for 1960 of all mineral commodities produced in the UMRCBS was approximately 831 million ~~dollars,~~ up from approximately 588 million ~~dollars~~ for 1950, and is nearly one-sixth the value of all farm products produced in the UMRCBS. Most of the mineral commodities, shown in table 5, increased in dollar value in the 1950-1960 decade, and these were portland cement, iron ore, petroleum, sand and gravel, and crushed stone; those showing a decrease were coal, copper, lead, and silver. A few commodities show a mixed behavior of lower production in 1960 but greater total dollar value, for example, iron ore and barite.

Coal in 1960 had the greatest dollar value with $174,622,865 representing 40,703,487 tons, but down from its 1950 value of $218,187,673 representing 54,736,582 tons. The changed mined tonnages of coal reflected on employment and water and land use.

Another important Basin commodity is iron ore which shows a decrease in tonnage from about 16 million tons with a value of $79,230,712 in 1950 to about 14.5 million tons with a value of $120,147,639 in 1960. Some price increases in ore are partly responsible for the greater total dollar value, but all of these factors reflect upon employment and water and land use.

Sand and gravel, crushed and broken stone, and petroleum have total dollar values for each in 1960 ~~which~~ [that] are somewhat the same, around 100 million ~~dollars~~ down to 88 million, but all are up significantly from the 1950 values. Again, the changed tonnages affect employment and water and land use.

TABLE 5. - Upper Mississippi River Basin, mineral production, 1950 and 1960

| Mineral | 1950 | | 1960 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Abrasives: Grinding pebbles..........short tons.. | 530 | $10,600 | W | W |
| Tube-mill liners................do.... | W | W | W | W |
| Barite...............................do.... | 209,311 | 1,890,292 | 180,702 | $2,587,820 |
| Cement: Masonry..............280-pound barrels.. | (1/) | (1/) | 1,804,132 | 5,664,996 |
| Natural...............376-pound barrels.. | W | W | ------- | ------- |
| Portland.......................do.... | 29,958,871 | 67,330,520 | 39,640,738 | 136,562,871 |
| Clays and shale 2/..................short tons.. | 3,282,922 | 4,799,120 | 4,503,135 | 12,759,604 |
| Clay produced for use in mfg. cement.......do.... | NA | NA | 1,181,852 | 1,164,797 |
| Coal (bituminous)...........................do.... | 54,736,582 | 218,187,673 | 40,703,487 | 174,622,865 |
| Cobalt...................................pounds.. | ------- | ------- | W | W |
| Copper...............................short tons.. | 2,982 | 1,240,512 | 1,087 | 697,854 |
| Gypsum......................................do.... | 981,647 | 2,507,651 | 1,282,817 | 5,427,529 |
| Iron ore 3/..........................long tons.. | 15,940,149 | 79,230,712 | 14,597,296 | 120,147,639 |
| Lead.................................short tons.. | 135,481 | 36,579,870 | 114,358 | 26,759,772 |
| Lime........................................do.... | 1,308,323 | 13,117,618 | 1,846,736 | 24,609,860 |
| Nickel...................................pounds.. | ------- | ------- | W | W |
| Peat.................................short tons.. | 10,853 | 98,553 | 23,829 | 260,775 |
| Petroleum.............thousand 42-gallon barrels.. | 22,862 | 63,328,767 | 32,916 | 97,435,441 |
| Sand and gravel......................short tons.. | 47,342,140 | 37,572,387 | 92,770,409 | 88,622,573 |
| Silver...................................ounces.. | 236,273 | 213,839 | 15,594 | 14,113 |
| Stone (crushed and broken) 4/.........short tons.. | 33,870,365 | 45,545,710 | 73,710,993 | 100,118,972 |
| Limestone for use in mfg. cement and lime..do.... | NA | NA | 11,044,626 | 10,555,795 |
| Stone (dimension)...........................do.... | 145,366 | 8,108,302 | 211,493 | 10,627,672 |
| Zinc........................................do.... | 28,339 | 8,048,276 | 41,556 | 10,721,448 |
| Value of items that cannot be disclosed: Tripoli and values indicated by footnote W.............. | ------- | 666,489 | ------- | 1,982,628 |
| Total.................................. | ------- | 588,476,891 | ------- | 831,345,024 |

W Withheld to avoid disclosing individual company confidential data. NA Not available.
1/ Masonry cement not considered as "mineral production" in 1950.
2/ Excludes clay produced for use in manufacturing cement.
3/ Includes iron ore containing from 5 to 35 percent manganese, natural, which is ordinarily classified by the Bureau of Mines as manganiferous ore.
4/ Excludes limestone produced for use in manufacturing cement and lime.

A few minerals show significant increases in unit dollar value for the tonnages produced, such as barite, clay and shales, copper, gypsum, and iron ore. Some minerals showed decreased unit values such as lead, zinc, and dimension stone.

## 14. MINERAL INDUSTRY PROJECTIONS, FUTURE INDUSTRY NEEDS, AND ACTIVITIES, 1960-2020

a. Methodology of Production Projections - General. In making projections of production and employment through 2020, the following general assumptions are made:

During the projection period, 1960-2020, ~~there will be~~ no major economic disturbance ~~which~~ will seriously affect the long-term growth patterns of the Nation's economy.

International political tensions will remain at about the present level. Military requirements for manpower are assumed to decline somewhat in the future.

Mechanism for training a labor force sufficiently well to meet the demands of technologic change will be provided.

Future price changes will not significantly affect the projected economic relationship, although it is assumed that inflationary pressures will continue.

b. Projections of Selected Mineral Commodities, 1970-2020. Projections of mineral production and employment for selected mineral commodities were based on data compiled by ~~the~~ Bureau of Mines canvasses of the mineral industry. Petroleum data were compiled by the States producing oil and furnished to the Bureau of Mines. Mineral production projections are shown in table 6.

TABLE 6. - Production projections for selected mineral commodities, Upper Mississippi River Basin

| Commodity | 1970 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Barite.............thousand short tons.. | 300 | 300 | (1/) | ----- |
| Coal............................do... | 56,500 | 74,300 | 87,100 | 77,500 |
| Gypsum..........................do... | 2,230 | 2,860 | 5,600 | 9,700 |
| Iron ore (usable)...thousand long tons... | 21,150 | 26,750 | 34,750 | 42,000 |
| Lead (recoverable content of ores) thousand short tons.. | 403 | 478 | 653 | 903 |
| Petroleum.............thousand barrels.. | 18,500 | 5,000 | 2,500 | 2,500 |
| Sand and gravel.....thousand short tons.. | 141,812 | 205,534 | 387,764 | 613,529 |
| Stone: | | | | |
| Crushed.......................do.... | 127,632 | 188,403 | 351,588 | 540,682 |
| Dimension.................short tons.. | 247,852 | 334,599 | 641,314 | 1,044,070 |
| Zinc (recoverable content of ores) thousand short tons.. | 47 | 49 | 53 | 58 |

1/ Mining at the indicated rate would substantially deplete estimated reserves. Development of new methods for recovering barite from tailings dumps could prolong production.

Regression analysis was employed to develop an equation which was used in computing the 1960 base year production; and a 14-year time series (1950-1963) was used for projecting individual mineral commodities. In some instances, minerals were not produced in every year of the time series, or data were not available; in these cases a shorter time series was used. The calculated value for 1960, in place of an actual production figure, was used for the base year as the starting point for making projections because it was believed to be more representative of the production trend.

Projections for minerals used in construction (sand and gravel, crushed stone, dimension stone, and gypsum) were based on projections of the value of construction (in 1960 dollars) in the Basin developed by the Corps of Engineers. The Corps of Engineers made construction projections (1970-2020) for the 11 economic subregions in the Basin broken down by selected activities, e.g. new construction, public, private, residential, non-residential, highways, maintenance, and repair, etc. The Bureau of Mines determined from an analysis of its sand and gravel canvass, the proportion of production used for highway construction, maintenance, and for building purposes. Rates of change based on Corps of Engineers projections for each subregion for appropriate construction activities were applied to these data, and projected sand and gravel output derived. A similar procedure was used in projecting other residentiary minerals used in construction.

(1) Sand and Gravel and Crushed Stone. To arrive at Basin planning area projections for sand and gravel and crushed stone, certain calculations were made to obtain quantities on a county basis; a percentage of the total economic subregion production was used based on actual production for 1960, and the calculated percentage applied to each county. The appropriate county figures were then totaled to arrive at Basin planning area projection totals.

Projected quantities of construction materials considered to be export commodities (dimension stone and gypsum) were based on the rate of change in construction expenditures for the entire Basin. It was assumed that the rate change would be determined by regional or even National demands for construction materials, rather than by local ones.

(2) Coal. Projections of coal production in the Basin were based on energy growth data supplied by the Federal Power Commission for coal consumed by the electric utility industry, and on data developed by the Division of Economic Analysis, Bureau of Mines, for non-utility consumption. Although energy demand was projected to increase at a substantial annual growth rate, the proportion of energy to be supplied by coal will decline as nuclear energy increases. Data on the amount of nuclear energy used for electric power generation, developed by the Federal Power Commission, were taken into consideration in projecting coal output.

(3) Iron Ore. Projections of iron ore production in Minnesota were based on data developed by the Bureau of Mines and the University of Minnesota (89), and it is assumed that the future production in the Basin will continue as 20 percent of the Minnesota State total. The development of the taconite industry had a major influence on projections of future iron ore production with production of taconite pellets increasing as natural ores decline. The downward trend of total iron ore production in recent years has been reversed and the projections indicate that total iron ore output may equal or exceed the high production level of postwar years.

Projections for the iron ore industry in Missouri reflect the announced planned output of the new mine operations.

(4) Lead and Zinc. Projections of lead and zinc production in Missouri are based on parameters reflecting National demand for these commodities. They were derived from rates of change in demand for varying future periods developed by several agencies including the Division of Economic Analysis, Bureau of Mines; National Planning Association; Predicasts; Resources of the Future, Inc.; and the U. S. Department of Commerce.

In the Illinois-Wisconsin-Iowa lead-zinc district projections of future production were maintained near the current level of output. It is the practice of operating companies in the district to maintain 10 to 15 year ore reserves. Since the peripheral limits of the district have not been firmly established, and there are areas having favorable characteristics for finding ore, it was assumed that production at the indicated rate may be maintained through the projection period.

(5) Petroleum. In petroleum projections, the declining oil production in recent years, diminishing reserves, and the effects of secondary production by waterflooding were considered. Published reserves have been declining at the rate of 6.4 percent per year since 1960, and about two-thirds of the output is from secondary production. It is assumed that from 1980 on to the end of the projection period, petroleum production will be minimal as the oilfields become exhausted.

Projections of employment in the mineral industry for use in the Economic Base Study, Appendix P, were based on productivity in the base year adjusted for changes in productivity over the projection period. Changes in productivity for each mineral commodity, e.g. coal, iron ore, construction minerals, base metals, etc., were developed from material compiled by the Bureau of Mines and other Federal and State agencies.

Employment in the petroleum industry was based on data developed by The National Planning Association from 1960 employment figures for Standard Industrial Classification 131 (crude petroleum and natural gas).

c. Water Requirements. Water is, and will continue to be a vital tool in the mineral industry. The emphasis toward higher quality products and the utilization of lower grade raw materials has been a major influence in the increasing use of water. Water use in the future is expected to increase with the growth of the mineral industry. For most commodities water use was projected at the same ratio of water use per ton of product for all projected years. For some commodities, predicted techological developments will increase water requirements; the water ratio in these cases was adjusted accordingly.

"Recirculated water" is a factor needing clarification and explanation. This water is defined as water reused in a plant to conserve new water, and is given as x-gallons per year for each commodity in the report. The gallonage reported may be large numerically, for example, "20,251 million gallons recirculated in 1960---." This large volume of water did not actually exist in the plant, but may have been only a small water volume that was pumped and repumped and reused continuously every day of the year through a registering meter which, at the end of a year, gave a cumulative reading of 20,251 million gallons. The actual water volume involved was only a small fraction of this cumulative volume. A more specific example is the following theoretical one: given 100 gallons of water stored in a tank and, assuming no losses from the system by leakage and evaporation, etc., let this volume be recirculated once each day for 365 days of a year. The recirculated water volume for the year would then be reported as 36,500

(100 gallons x 365 days) gallons. Thus, the actual water volume involved (100 gallons) is but a small fraction of the reported recirculated volume.

Therefore in this report, when reading values of recirculated water the large numerical volume in gallons should be recognized as being a cumulative value of a small actual volume reused over and over many times.

The sand and gravel industry is likely to require an increase in the water ratio for processing as the demand for cleaner and better quality sand and gravel has been steadily increasing over the past twenty years. Construction specifications are requiring closer tolerances on raw materials. To meet many of these newer requirements, products produced by the aggregate industry must be beneficiated with water (table 7). Consequently, based on this trend, the water ratios per ton of product for the aggregate industry have been increased 1 percent for every 10 years in all projections after 1970. This increase in water use ratio is expected to affect the crushed stone industry, also.

The depletion of direct-shipping iron ores and the increase of beneficiation practices has had a significant effect on the water requirements in the iron mining industry. In 1965, 63 percent of the iron ore shipped from Minnesota was from "natural ores" and 37 percent from beneficiated taconite. The predictions are that by 1970, over 60 percent, and by 1980, over 90 percent of the iron ore from Minnesota will be beneficiated taconite. Because of these developments, water use ratios for the period 1970-2020 in the Basin are based only on taconite operations (table 7).

During the past 15 years, the coal industry has made great advances in obtaining a higher quality product through beneficiation principally with the beneficiation process of washing. In 1949, only 35 percent of the Nation's coal production was beneficiated and, in 1964, 64 percent. During the same period coal production increased 9 percent while new water intake increased 7 percent. Coal spokesmen imply that this new water intake was a result of coal production increase, and that the increased need for water for beneficiation was obtained through greater recirculation (32) (table 7). Based on this assumption, future water requirements in the coal industry in the Basin were increased proportionately with coal production. As there are no anticipated radical technological developments in coal preparation, new water, discharged, or used water ratios have not been altered. Recirculation ratios, however, were increased 1 percent per every 10 years in all projections starting in 1970.

The water data from the Bureau of Mines 1962 mineral industry water canvass was used to determine water ratios per ton of selected mineral product for each plan area. These ratios were applied to the 1960 production to arrive at the water use in the mineral industry for that year. Table 7 shows the weighted average water use ratios for the entire Basin.

TABLE 7. - Upper Mississippi River Basin average water use ratios, 1960 (gallons per ton of product)

| Mineral commodity | New water intake | Water discharged | Water recirculated | Water consumed |
|---|---|---|---|---|
| Crushed limestone | 33 | 31 | 22 | 2 |
| Dimension limestone | 3,020 | 2,985 | 2,650 | 35 |
| Coal | 104 | 95 | 450 | 9 |
| Sand and gravel | 162 | 157 | 187 | 4 |
| Iron ore (concentrate) | 1,210 | 950 | 3,530 | 260 |
| Taconite (pellets) | 591 | 324 | 4,430 | 267 |
| Zinc | 13,773 | 13,739 | 6,886 | 34 |
| Natural abrasives | 94 | 91 | 0 | 3 |

~~Due~~ Owing to unusual patterns of water use and other factors, the water use data in this report may not coincide with the National pattern.

d. Land Use by the Mineral Industry. Little history is available on the land requirements, land use, or reclamation of land by the mineral industries. Although there is more information available regarding coal strip mining than for other mineral commodities, coverage and details available vary from State to State. In recent years, several States where coal is strip mined have passed legislation regulating strip mine operations and land reclamation. Until very recently other mining activity received little regulation concerning land use other than local zoning restriction.

The Bureau of Mines in cooperation with the States and the Department of Agriculture made a survey of land use by the open pit or surface mining industry. Results of this survey are not yet available, but data collected has been used in this report to estimate the land use in the Basin and as a guide in making projections.

The Department of Agriculture made a survey of all counties, and tabulated all the land disturbed by mining to January 1, 1965. This survey presents an estimate of past land use as of that date, but obviously may not include all land disturbed by mining since some former mined areas may now be utilized in a manner obscuring early operations. Land disturbed by past mining may now be obscured by building developments on old gravel pits, ancient mined areas now being farmed, natural vegetation reestablished on former mined areas,or lakes occupying old pits. Therefore dividing the amount of disturbed area by the historical production would not give a precise figure for the land use per unit of mineral production.

The land needs for future mineral production were estimated by using the projected mineral production and the available knowledge of characteristics of mineral deposits. By assuming an average mining depth for surface deposits, based on the characteristics of the deposits and probable future mining practice, an estimate of the amount of land which will be required for the mining industry can be determined. This has been done for each of the mineral commodities of significance in each plan area. While a high degree of uncertainty exists in these projections, it does give an indication of the magnitude of the land needs by the industry. Land needs for underground mines are minor requiring only sufficent land for the plant site and waste disposal.

Estimates of amount of land which may be reclaimed after a mining operation is completed are even more difficult to make. A few of the factors involved are; the amount of future land reclaimed will depend on governmental regulations, the willingness of operators voluntarily to reclaim land, the value of the reclaimed land, ~~and other factor~~s. In 1962, in Illinois, a compulsory law was enacted requiring coal operators to reclaim mined land they owned in fee.

For the coal mining industry, published data are not available on land use and land reclamation. Work in this field is in progress and should be available in the near future.

Disregarding all lands affected by mining prior to 1960, table 8 shows a summary of Basin coal land requirements in 1960, and for the projected years 1970, 1980, 2000, and 2020. These projections are based on the following assumptions:

1. The coal industry will react favorably to projected growth.
2. The trend toward increased strip mining will continue.
3. Strip mining will yield an average of 75 percent recovery.
4. Thickness of coalbed now mined will remain about the same.
5. Underground mining will require an average of ~~two~~ 2 acres per million tons mined for waste disposal and plant sites.

6. Surface subsidence will be kept to a minimum.

7. By 1970, all States in the Basin will have a land reclamation law in effect.

8. ~~That~~ 6 percent of the mined lands will not be reclaimed ~~due~~ to lack of regulations from 1960-1970 and unfavorable chemical and physical composition of the overburden.

TABLE 8. - Upper Mississippi River Basin projected land use by the coal industry (in acres)

| | | | | | 1960-2020 Cumulative | | |
|---|---|---|---|---|---|---|---|
| 1960 | 1970 | 1980 | 2000 | 2020 | Required | Reclaimed | Unreclaimed |
| 3,464 | 4,883 | 6,460 | 7,417 | 5,691 | 367,575 | 345,203 | 22,372 |

In recent years, some States have adopted and enacted laws to control strip mining. In Illinois, "the open cut mining law" became effective January 1, 1962. In Iowa, the county board of supervisors has jurisdiction as outlined in Chapter 467C (Soil Conservation and Flood Control - Strip Mine Regulated) in the 1962 mining code. This State is now in the process of revising ~~their~~ strip mining laws. ~~The~~ present ~~strip mine laws~~ deal primarily with land reclamation.

Illinois produces approximately 95 percent of the Basin's coal with a large percentage of the total derived from strip mines. Prior to January 1962, Illinois coal operators voluntarily reclaimed part of their mined land, and it has been estimated that 55 percent of the State's mined land has been reclaimed successfully (32). It appears that one-half of all land in the Basin mined for coal has been reclaimed or partially reclaimed.

As indicated in the discussion of petroleum operations, very little land is required. No projections were made in this report for land required for petroleum production.

Land needs for iron ore mining differ greatly between underground and open pit mining. In open pit mining, besides the needs for plant sites, land for the mining or pit area is required as well as disposal areas for overburden and waste. The large volumes of overburden and rock waste from most open pit iron mining operations are deposited in high piles not readily lending themselves to leveling and subsequent reclamation. The waste material produced by treatment plants is collected in ponds covering large areas. Underground iron mining does not require the extensive land areas for pits and overburden disposal but may require significant areas for stockpiling and disposal of rock waste and tailings.

Lead and zinc are mined by underground methods and land requirements are modest. Besides the plant site, only land for tailings and waste disposal areas are necessary.

Stone, sand and gravel, and clay mining require land for the pit and plant. Overburden or waste material produced is usually replaced in worked out areas of the pits. The land requirements necessary to meet projected demands for these materials may become critical in urban areas. Projecting the availability of land for future mining operations is an extremely difficult problem. As detailed information is unavailable concerning these mineral deposits, it was assumed that the relationship of non-urban areas to the total area in a plan area will reflect the availability of land for mineral exploration.

SECTION VI
MINERAL INDUSTRIES IN THE BASIN, 1960 INVENTORY AND PROJECTIONS, 1970, 1980, 2000, and 2020 BY SUBDIVISION PLANNING AREAS

## 15. PLAN AREA 1 - MISSISSIPPI HEADWATER AREA

General location - East-central Minnesota and west-central Wisconsin, (figure 4).

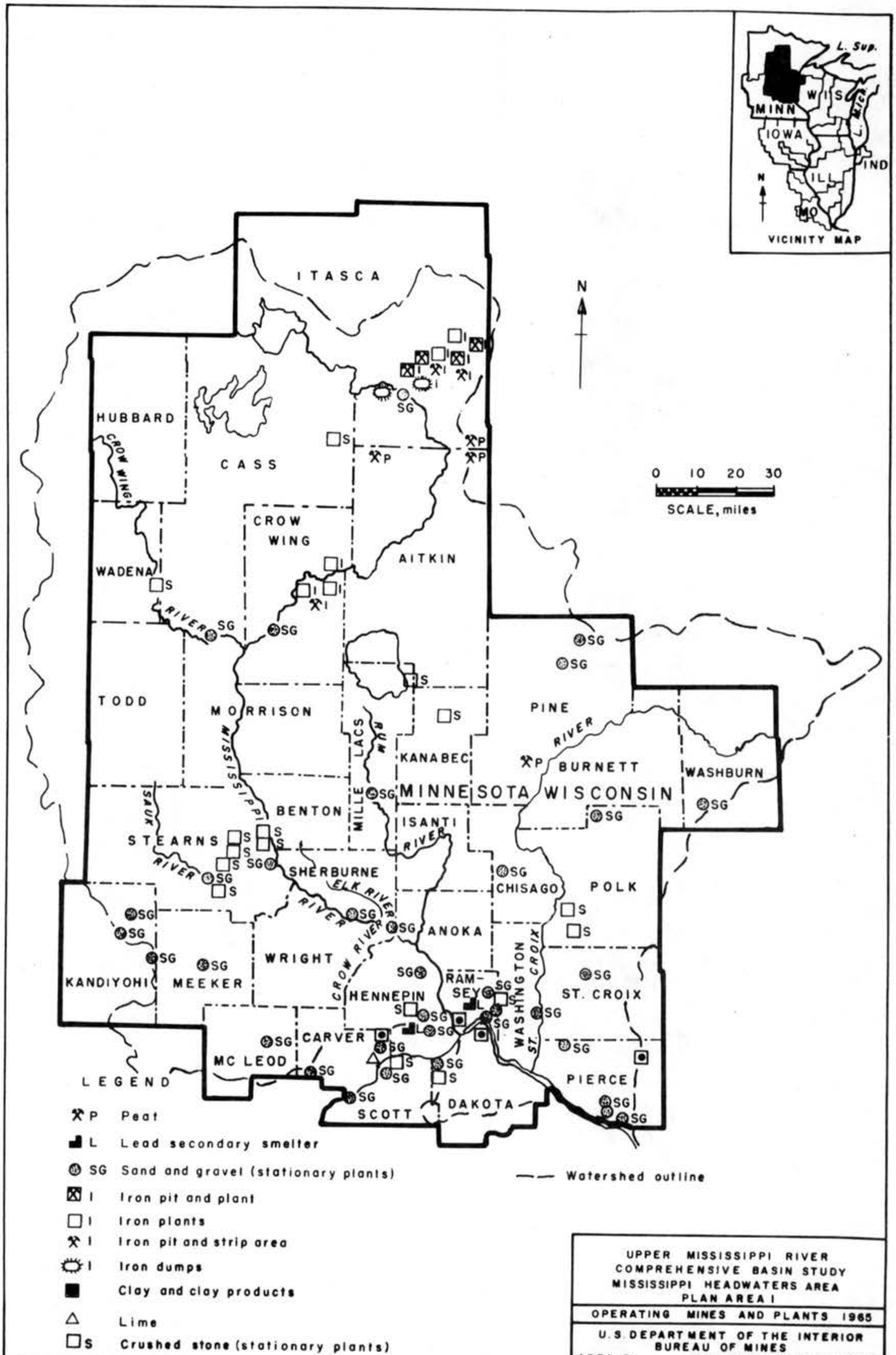
Area - 32 counties, 26,000 square miles, 4.6 percent urbanized.

Population - 2,073,613 total, 74 percent urban.

Principal drainage systems in the plan area are the Mississippi River and tributary basins of St. Croix, Sauk, Crow Wing, Crow, Elk, and Rum Rivers.

Mineral production for 1960 in the Mississippi Headwater area, Plan Area 1, was valued at $129,785,590, ranking first in and representing 16 percent of the Basin's total mineral value, (table 9). Iron ore accounted for 88 percent of the plan area's total mineral value, sand and gravel 9 percent, and both crushed and dimension stone about 3 percent. Iron ore production comprised 16 percent of the Nation's total iron ore production.

Future production of mineral commodities in Plan Area 1 are projected to increase about fivefold by 2020, table 10. Reserves of these mineral commodities are adequate to meet projected demands. Iron ore and dimension stone, being export commodities, will experience growth based upon national needs. Crushed stone and sand and gravel production will depend principally on local needs. Figure 4 shows the locations of mines and permanent plants operating in the plan area in 1965.



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ELK RIVER
CROW RIVER
ST. CROIX
LEGEND
P Peat
L Lead secondary smelter
SG Sand and gravel (stationary plants)
I Iron pit and plant
I Iron plants
I Iron pit and strip area
I Iron dumps
Clay and clay products
Lime
S Crushed stone (stationary plants)
Watershed outline
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
MISSISSIPPI HEADWATERS AREA
PLAN AREA I
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3
MINNEAPOLIS, MINNESOTA

TABLE 9. - Mississippi Headwater Basin, mineral production in Plan Area 1, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Iron ore 1/..............................long tons... | 13,900,671 | $114,002,406 |
| Sand and gravel........................short tons... | 13,574,190 | 11,493,836 |
| Stone (crushed and broken)...................do..... | 1,421,680 | 2,378,923 |
| Stone (dimension)...........................do..... | 23,342 | 1,794,660 |
| Value of items that cannot be disclosed: Clays and shale and peat.................................. | ---------- | 115,765 |
| Total........................................ | ---------- | $129,785,590 |

1/ Includes iron ore containing from 5 to 35 percent manganese, natural, which is ordinarily classified by the Bureau of Mines as "manganiferous ore."

TABLE 10. - Mississippi Headwater Basin Plan Area 1 - Projected mineral production and employment (thousand short tons, except as noted, and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Iron ore (usable) | 1/ 15,000 | 3,300 | 1/ 16,000 | 3,600 | 1/ 22,000 | 4,700 | 1/ 28,000 | 5,900 | 1/ 1,175,000 |
| Sand and gravel | 23,243 | 1,014 | 35,278 | 1,259 | 66,787 | 1,746 | 103,264 | 2,137 | 3,212,690 |
| Crushed stone | 2,490 | 319 | 3,958 | 417 | 7,800 | 575 | 12,206 | 654 | 370,590 |
| Dimension stone | 30 | 376 | 41 | 406 | 78 | 555 | 127 | 633 | 3,824 |
| TOTAL . . . | X X X | 5,009 | X X X | 5,682 | X X X | 7,576 | X X X | 9,324 | X X X X X X |

1/ Thousand long tons.

New water use in the mineral industry in 1960 in the plan area was 6,639 million gallons of new water, of which 5,332 million gallons were discharged and 1,307 million gallons were consumed. In addition, 20,251 million gallons were recirculated to meet processing requirements. Iron ore was the principal user of new water with 66 percent of the plan area's total, followed by sand and gravel with 29 percent. The major water sources for mineral processing were streams and lakes with wells contributing lesser amounts.

Future new water requirements are projected to increase more than threefold by 2020 to 22,682 million gallons, table 11. In addition, 50,780 million gallons of water will be recirculated in plants in 2020 to meet processing requirements. Sand and gravel will account for 63 percent of the plan area's 2020 water needs.

Land requirements for 1960 were 786 acres, sand and gravel being the major user. Through 1964 in the plan area, about 36,000 acres have been disturbed by mineral surface operations. Future land requirements are projected to increase almost sixfold by 2020 to 4,477 acres annually, table 12, and will require a cumulative area of 145,764 acres for the 1960-2020 projection period, sand and gravel needing 75 percent. Land reclamation has been minor and has been confined principally to operations within the Minneapolis-St. Paul Metropolitan district.

a. <u>Iron Ore</u>. Iron ore production for 1960 was about 13.9 million tons with a value of $114,002,406, ranking first in and representing 88 percent of the total plan area's mineral value. About 89 percent of the total production was from the Itasca County portion of the Mesabi

TABLE 11. - Mississippi Headwater Basin Plan Area 1 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Iron ore (usable) | 4,381 | 3,146 | 19,877 | 1,235 | 5,055 | 3,630 | 22,935 | 1,425 |
| Sand and gravel | 1,923 | 1,854 | 374 | 69 | 3,231 | 3,115 | 628 | 116 |
| Crushed stone | 335 | 332 | - | 3 | 605 | 600 | - | 5 |
| TOTAL . . . . | 6,639 | 5,332 | 20,251 | 1,307 | 8,891 | 7,345 | 23,563 | 1,546 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Iron ore (usable) | 2,736 | 1,424 | 27,360 | 1,312 | 3,762 | 1,958 | 37,620 | 1,804 |
| Sand and gravel | 4,953 | 4,775 | 962 | 178 | 9,469 | 9,128 | 1,839 | 341 |
| Crushed stone | 962 | 954 | - | 8 | 1,895 | 1,880 | - | 15 |
| TOTAL . . . . | 8,651 | 7,153 | 28,322 | 1,498 | 15,126 | 12,966 | 39,459 | 2,160 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Iron ore (usable) | 4,788 | 2,492 | 47,880 | 2,296 |
| Sand and gravel | 14,928 | 14,391 | 2,900 | 537 |
| Crushed stone | 2,966 | 2,942 | - | 24 |
| TOTAL . . . . | 22,682 | 19,825 | 50,780 | 2,857 |

TABLE 12. - Mississippi Headwater Basin Plan Area 1 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Iron ore (usable) | 288 | 333 | 356 | 489 | 622 | 26,120 |
| Sand and gravel | 452 | 775 | 1,176 | 2,226 | 3,442 | 107,090 |
| Crushed stone | 45 | 83 | 132 | 260 | 406 | 12,350 |
| Dimension stone | 1 | 2 | 3 | 4 | 7 | 204 |
| TOTAL . . . . | 786 | 1,193 | 1,667 | 2,979 | 4,477 | 145,764 |

range and the remainder from the Cuyuna range, Crow Wing County and Spring Valley, Fillmore County.

Future production of iron ore is projected to increase about two times by 2020 to 28 million tons, and will require a cumulative total of 1,175 million tons for the 1960-2020 projection period. Reserves of iron ore, including magnetic and nonmagnetic taconites, total approximately 21 billion tons and will be more than adequate to meet projected demands.

New water requirements for 1960 for the iron ore industry comprised 66 percent of the total mineral industry intake of new water with 4,381 million gallons. Over 80 percent of the iron ore mined was beneficiated. Water discharged from beneficiation plants went to tailings basins for settling of solids and the clear water recirculated. The recirculated water totalled 20,251 million gallons. Water consumed was 20 percent of new water intake and discharge water was 3,146 million gallons.

Future new water requirements for iron ore are projected to remain about constant by 2020 at 4,788 million gallons annually, 21 percent of the plan area's 2020 total water needs. The industry's pattern of obtaining this water from lakes, streams, and abandoned mines is expected to continue through the projection period. Recirculation of 47,880 million gallons of process water from plant wastes in large tailings basins will hold new water intake to a minimum.

Land requirements for 1960 for iron ore were 288 acres, 37 percent of the plan area's total mineral land needs. Through 1964 in the plan area, 19,600 acres ~~have~~ has been disturbed by the industry's operations. Future land requirements are projected to increase slightly more than double by 2020 to 622 acres, and will require a cumulative area of 26,120 acres for the 1960-2020 projection period. The major portion of these land requirements are currently owned or controlled by the iron mining industry. There is no current law requiring land rehabilitation, and unless such a law is passed, no major land reclamation is expected. Minor land reclamation to reduce safety hazards or alleviate local health problems will be practiced.

b. Sand and Gravel. Sand and gravel production for 1960 was 13,574,190 tons with a value of $11,493,836, ranking second in and representing about 9 percent of the plan area's total mineral value.

Future production of sand and gravel is projected to increase more than sevenfold by 2020 to 103 million tons annually, and will require a cumulative total of 3,212 million tons for the 1960-2020 projection period. Reserves of sand and gravel are adequate to meet the projected demands.

Sand and gravel in almost inexhaustible quantities is available in the plan area from glacial deposits. The major area of sand and gravel production is within the Minneapolis - St. Paul Metropolitan district. Future availability of land within the district will be limited by zoning and residentiary use. This will require relocation of sand and gravel operations to areas outside the district. Higher transportation costs will accrue but availability of reserves will not limit production.

New water requirements for 1960 for sand and gravel were 1,923 million gallons, 29 percent of the plan area's water intake, discharged water was 1,854 million gallons, and consumed water was 69 million gallons. In addition, 374 million gallons were recirculated to meet processing requirements.

Future new water requirements for sand and gravel are projected to increase about eightfold by 2020 to 14,928 million gallons, about 67 percent of the plan area's 2020 water needs.

Land requirements for 1960 for sand and gravel were 452 acres, 58 percent of the total mineral land needs. Through 1964, about 15,000 acres of land have been disturbed by sand and gravel operations. Future land requirements are projected to increase nearly eightfold by 2020 to 3,442 acres annually, and will require a cumulative area of 107,090 acres for the 1960-2020 projection period. Land reclamation has received minor attention. The only land that has been rehabilitated is in areas where urban encroachment has required discontinuance of operations. In these particular areas the land was rehabilitated and utilized as building sites.

c. <u>Crushed Stone</u>. Crushed stone production for 1960 was 1,421,680 tons with a value of $2,378,923, ranking third in and representing less than 2 percent of the plan area's total mineral value.

Future production of crushed stone is projected to increase nearly ninefold by 2020 to 12 million tons annually, and will require a cumulative total of 370 million tons for the 1960-2020 projection period. Reserves of stone, on a geologic basis, are considered inexhaustible, but quarry sites will be limited to areas of relatively thin overburden. Suitable areas for production of stone are available to meet projected demands.

Most of the stone crushed in 1960 was limestone with smaller amounts of crushed and broken granite. Glacial drift thicknesses limited the selection of quarry sites to places where the stone outcropped or the drift overburden was thin. The limestone was quarried principally in the southern portion of the plan area.

New water requirements for 1960 for crushed stone were 335 million gallons, 5 percent of the plan area's total new water needs. These water needs are relatively small. The industry will rely on wells, streams, and lakes for water and should have no problems in obtaining suitable water sources for its needs. Future water requirements are projected to increase nearly ninefold by 2020 to 2,966 million gallons annually, about 13 percent of the plan area's 2020 new water needs.

Land requirements for 1960 for crushed stone were 45 acres, nearly 6 percent of the total mineral land needs. Through 1964 in the plan area, 1,200 acres of land were disturbed by stone operations, a portion of which has been reclaimed. Future land requirements are projected to increase about ninefold by 2020 to 406 acres annually, less than one-tenth the plan area's total 2020 land needs, and will require a cumulative area of 12,350 acres for the 1960-2020 projection period. Areas possibly reclaimed are unknown due to unavailability of data.

d. Dimension Stone. Dimension stone production for 1960 was 23,342 tons with a value of $1,794,660, ranking fourth in and representing less than 2 percent of the plan area's total mineral value.

Future production is projected to increase nearly sixfold by 2020 to 127,000 tons annually, and will require a cumulative total of nearly 4 million tons for the 1960-2020 projection period. Reserves of stone are estimated to be more than adequate and will easily meet all projected demands. The dimension stone industry is centered principally near St. Cloud, Stearns County. Typical dimension stone quarry is shown in figure 5.

Water consumption by the dimension stone industry, present and future, is considered insignificant and not estimated. Its water needs will be easily supplied.

Land requirements for dimension stone, present and future, are relatively insignificant, requiring 7 acres in 1960 and projected to need 7 acres annually by 2020.

e. Miscellaneous. Clay, shale, and peat accounted for less than 0.5 percent of the mineral industry land use. Water use by these commodities was insignificant.

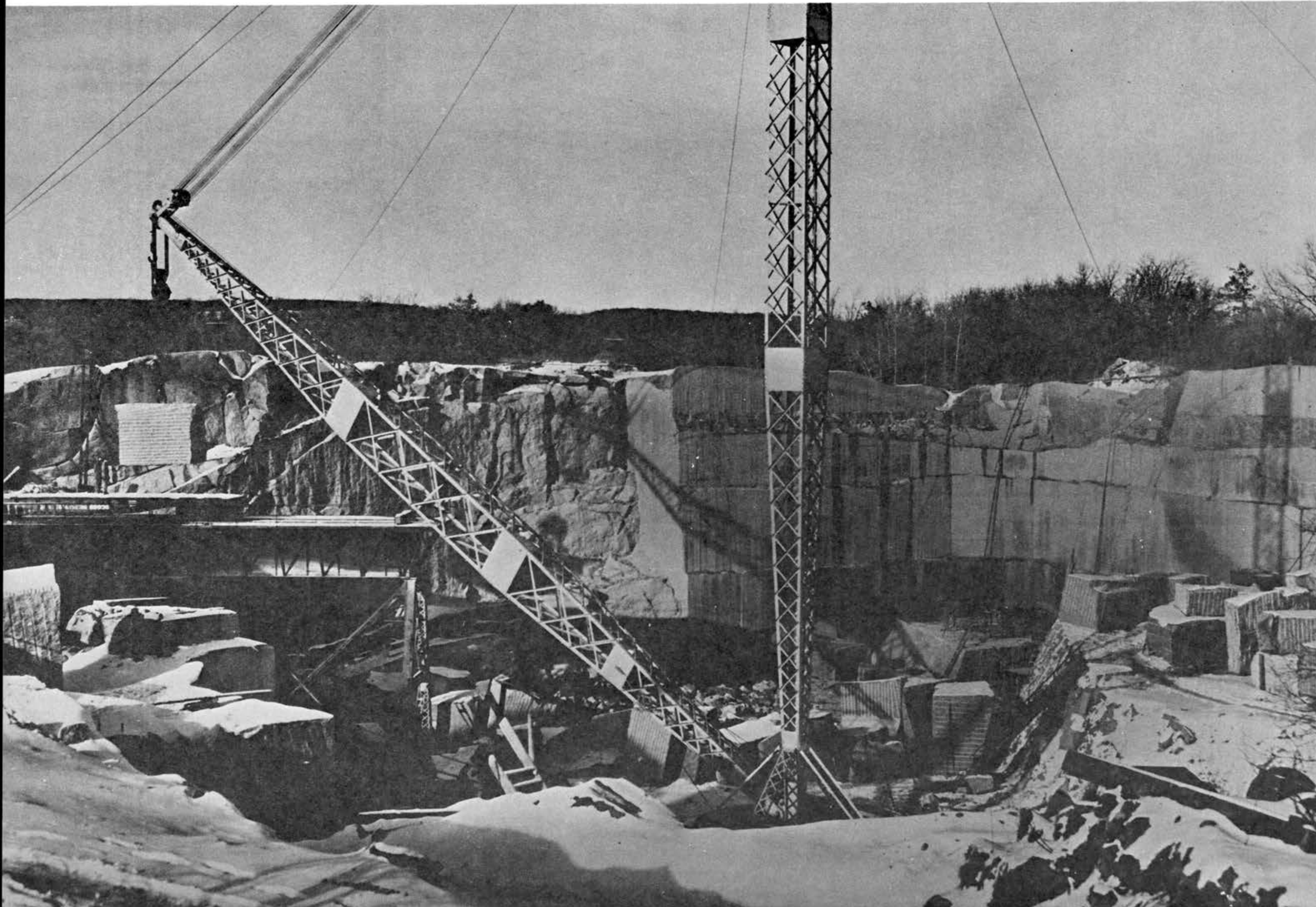
16. PLAN AREA 2 - CHIPPEWA AND BLACK RIVER BASINS

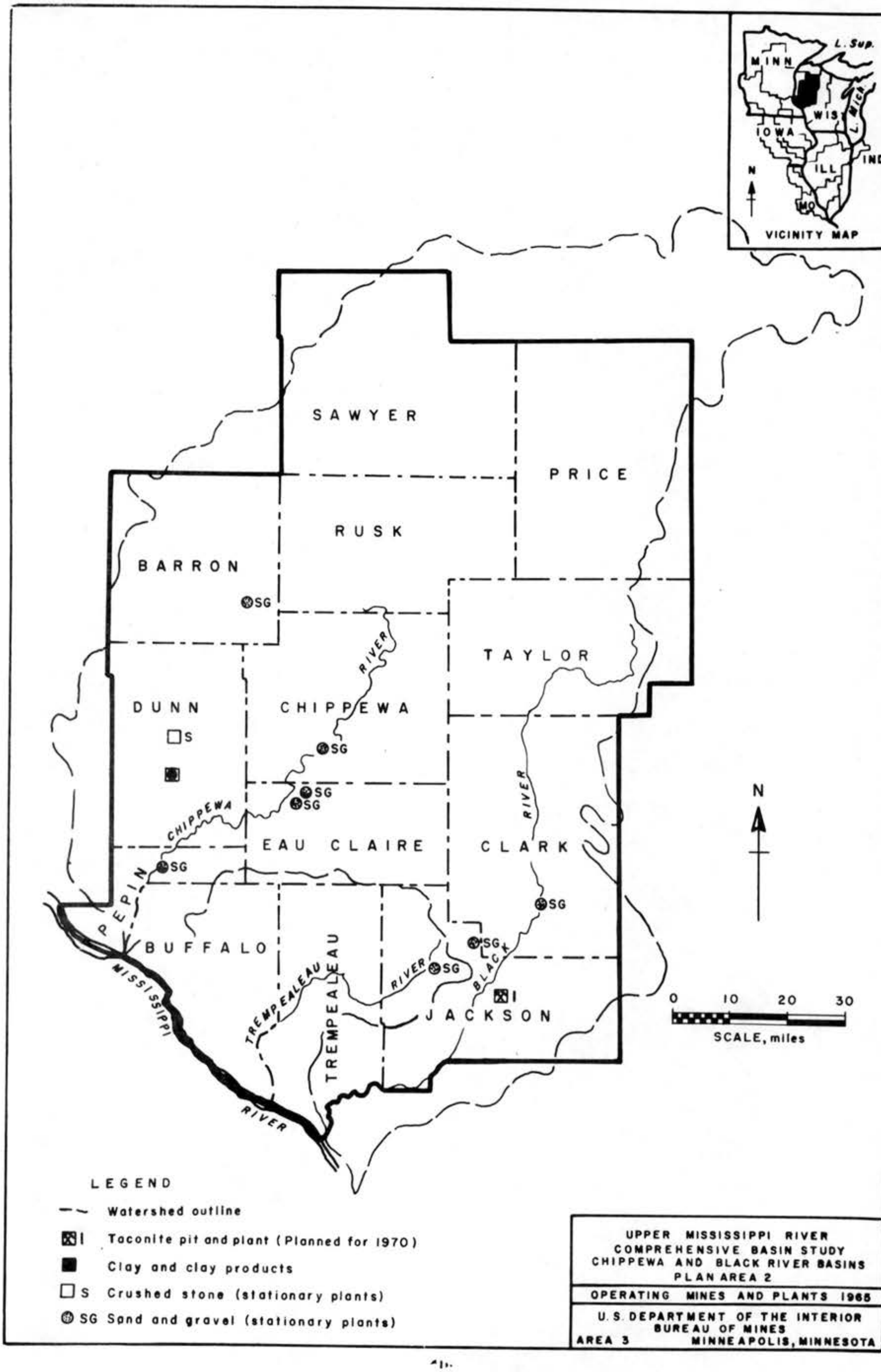
General location - North-central Wisconsin, Figure 6.

Area - 13 counties, 11,738 square miles, 3.3 percent urbanized.

Population - 311,893 total, 27 percent urban.

The plan area lies predominantly in the watershed of the Chippewa, Trempealeau, and Black Rivers.

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Watershed outline
I Taconite pit and plant (Planned for 1970)
Clay and clay products
S Crushed stone (stationary plants)
SG Sand and gravel (stationary plants)
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
CHIPPEWA AND BLACK RIVER BASINS
PLAN AREA 2
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

Mineral production for 1960 in the Chippewa and Black River Basins, Plan Area 2, was valued at $2,458,258, ranking 16th in and representing less than 1 percent of the Basin's total mineral value, table 13. Sand and gravel accounted for 78 percent of the plan area's total mineral value and crushed stone 21 percent. Taconite processed to high grade iron ore pellets will become important by 1970 when a new plant goes into production.

Future production of mineral commodities in Plan Area 2 are projected to increase more than fivefold by 2020, table 14. Reserves are adequate to meet the projected demands. Figure 6 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water requirements for 1960 were 29 million gallons, sand and gravel taking all; discharged water was 26 million gallons; and consumed water was 3 million gallons. In addition 153 million gallons were recirculated to meet processing requirements. Sources of water were wells, lakes, and streams in that order of significance.

Future new water requirements in Jackson County are projected to increase substantially in 1970 due to construction of a taconite processing plant with a rated annual production of 750,000 tons of iron ore pellets, table 15, and may ultimately require as much as 450 million gallons of water intake per year when at full production. Some of this water will be discharged.

F-113

TABLE 13. - Chippewa and Black River Basins, mineral production in Plan Area 2, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Sand and gravel........................short tons.. | 2,615,303 | $1,914,284 |
| Stone (crushed and broken)...................do.... | 460,948 | 521,188 |
| Value of items that cannot be disclosed: Clays and shale and dimension stone..................... | --------- | 22,766 |
| Total........................................ | --------- | $2,458,238 |

TABLE 14. - Chippewa and Black River Basins Plan Area 2 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Sand and gravel | 3,998 | 161 | 5,696 | 188 | 9,714 | 235 | 14,008 | 268 | 475,344 |
| Crushed stone | 692 | 53 | 990 | 63 | 1,700 | 75 | 2,467 | 80 | 82,647 |
| Dimension stone | (1/) | 3 | (1/) | 4 | 2 | 5 | 3 | 6 | 88 |
| Iron ore | 750 | 200 | 750 | 200 | 750 | 200 | - | - | 22,500 |
| TOTAL . . . | X X X | 417 | X X X | 455 | X X X X | 515 | X X X | 354 | X X X X X |

1/ Less than 1,000 tons.

TABLE 15. - Chippewa and Black River Basins Plan Area 2 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 29 | 26 | 153 | 3 | 44 | 40 | 236 | 4 |
| Iron ore (usable) | - | - | - | - | 450 | 235 | 4,875 | 215 |
| TOTAL . . . . | 29 | 26 | 153 | 3 | 494 | 275 | 5,111 | 219 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 63 | 58 | 339 | 5 | 109 | 99 | 585 | 10 |
| Iron ore (usable) | 450 | 235 | 4,875 | 215 | 450 | 239 | 4,875 | 215 |
| TOTAL . . . . | 513 | 293 | 5,214 | 219 | 559 | 338 | 5,460 | 225 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 160 | 146 | 860 | 14 |
| TOTAL . . . . | 160 | 146 | 860 | 14 |

The water requirements for crushed stone were shown to be relatively small by the Bureau of Mines water canvass of 1962 and were not tabulated.

Clay, shale, and dimension stone accounted for the remaining 1 percent of the plan area's mineral value.

Land requirements for 1960 were 73 acres, sand and gravel taking most of the acreage. Through 1964 in the plan area, about 4,500 acres of land have been disturbed by mineral operations. Future land requirements are projected to increase more than fivefold by 2020 to 399 acres annually, and will require a cumulative area of 13,927 acres for the 1960-2020 projection period, table 16.

a. Sand and Gravel. Sand and gravel production for 1960 was 2,615,303 tons with a value of $1,914,284, ranking first in and representing about 78 percent of the plan area's total mineral value.

Future production of sand and gravel is projected to increase more than fivefold by 2020 to 14 million tons, and will require a cumulative total of 475 million tons for the 1960-2020 projection period. Reserves are estimated to be more than adequate to meet the projected demands, as determined by geological occurrences of sand and gravel as described in the literature (56, 110, 118).

New water requirements for 1960 and for the projection period have already been treated in the review of the plan area and, as there indicated, the industry used 29 million gallons in 1960 and will use 160 million gallons in 2020.

Land requirements for 1960 for sand and gravel were 67 acres, about 92 percent of the total mineral land needs, and will require a cumulative area of 12,188 acres for the 1960-2020 projection period.

TABLE 16. - Chippewa and Black River Basins Plan Area 2 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Sand and gravel | 67 | 103 | 146 | 249 | 359 | 12,188 |
| Crushed stone | 6 | 10 | 14 | 23 | 40 | 1,138 |
| Dimension stone | - | - | - | - | - | 1 |
| Iron ore (usable) | - | 20 | 20 | 20 | - | 600 |
| TOTAL . . . . | 73 | 133 | 180 | 292 | 399 | 13,927 |

Possible reclaimed acreage is unestimated because of unavailability of data.

b. <u>Crushed Stone and Dimension Stone.</u> A cumulative production of almost 83 million short tons of crushed stone and 88, ~~thousand~~ short tons of dimension stone is projected for the period 1960-2020. The reserves were estimated as for sand and gravel by comparing the projected demand to the amount indicated, by analysis and inference of geologic data from the literature (<u>55</u>, <u>56</u>). The indicated available quantities meet the projected requirements by several times. The current water utilization by the crushed stone and dimension stone producers is relatively insignificant and has not been projected. The total cumulative land requirement indicated for the production of crushed stone by 2020 is 1,138 acres and for dimension stone only ~~one~~ 1 acre. Plant site set up, spoils dumps, etc., makes the latter value unrealistic but demonstrates the relative insignificance of land utilization for this commodity.

## 17. <u>PLAN AREA 3 - WISCONSIN RIVER BASIN</u>

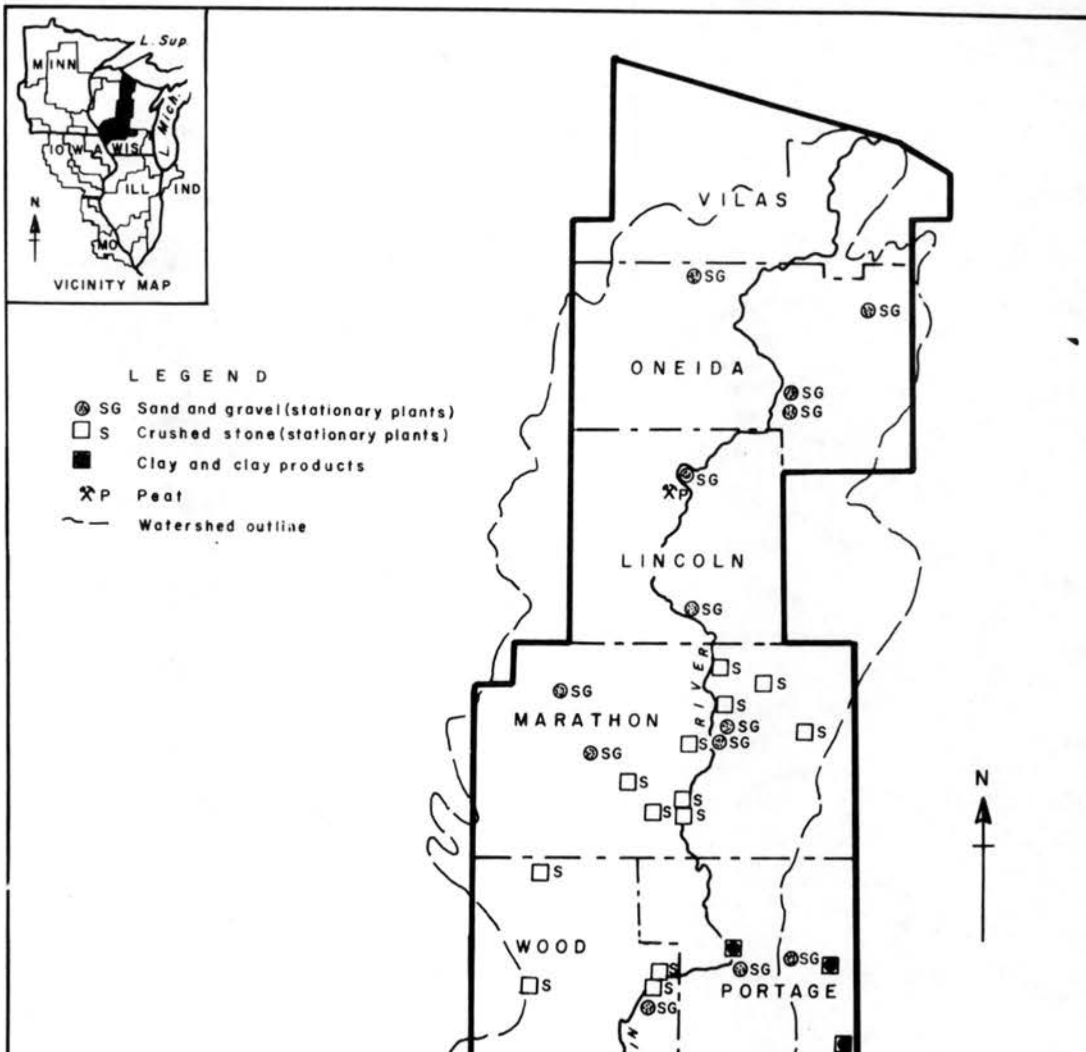
General location - The plan area extends from the southwest to northeast sections of Wisconsin, figure 7.

Area - 15 counties, 12,536 square miles, 4.1 percent urbanized.

Population - 500,072 total, 43 percent urban.

The plan area lies predominantly in the watershed of the Wisconsin River.

Mineral production for 1960 in the Wisconsin River Basin, Plan Area 3, was valued at $8,593,340 ranking 12th in and representing about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Clay and clay products
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ADAMS
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WISCONSIN RIVER BASIN
PLAN AREA 3
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

1 percent of the Basin's total mineral value, table 17. Crushed stone accounted for 56 percent of the plan area's total mineral value, sand and gravel 27 percent, and dimension stone about 17 percent. The production of abrasives, clay and shale had a combined value of slightly more than 1 percent of the total.

Future production of major commodities is projected to increase about sixfold by 2020, table 18. Reserves are estimated to be adequate to meet the projected demands. Figure 7 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water requirements for 1960 were 217 million gallons, discharged water was 209 million gallons, and consumed water was 8 million gallons. In addition, 43 million gallons of water were recirculated to meet processing requirements. Sand and gravel used nearly all of the water. The sources of most of the new water were streams, the most important, and wells and lakes contributing lesser amounts.

Future water requirements are projected to increase nearly sevenfold by 2020 to 1,496 million gallons, table 19, with sand and gravel, again, requiring nearly all of it.

Land requirements for 1960 were 101 acres, sand and gravel taking about 68 percent. Through 1964 in the plan area, about 6,000 acres of land have been disturbed by mineral operations. Only 126 acres have been reclaimed and 343 acres partially reclaimed.

Future land requirements in plan area 3 are projected to increase more than sixfold by 2020 to 647 acres annually, table 20, sand and gravel again taking the major portion, and will require a cumulative area of 21,922 acres for the 1960-2020 projection period; sand and gravel will take about two-thirds of this acreage. Future possible

TABLE 17. - Wisconsin River Basin, mineral production in Plan Area 3, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Abrasives (grinding pebbles).............short tons.. | 350 | $10,500 |
| Clays and shale.............................do.... | 1,000 | 1,250 |
| Sand and gravel.............................do.... | 2,769,853 | 2,349,691 |
| Stone (crushed and broken) 1/...............do.... | 3,399,602 | 4,761,493 |
| Stone (dimension)...........................do.... | 13,689 | 1,470,406 |
| Total........................................ | --------- | 2/$8,593,340 |

1/ Excludes limestone produced for use in manufacturing cement and lime.
2/ Incomplete total. Excludes the values of tube-mill liners and limestone produced for use in manufacturing lime to avoid disclosing individual company confidential data.

TABLE 18. - Wisconsin River Basin Plan Area 3 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Sand and gravel | 4,294 | 170 | 6,322 | 206 | 11,577 | 276 | 17,625 | 332 | 561,547 |
| Crushed stone | 5,134 | 378 | 7,714 | 464 | 14,310 | 600 | 21,923 | 667 | 687,925 |
| Dimension stone | 22 | 108 | 30 | 122 | 58 | 164 | 95 | 198 | 2,859 |
| TOTAL . . . | X X X | 656 | X X X | 792 | X X X | 1,040 | X X X | 1,197 | X X X X X X |

TABLE 19. - Wisconsin River Basin Plan Area 3 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 208 | 203 | 24 | 5 | 335 | 326 | 39 | 9 |
| Crushed stone | 9 | 6 | 19 | 3 | 15 | 10 | 31 | 5 |
| Dimension stone | - | - | - | - | - | - | - | - |
| TOTAL . . . . | 217 | 209 | 43 | 8 | 350 | 336 | 70 | 14 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 498 | 485 | 57 | 13 | 921 | 897 | 106 | 24 |
| Crushed stone | 23 | 15 | 46 | 8 | 43 | 29 | 86 | 14 |
| Dimension stone | - | - | - | - | - | - | - | - |
| TOTAL . . . . | 521 | 500 | 103 | 21 | 964 | 926 | 192 | 38 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 1,430 | 1,393 | 165 | 37 |
| Crushed stone | 66 | 44 | 132 | 22 |
| Dimension stone | - | - | - | - |
| TOTAL . . . . | 1,496 | 1,437 | 297 | 59 |

TABLE 20. - Wisconsin River Basin Plan Area 3 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Sand and gravel | 68 | 110 | 162 | 297 | 452 | 14,399 |
| Crushed stone | 33 | 56 | 85 | 158 | 194 | 7,552 |
| Dimension stone | (1/) | (1/) | (1/) | (1/) | 1 | 41 |
| TOTAL . . . . | 101 | 166 | 247 | 455 | 647 | 21,992 |

1/ Less than 1 acre.

reclaimed acreage is unestimated ~~due~~ to unavailability of data.

The water and land requirements for dimension stone were small and were not tabulated.

a. <u>Sand and Gravel</u>. Sand and gravel production for 1960 in plan area 3 was 2,769,853 tons with a value of $2,349,691, ranking second in and representing about 27 percent of the plan area's total mineral value.

Future production of sand and gravel in Plan Area 3 is projected to increase more than sixfold by 2020 to 17 million tons, and will require a cumulative total of 561 million tons for the 1960-2020 projection period. Reserves of sand and gravel are adequate to meet the projected demands, as estimated by an analysis of the literature (56, 110, 118) describing occurrences of sand and gravel in the plan area.

New water requirements for 1960 for sand and gravel in Plan Area 3 were 208 million gallons; this is almost all of the water used for mineral operations in the plan area. Future water requirements are projected to increase nearly sevenfold by 2020 to 1,430 million gallons annually, again, sand and gravel taking almost all of the new water used in the plan area. Most of the water used in 2020 will be discharged and 37 million gallons will be consumed.

Land requirements for 1960 in Plan Area 3 for sand and gravel were 68 acres, nearly 68 percent of the total land needs for mineral operations. Future land requirements are projected to increase nearly sevenfold by 2020 to 452 acres annually, about 70 percent of the plan area's total needs, and will require a cumulative area of 14,399 acres for the 1960-2020 projections period. These estimated areas were based on the indicated land use ratio for this area.

b. <u>Crushed Stone</u>. Crushed stone production for 1960 in Plan Area 3 was 3,399,602 tons with a value of $4,761,493, ranking first in and representing nearly 56 percent of the plan area's total mineral value.

Future production of crushed stone in Plan Area 3 is projected to increase more than sixfold by 2020 to about 22 million tons, and will require a cumulative total of 688 million tons for the 1960-2020 projection period. Reserves of stone in the plan area are more than adequate by several times to meet the projected demands, and they were estimated on the same basis as for sand and gravel by analyzing the geologic data in the literature (<u>55</u>, <u>56</u>).

New water requirements for 1960 in Plan Area 3 for crushed stone were 9 million gallons, insignificant compared with the needs of sand and gravel. Future water requirements are projected to increase about sevenfold by 2020 to 66 million gallons annually, again insignificant compared to the needs of sand and gravel. Proportionally, however, much used water will be recirculated--132 million gallons annually--to meet processing requirements.

Land requirements for 1960 in Plan Area 3 for crushed stone were 33 acres, about one-third of the plan area's total acreage used for mineral operations. Future land requirements are projected to increase about sixfold by 2020 to 194 acres annually, about one-third of total land needs, and will require a cumulative area of 7,552 acres for the 1960-2020 projection period. Possible reclaimed acreage is unestimated because of unavailability of data.

c. <u>Dimension Stone</u>. Dimension stone production for 1960 in Plan Area 3 was 13,689 tons with a value of $1,470,406, ranking third in and

and representing about 17 percent of the plan area's total mineral value.

Future production of dimension stone is projected to increase about fourfold by 2020 to 95,000 tons annually, and will require a cumulative total of nearly 3 million tons for the 1960-2020 projection period. Reserves of dimension stone are adequate to meet the projected demands, and they were estimated on the same basis and from the same literature as sand and gravel.

New water, currently utilized by dimension stone producers, is relatively insignificant and past and projected use has not been estimated.

Land requirements also have been insignificant and are so considered for projections. However, a cumulative area of 41 acres has been evaluated for the 1960-2020 projection period.

18. PLAN AREA 4 - ROCK RIVER BASIN

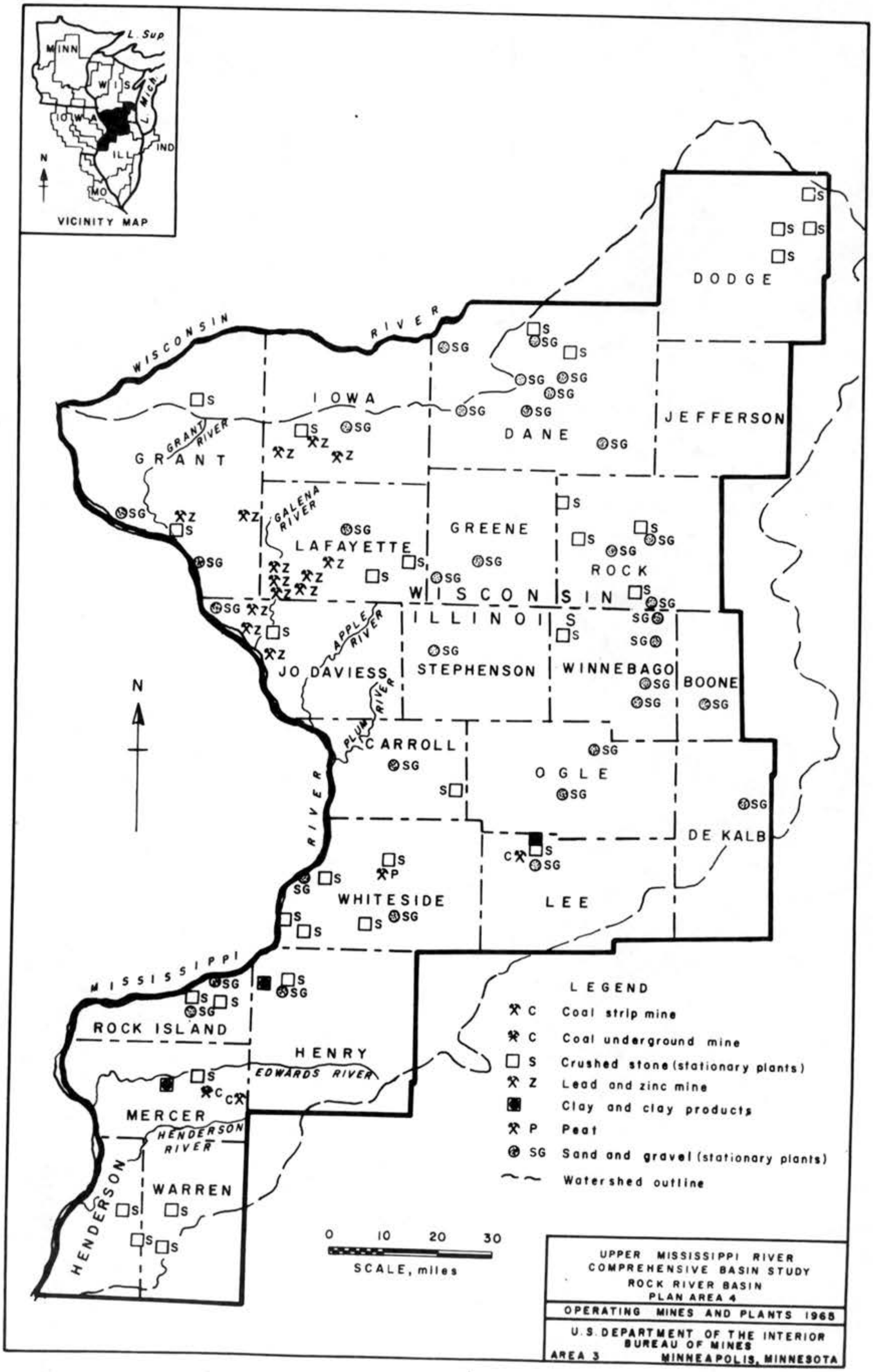
General location - Northwestern Illinois and southwestern Wisconsin, figure 8.

Area - 22 counties, 14,522 square miles, 4.2 percent urbanized.

Population - 1,310,678 total, 62 percent urban.

Principal drainage systems in the area are the Edwards, Henderson, Grant, Galena, Apple, and Plum Rivers.

Mineral production for 1960 in the Rock River Basin, Plan Area 4, was valued at $33,987,402, ranking 7 in and representing about 4 percent of the Basin's total mineral value (table 21). Within the plan area, zinc production accounted for 29 percent of the plan area's total mineral value (and 93 percent of the value of all zinc produced



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WISCONSIN
ILLINOIS
APPLE RIVER
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
PLUM RIVER
CARROLL
OGLE
DE KALB
LEE
WHITESIDE
RIVER
MISSISSIPPI
ROCK ISLAND
HENRY
EDWARDS RIVER
MERCER
HENDERSON RIVER
HENDERSON
WARREN
N
LEGEND
C Coal strip mine
C Coal underground mine
S Crushed stone (stationary plants)
Z Lead and zinc mine
Clay and clay products
P Peat
SG Sand and gravel (stationary plants)
Watershed outline
0 10 20 30
SCALE, miles
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
ROCK RIVER BASIN
PLAN AREA 4
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 21. - Rock River Basin, mineral production in Plan Area 4, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Lead.....................................short tons.. | 2,410 | $563,940 |
| Sand and gravel................................do.... | 8,331,774 | 7,158,549 |
| Stone (crushed and broken) 1/.................do.... | 6,545,998 | 7,105,006 |
| Zinc...........................................do.... | 38,735 | 9,993,630 |
| Value of items that cannot be disclosed: Cement (portland and masonry), clays and shale, coal, lime, dimension stone, and limestone produced for use in manufacturing cement and lime............... | --------- | 9,166,277 |
| Total.......................................... | --------- | $ 33,987,402 |

1/ Excludes limestone produced for use in manufacturing cement and lime.

in the Basin), and sand and gravel and crushed stone each for 21 percent. Undisclosed commodities, such as clay, shales, coal, dimension stone, limes, and limestone used in cement manufacturing, combined totaled a value of $9,166,277, about 27 percent of the plan area's total mineral value.

Future production of mineral commodities in Plan Area 4 is mixed: sand and gravel and crushed stone are projected to increase nearly sevenfold by 2020 (table 22), coal will increase slightly, and lead and zinc will remain nearly constant for the 1960-2020 projection period. Coal is not expected to constitute a major mineral commodity in the plan area by 2020. Reserves in the plan area will be adequate for sand and gravel and crushed stone, zinc will hold constant, and coal and the character of its deposits will have competitive disadvantages. Figure 8 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water requirements for 1960 in Plan Area 4 were 1,370 million gallons, sand and gravel using half; discharged water was 1,324 million gallons; and consumed water was 46 million gallons. In addition, 1,609 million gallons ~~were~~ was recirculated to meet processing requirements. Quality of the discharged water is unknown. Approximately 34 percent of the new water came from mines and most of the remainder was from streams and lakes. A minimal quantity came from ground water sources.

Future new water requirements in Plan Area 4 are projected to increase more than fivefold by 2020 to 7,485 million gallons annually (table 23), sand and gravel taking about 88 percent of the 2020 needs.

TABLE 22. - Rock River Basin Plan Area 4 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Coal | 100 | (1/) | 200 | (1/) | 300 | (1/) | 200 | (1/) | 12,500 |
| Lead | 3 | - | 3 | - | 3 | - | 3 | - | - |
| Zinc | 39 | 360 | 40 | 350 | 40 | 315 | 40 | 280 | |
| Sand and gravel | 12,866 | 562 | 18,874 | 672 | 35,891 | 926 | 56,100 | 1,141 | 1,735,774 |
| Crushed stone | 10,935 | 699 | 15,999 | 841 | 28,737 | 1,059 | 43,597 | 1,164 | 1,390,458 |
| TOTAL . . . | X X X | 1,621 | X X X | 1,863 | X X X | 2,300 | X X X | 2,585 | X X X X X X |

1/ Less than 100.

TABLE 23. - Rock River Basin Plan Area 4 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | 5 | 5 | 4 | - | 5 | 5 | 4 | - |
| Lead and zinc | 468 | 467 | 234 | 1 | 578 | 577 | 289 | 1 |
| Sand and gravel | 844 | 806 | 1,371 | 38 | 1,441 | 1,377 | 2,342 | 64 |
| Crushed stone | 53 | 46 | - | 7 | 88 | 77 | - | 11 |
| TOTAL . . . . | 1,370 | 1,324 | 1,609 | 46 | 2,112 | 2,036 | 2,635 | 76 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | 9 | 9 | 8 | - | 14 | 14 | 12 | - |
| Lead and zinc | 592 | 591 | 296 | 1 | 592 | 591 | 296 | 1 |
| Sand and gravel | 2,135 | 2,040 | 3,469 | 95 | 4,100 | 3,917 | 6,663 | 183 |
| Crushed stone | 128 | 112 | - | 16 | 230 | 201 | - | 29 |
| TOTAL . . . . | 2,864 | 2,752 | 3,773 | 112 | 4,936 | 4,723 | 6,971 | 213 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Coal | 9 | 9 | 8 | - |
| Lead and zinc | 592 | 591 | 296 | 1 |
| Sand and gravel | 6,535 | 6,243 | 10,619 | 292 |
| Crushed stone | 349 | 305 | - | 44 |
| TOTAL . . . . | 7,485 | 7,148 | 10,923 | 377 |

Land requirements for 1960 in Plan Area 4 were 232 acres, sand and gravel using more than half. Future land requirements are projected to increase more than sixfold by 2020 to 1,490 acres annually, (table 24), with sand and gravel requiring about two-thirds, and will require a cumulative area of 47,411 acres for the 1960-2020 projection period. Possible reclaimed acreage is unestimated due to unavailability of data.

a. Sand and Gravel. Sand and gravel production for 1960 in Plan Area 4 was 8,331,774 tons with a value of $7,158,549, ranking second in and representing about 21 percent of the plan area's total mineral value. Figure 9 shows the Capital Sand and Gravel Plant, Madison, Wisconsin.

Future production of sand and gravel is projected to increase nearly sevenfold by 2020 to 56 million tons annually, and will require a cumulative total of 1,735 million tons for the 1960-2020 projection period. Reserves of sand and gravel in the plan area are far greater than the projected demands. In several counties, however, where the glacial drift is thin or mining reserves are limited, the needs are expected to be supplied either by crushed stone or from nearby counties or river channel deposits. Most of the area is covered by drift, with two exceptions: one, the "Driftless Area" of southwestern Wisconsin and the other, northernmost counties of the plan area where glacial deposits are limited. In the latter area, river and flood plain deposits have been the source of some sand and gravel. Except for these two areas where glacial outwash is scarce, sand and gravel production was not restricted because of deficiencies of reserves.

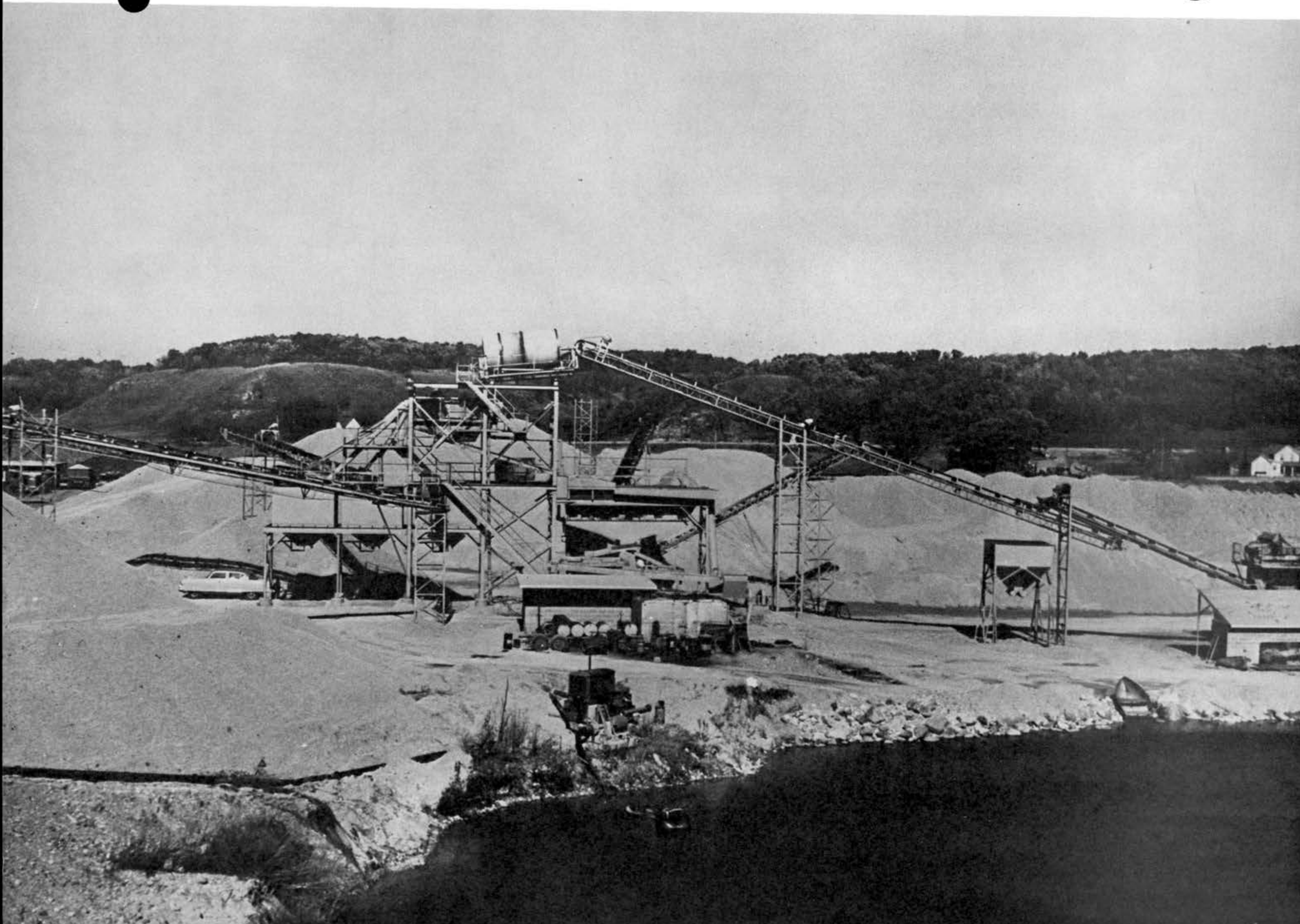


TABLE 24. - Rock River Basin Plan Area 4 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Coal | 3 | 4 | 15 | 36 | 27 | 1,270 | 1,252 |
| Sand and gravel | 141 | 218 | 320 | 608 | 951 | 29,420 | (1/) |
| Stone | 75 | 124 | 182 | 327 | 496 | 15,826 | (1/) |
| Lead-zinc | 13 | 16 | 16 | 16 | 16 | 895 | (1/) |
| TOTAL . . . . | 232 | 362 | 533 | 987 | 1,490 | 47,411 | 1,252 |

1/ No estimates ~~have~~ has been made.

New water requirements for 1960 in Plan Area 4 were 844 million gallons, about 62 percent of the plan area's total, discharged water was 806 million gallons, and consumed water was 38 million gallons. In addition, 1,371 million gallons ~~were~~ was recirculated to meet processing requirements.

Future water requirements for sand and gravel are projected to increase nearly eighfold by 2020 to 6,535 million gallons annually, nearly 88 percent of the plan area's 2020 water total.

Land requirements for 1960 in Plan Area 4 were 141 acres, nearly two-thirds of the plan area's total. Although sand and gravel reserves did not limit production in the areas of high demand, the availability of land, which could be used for mining, exerted considerable influence on the location and depths to which pits were mined. Future land needs for sand and gravel are projected to increase nearly sevenfold by 2020 to 951 acres annually, nearly two-thirds of the plan area's total 2020 needs, and will require a cumulative area of 29,420 acres for the 1960-2020 projection period. Some of this land may be reclaimed for other uses, particularly in the vicinity of urban communities, but no estimates have been made.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 4 was 6,545,998 tons with a value of $7,105,006, ranking third in and representing about 21 percent of the plan area's total mineral value. All of this crushed stone was produced from limestone. Glacial drift limited the quarry sites to areas where the limestone outcropped or the drift was thin enough that stripping was economic.

Future production of crushed stone is projected to increase more than sixfold by 2020 to 43 million tons annually, and will require a cumulative total of 1,390 million tons for the 1960-2020 projection period. Reserves of stone in the plan area are more than adequate to meet the projection demands, even though quarry sites are limited to those locations where the overburden is relatively thin. Present areas quarried are sufficient in reserves to meet the projected demands.

New water requirements for 1960 for crushed stone were relatively insignificant with 53 million gallons, less than 4 percent of the plan area's total water needs. Future water requirements are projected to increase more than sixfold by 2020 to 349 million gallons annually, less than 5 percent of the plan area's total water needs. Water sources are surface drainage or wells and should present no problems of water supply.

Land requirements for 1960 in Plan Area 4 for stone operations were 75 acres, 32 percent of the plan area's total land needs. Future land requirements are projected to increase more than sixfold by 2020 to 496 acres annually, about one-third of the plan area's total 2020 land needs, and will require a cumulative area of 15,826 acres for the 1960-2020 projection period. Possible reclaimed land is unestimated but some of the land may be reclaimed for other uses.

c. Lead-Zinc. Lead production for 1960 in Plan Area 4 was 2,410 tons with a value of $563,940, and zinc production was 38,735 tons with a value of $9,993,630, both combined ranking first in and representing 31 percent of the plan area's total mineral value. All lead and zinc production came from underground mines and the ore was processed that year in six concentration plants using jigs and flotation.

Future zinc production, and lead which is a byproduct of zinc mining, is projected to increase moderately by 1980 to 43,000 tons annually and remain about constant to 2020. This is based on the assumption that exploration will continue to develop reserves approximately at the same rate as they are mined. Cumulative tonnages for the projection period are not estimated. Reserves of zinc, therefore, will remain somewhat constant, new yearly reserves being discovered as fast as known reserves are depleted.

New water requirements for 1960 for zinc were 468 million gallons, about 34 percent of the plan area's total water needs; almost all of this water was discharged. Operating mines were the principal sources of water. Discharged water from plants first went to tailings ponds where the solids were settled out before the resulting clear water was released to local drainage.

Future new water requirements for lead and zinc are projected to increase slightly by 2020 to 592 million gallons annually, about 8 percent of the plan area's total 2020 water needs. About one-half of the required water for processing will be provided by recirculation.

Land requirements for 1960 in Plan Area 4 for lead and zinc were 13 acres, only 6 percent of the plan area's total land needs. The principal land use was for mine and mill plant sites and tailings disposal areas. It is estimated that active lead-zinc mining operations utilized over 300 acres of land. In addition there is a substantial area in southwest Wisconsin and northwest Illinois covered by tailings from former zinc mining operations. No attempt has been made to estimate the area, the status, or the conditions of these lands.

Future land needs for lead and zinc are projected to increase slightly by 1970 and thereafter remain constant at 16 acres annually until 2020 and will require a cumulative area of 895 acres for the 1960-2020 projection period. Possible reclaimed acreage is unestimated due to unavailability of data. The principal land need will be for the storage of tailings.

d. Bituminous Coal. Coal production for 1960 in Plan Area 4 was 100,526 tons. Because of respect of confidential information, value of coal produced was included with other commodities to avoid disclosure. Two underground and one strip mine were in operation, and less than 3,000 tons of coal were strip-mined.

Future coal production in Plan Area 4 is projected to double by 1980 to 200,000 tons annually, rise to 300,000 tons annually by 2000, and return to 200,000 tons annually by 2020. Cumulative tonnage required will be 12.5 million tons for the 1960-2020 projection period. Reserves of coal in the plan area are limited and, because of this, will not contribute substantially to the Basin's total coal production. Reserves of coal, however, are estimated at 180 million tons of all classes. Coal seams are relatively thin--about ~~four~~ 1 feet--placing them at a competitive disadvantage with the thicker seams in other areas, but they will probably be mined in the future when the thicker seams become exhausted.

New water requirements for coal in 1960 were relatively insignificant in the plan area with ~~five~~ 5 million gallons, less than 1 percent of the total. Coal mined in the plan area was not washed; however, coal mined in Plan Area 5B was washed in Plan Area 4, accounting for the water used. The sources of water were lakes and ground water. Future water requirements are projected to rise by 2020 to ~~nine~~ 9 million gallons annually, still relatively insignificant in the plan area.

Land requirements for 1960 in Plan Area 4 for coal were estimated to be three acres, based on coal bed thickness and type of mining. Future land requirements are projected to increase ninefold by 2020 to 27 acres annually and will require a cumulative area of 1,270 acres for the 1960-2020 projection period. Of this cumulative total, 1,252 acres will be reclaimed.

e. Petroleum. Plan Area 4 is not a petroleum producing area. Petroleum industry activity during 1960 was limited to exploration drilling; water requirements for drilling operations totaled about 700,000 gallons.

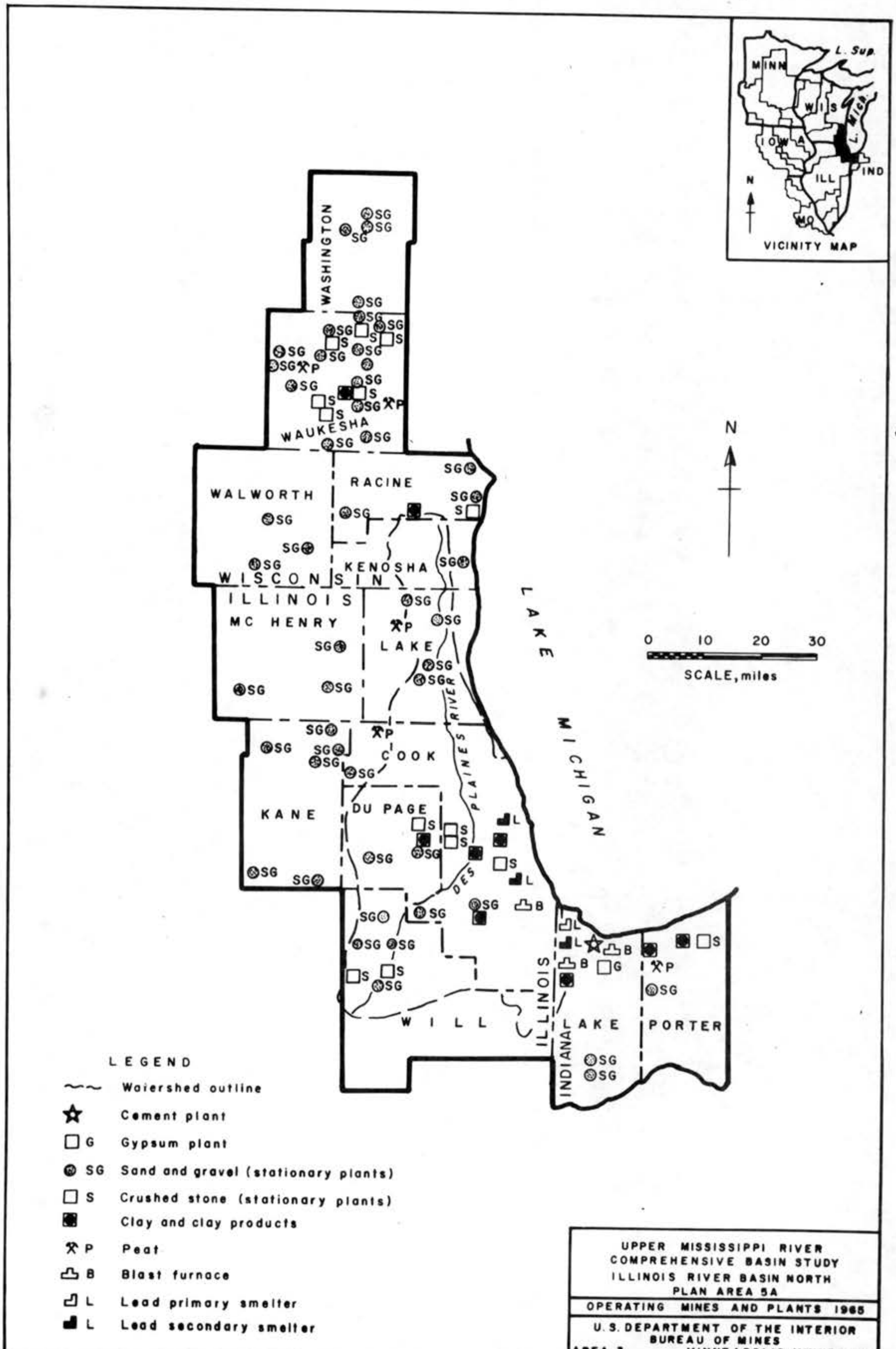
## 19. PLAN AREA 5A - ILLINOIS RIVER BASIN NORTH

General location - Southeastern Wisconsin, northeastern Illinois, and northwestern Indiana, (figure 10).

Area - 13 counties, 6,807 square miles, 20.3 percent urbanized.

Population - 7,293,593 total, 92 percent urban.

The plan area contains numerous short streams draining into Lake Michigan and most of the headwater tributaries of the Illinois River.



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Watershed outline
Cement plant
G Gypsum plant
SG Sand and gravel (stationary plants)
S Crushed stone (stationary plants)
Clay and clay products
P Peat
B Blast furnace
L Lead primary smelter
L Lead secondary smelter
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
ILLINOIS RIVER BASIN NORTH
PLAN AREA 5A
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

Mineral production for 1960 in the north part of the Illinois River Basin, Plan Area 5A, was $85,673,842, ranking sixth in and representing 10 percent of the Basin's total mineral value, table 25. Within the plan area, undisclosed commodities of coal, peat, lime, and materials used in cement manufacturing, combined had a value of $38,926,287 or about 45 percent of the plan area's total, while crushed stone accounted for nearly 31 percent and sand and gravel for nearly 22 percent. Clays and shales and dimension stone accounted for only about 2 percent of the plan area's total mineral value.

Future production of mineral commodities, excepting coal, in Plan Area 5A are projected to increase about sevenfold by 2020, (table 26). Reserves are adequate to meet the projected demands for all commodities, except coal, which may be exhausted before the year 2000. Figure 10 shows the locations of all mines and permanent plants operating in the plan area in 1965.

New water use for 1960 in Plan Area 5A was 3,632 million gallons, 70 percent of which was used for sand and gravel, and most of the water was discharged. In addition, 3,377 million gallons were recirculated to meet processing requirements.

Future new water requirements are projected to increase nearly eightfold by 2020 to 28,783 million gallons annually, table 27, with 69 percent of the 2020 volume taken by sand and gravel.

Land requirements for 1960 in Plan Area 5A, excluding clay, shales, and peat, are 592 acres, 70 percent of which was used by sand and gravel. Through 1964 in the plan area, about 21,000 acres of land have been disturbed by surface mining operations, 44 percent of which (9,071 acres) has been wholly or partially reclaimed.

TABLE 25. - Illinois River Basin North, mineral production in Plan Area 5A, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale........................short tons.. | 697,973 | $1,068,520 |
| Sand and gravel.............................do.... | 22,639,363 | 18,504,113 |
| Stone (crushed and broken)..................do.... | 19,506,290 | 26,476,377 |
| Stone (dimension)...........................do.... | 40,348 | 698,545 |
| Value of items that cannot be disclosed: Cement (portland and masonry), bituminous coal, lime, and peat........................................ | ---------- | 38,926,287 |
| Total........................................ | ---------- | $85,673,842 |

TABLE 26. - Illinois River Basin North Plan Area 5A - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Coal | 600 | 100 | 100 | (1/) | | | | | 8,500 |
| Sand and gravel | 35,557 | 1,485 | 52,519 | 1,796 | 100,946 | 2,521 | 157,226 | 3,107 | 4,859,526 |
| Crushed stone | 31,517 | 1,851 | 48,090 | 2,325 | 91,845 | 3,099 | 140,190 | 3,447 | 4,361,808 |
| Dimension stone | 46 | 115 | 61 | 130 | 118 | 175 | 192 | 206 | 5,790 |
| TOTAL . . . | X X X | 3,551 | X X X | 4,251 | X X X | 5,795 | X X X | 6,760 | X X X X X |

1/ Less than 100.

TABLE 27. - Illinois River Basin North Plan Area 5A - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | - | - | - | - | - | - | - | - |
| Sand and gravel | 2,521 | 2,438 | 2,229 | 83 | 4,302 | 4,160 | 3,805 | 142 |
| Crushed stone | 1,107 | 1,072 | 1,142 | 35 | 2,017 | 1,954 | 2,080 | 63 |
| Dimension stone | 4 | 3 | 6 | 1 | 6 | 5 | 9 | 1 |
| TOTAL . . . . | 3,632 | 3,513 | 3,377 | 119 | 6,325 | 6,119 | 5,894 | 206 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | - | - | - | - | - | - | - | - |
| Sand and gravel | 6,418 | 6,206 | 5,676 | 212 | 12,459 | 12,047 | 11,017 | 412 |
| Crushed stone | 3,078 | 2,982 | 3,174 | 96 | 5,878 | 5,694 | 6,062 | 184 |
| Dimension stone | 8 | 6 | 12 | 2 | 16 | 12 | 24 | 4 |
| TOTAL . . . . | 9,504 | 9,194 | 8,862 | 310 | 18,353 | 17,753 | 17,103 | 600 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Coal | - | - | - | - |
| Sand and gravel | 19,785 | 19,131 | 17,496 | 654 |
| Crushed stone | 8,972 | 8,692 | 9,253 | 280 |
| Dimension stone | 26 | 19 | 38 | 7 |
| TOTAL . . . . | 28,783 | 27,842 | 26,787 | 941 |

Future land requirements in Plan Area 5A are projected to increase more than fivefold by 2020 to 3,439 acres annually, table 28, with sand and gravel taking 83 percent of the 2020 total, and will require a cumulative area of 108,494 acres for the 1960-2020 projection period. The availability of much of this acreage will depend on the disposition of complex land and water problems brought about by the spread of urbanization from the City of Chicago.

a. Sand and Gravel. Sand and gravel production for 1960 in Plan Area 5A was 22,639,363 tons with a value of $18,504,113, ranking first in and representing 22 percent of the plan area's total mineral value.

Future production of sand and gravel in Plan Area 5A is projected to increase nearly sevenfold by 2020 to 157 million tons annually, and will require a cumulative tonnage of 4,859 million tons for the 1960-2020 projection period. Reserves of sand and gravel are more than adequate to meet the projected demands. However, what effect expanding urbanization will have on the availability of reserves is not known. Important deposits have already been covered by houses, highways, and other constructions.

New water requirements for 1960 in Plan Area 5A for sand and gravel were 2,521 million gallons, 69 percent of the plan area's total. Almost all of this water was discharged and 83 million gallons consumed. In addition, 2,229 million gallons of water ~~were~~ was recirculated to meet processing requirements. Streams were the principal sources of water supply, with lesser quantities derived from wells and lakes.

TABLE 28. - Illinois River Basin North Plan Area 5A - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Coal | 99 | 148 | 25 | - | - | 2,100 | 1,482 |
| Crushed stone | 81 | 130 | 199 | 379 | 579 | 18,015 | (1/) |
| Sand and gravel | 412 | 646 | 955 | 1,835 | 2,859 | 88,355 | - |
| Dimension stone | (2/) | (2/) | (2/) | 1 | 1 | 24 | - |
| TOTAL . . . . | 592 | 924 | 1,179 | 2,215 | 3,439 | 108,494 | 1,482 |

1/ No estimate has been made.
2/ Insignificant.

Future new water requirements for sand and gravel are projected to increase more than sevenfold by 2020 to 19,785 million gallons annually. Almost all of this water will be discharged. Current sources, streams and wells, will probably be hard pressed to supply all future water requirements, and water use will require careful planning.

Land requirements for 1960 in Plan Area 5A for sand and gravel were 412 acres, 70 percent of the plan area's total land needs. Through 1964 in the plan area, about 10,500 acres of land ~~have~~ has been disturbed by sand and gravel operations, of which 42 percent was reclaimed for other uses.

Future land requirements for sand and gravel in Plan Area 5A are projected to increase sevenfold by 2020 to 2,859 acres annually, about 83 percent of the plan area's total, and will require a cumulative area of 88,355 acres for the 1960-2020 projection period. Possible reclaimed land is unestimated. Many conflicting land use problems are expected to arise. Land requirements are based on an assumed output of 55,000 tons of sand and gravel per acre mined to a depth of 25 feet.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 5A was 19,506,290 tons with a value of $26,476,377, ranking first in and representing 31 percent of the plan area's total mineral value.

Future crushed stone production in Plan Area 5A is projected to increase more than sevenfold by 2020 to 140 million tons annually, and will require a cumulative tonnage of 4,361 million tons for the 1960-2020 projection period. Reserves of stone are adequate to meet projected demands several times over, and rock strata suitable for crushed stone and limestone for cement and lime are available throughout most of the plan area.

New water requirements for 1960 in Plan Area 5A were 1,107 million gallons, about 30 percent of the plan area's total new water needs, and most of this water was discharged. In addition, 1,142 million gallons of used water were recirculated to meet processing requirements. Water-filled quarries and streams supplied nearly all of the water used.

Future new water requirements are projected to increase eightfold by 2020 to 8,972 million gallons annually, about 31 percent of the plan area's 2020 new water needs. Nearly all of this water will be discharged and 9,253 gallons will be recirculated. Current sources of water, flooded mines and streams, will probably continue to be the principal supply sources.

Land requirements for 1960 in Plan Area 5A for crushed stone were 81 acres, 14 percent of the plan area's total land needs, assuming an average quarrying depth of 100 feet and one and one-half tons of crushed stone per cubic yard of material quarried. Through 1964, 2,000 acres of land have been disturbed by quarrying operations, of which less than 10 percent has been reclaimed for other uses.

Future land requirements are projected to increase about sevenfold by 2020 to 579 acres annually, about 17 percent of the plan area's 2020 land needs, and will require a cumulative area of 18,015 acres for the 1960-2020 projection period. Of the latter area, no estimates have been made of possible reclaimed acreage.

Although considerably less land will be required for stone production than other mineral commodities, problems of land acquisition must be faced similar to, if not more difficult than, those confronting sand and gravel producers. Quarries, from which all of the area's crushed stone is derived, are not easily reclaimed for restoration to other uses as are sand and gravel pits.

c. Dimension Stone. Dimension stone production for 1960 in Plan Area 5A was 40,348 tons with a value of $698,545, less than 1 percent of the plan area's total mineral value.

Future production of dimension stone is projected to increase about fourfold by 2020 to 192,000 tons annually, and will require a cumulative total of nearly six million tons for the 1960-2020 projection period. Reserves of stone are unlimited to meet the projected demands as strata for dimension stone abound in the plan area.

New water requirements for 1960 in Plan Area 5A for dimension stone are insignificant at ~~four~~ 4 million gallons, compared ~~to~~ the quantities used by sand and gravel and crushed stone. Sources of water are wells. Future water requirements are projected to increase about sixfold by 2020 to 26 million gallons annually, a volume insignificant compared to the plan area's total 2020 new water needs. Wells have supplied water requirements for dimension stone operations and are expected to supply most, if not all, future water needs.

Land requirements for 1960 in Plan Area 5A for dimension stone were insignificant and not estimated. For the most part, dimension stone is a byproduct of crushed stone producers and the stone is derived from the same quarries. The 1960 dimension stone output represented about 0.1 percent of the volume of material quarried for crushed stone. Through 1964, the area of land disturbed by dimension stone operations is included with that reported for crushed stone. Future land requirements for dimension stone are projected to be ~~one~~ acre annually by 2020, and will require a cumulative area of 24 acres for the 1960-2020 projection period, assuming a quarrying depth of 100 feet in the estimation.

d. Bituminous Coal. Bituminous coal production for 1960 in Plan Area 5A was 368,573 tons, all of which came from one strip mine in Will County, Illinois. The mineral value of the produced coal is included with cement, lime, and peat, table 25, to avoid disclosing individual company confidential data.

Future coal production in Plan Area 5A is projected to have an early demise long before the end of the 20th century, and the rate of production will drop to 100,000 tons annually by 1980. A cumulative tonnage of 8.5 million tons is estimated to be required for the projection period, from 1960 to the time of demise. Reserves of coal are estimated to be 13.7 million tons and, of course, will become exhausted before the end of the present century.

New water requirements for 1960 in Plan Area 5A for coal were zero, as no water was used by the coal industry because the produced coal was washed in the adjoining Kankakee County (Plan Area 5B) where it was transported. No water will be used in the future by coal in Plan Area 5A, as the coal will continue to be transported to Kankakee County for washing.

Land requirements for 1960 in Plan Area 5A for coal were 99 acres, based on known thickness of overburden and coalbed thickness, and represented about 17 percent of the plan area's total land needs. Through 1964, approximately 8,000 acres of land were disturbed by coal operations, with 4,530 acres reclaimed for other uses. Future land requirements for coal are projected to increase to 148 acres annually by 1970, decline to 25 acres annually by 1980, and then diminish to zero sometime thereafter. A cumulative area of 2,100 acres will be required for the projection period, 1960 to 1980-2000, with 1,482 acres estimated reclaimed.

e. Other Minerals. Included in this category are clays, shale, and peat. Clay and shale production totalled 697,973 tons with a value of $1,068,520, which accounted for about 1 percent of the total value of all minerals produced in the plan area during 1960. Peat is included with coal, lime, and cement, all of which had a combined value of $38,926,287 or 45 percent of the 1960 total. No water was used in clay, shale, or peat production, and estimates of land used annually by producers of these commodities are not available.

Estimates of clay, shale, and peat reserves are not available and future land use requirements for these commodities have not been computed. However, clay producers disturbed 320 acres of land through 1964 of which 65 acres have been reclaimed for other use.

20. PLAN AREA 5B -- ILLINOIS RIVER BASIN SOUTH

General location - Central Illinois and northwestern Indiana, figure 11.

Area - 43 counties, 25,407 square miles, 5.1 percent urbanized.

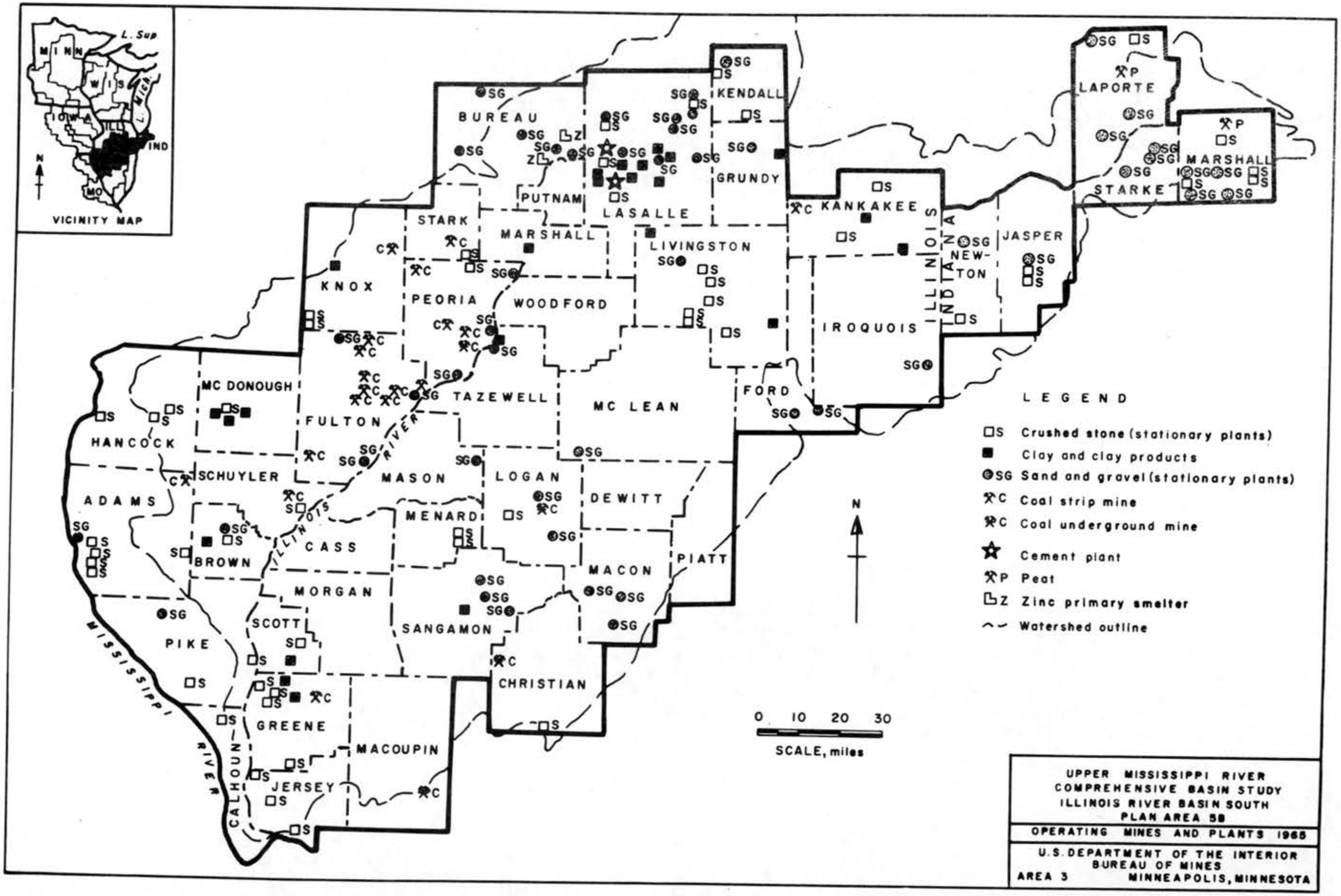
Population - 1,764,461 total, 55 percent urban.

Plan Area 5B lies in the Illinois River watershed.

Mineral production for 1960 in the Illinois River Basin South, Plan Area 5B, was valued at $121,912,102, ranking second in and representing 15 percent of the Basin's total mineral value, (table 29). Within the plan area, coal represented 47 percent of the plan area's total mineral value, sand and gravel 15 percent, and crushed stone 9.5 percent.

Future production of mineral commodities in Plan Area 5B ~~are~~ is projected to increase ~~manyfold~~ by 2020, table 30, with sand and gravel increasing about ninefold. Petroleum production will decline sharply after 1970 and coal production will decline slightly after 2000. Reserves of all commodities, excepting petroleum are adequate to meet the projected demands. Figure 11 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water requirements for 1960 in Plan Area 5B for all mineral commodities, excepting petroleum, were 4,141 million gallons, sand and gravel using 63 percent of this; discharged water was 4,008 million gallons; and consumed water was 133 million gallons. In addition, 11,881 million gallons ~~were~~ recirculated to meet mineral processing requirements. The petroleum industry uses an additional 60 million gallons of water in its operations. Sources of water were lakes.



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GREENE
MACOUPIN
JERSEY
CALHOUN
ILLINOIS RIVER
MISSISSIPPI RIVER
LEGEND
S Crushed stone (stationary plants)
Clay and clay products
SG Sand and gravel (stationary plants)
C Coal strip mine
C Coal underground mine
Cement plant
P Peat
Z Zinc primary smelter
Watershed outline
N
0 10 20 30
SCALE, miles
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
ILLINOIS RIVER BASIN SOUTH
PLAN AREA 5B
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 29. - Illinois River Basin South, mineral production in Plan Area 5B, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale 1/......................short tons.. | 1,252,462 | $3,791,869 |
| Coal (bituminous)............................do.... | 14,102,642 | 56,806,769 |
| Petroleum...............thousand 42-gallon barrels. | 2,164 | 6,405,224 |
| Sand and gravel.........................short tons.. | 12,272,507 | 18,232,322 |
| Stone (crushed and broken) 2/................do.... | 8,390,234 | 11,425,276 |
| Limestone for use in mfg. cement and lime.....do.... | 2,082,277 | 1,402,185 |
| Value of items that cannot be disclosed: Cement (portland and masonry), lime, dimension stone, and limestone produced for use in manufacturing cement and lime........................................ | ---------- | 23,848,457 |
| Total........................................ | ---------- | $121,912,102 |

1/ Excludes clay produced for use in manufacturing cement.
2/ Excludes limestone produced for use in manufacturing cement and lime.

TABLE 30. - Illinois River Basin South Plan Area 5B - Projected mineral production and employment (thousand short tons, except as noted, and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Coal | 18,900 | 2,800 | 25,500 | 2,900 | 30,000 | 2,900 | 26,700 | 2,500 | 1,514,500 |
| Petroleum | 1/ 1 | 100 | 1/ 1 | 100 | 1/ .5 | 50 | 1/ .5 | 50 | 50 |
| Sand and gravel | 20,001 | 868 | 28,765 | 1,024 | 60,110 | 1,565 | 112,962 | 2,329 | 3,039,290 |
| Crushed stone | 15,861 | 923 | 23,640 | 1,129 | 50,634 | 1,688 | 88,075 | 2,138 | 2,453,320 |
| Dimension stone | (2/) | 2 | (2/) | 2 | (2/) | 3 | 1 | 3 | 42 |
| TOTAL . . . | X X X | 4,693 | X X X | 5,148 | X X X | 6,206 | X X X | 7,020 | X X X X X X |

1/ Million barrels.
2/ Less than 1,000 short tons.

Future new water requirements in Plan Area 5B are projected to increase more than sixfold by 2020 to 26,799 million gallons annually, sand and gravel taking about 90 percent of the total 2020 new water, table 31. Almost all of the 2020 new water will be discharged. Water requirements for the petroleum industry will decrease as oil production declines. The principal sources of water will probably continue to be lakes.

Land requirements for 1960 in Plan Area 5B for all minerals was 2,075 acres, coal operations taking 86 percent. This acreage does not include the insignificant areas used by the petroleum and dimension stone industries. Through 1964, the Bureau of Mines 1964 strip mine survey indicates that about 90,000 acres of land ~~have~~ been disturbed by all mining operations, with about 57,000 acres reclaimed and restored to other uses.

Future land requirements in Plan Area 5B are projected to increase more than twofold by 2020 to 5,720 acres annually, table 32, coal operations using 53 percent of the total 2020 area, and will require a cumulative area of 255,240 acres for the 1960-2020 projection period. An area of 173,270 acres from the cumulative total may be reclaimed, all from coal mining operations.

a. <u>Sand and Gravel</u>. Sand and gravel production for 1960 in Plan Area 5B was 12,272,507 tons with a value of $18,232,322, ranking second in and representing about 15 percent of the plan area's total mineral value.

TABLE 31. - Illinois River Basin South Plan Area 5B - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recircu-lated | Consumed | Intake | Discharged | Recircu-lated | Consumed |
| Coal | 1,554 | 1,480 | 6,053 | 74 | 1,985 | 1,890 | 7,807 | 95 |
| Sand and gravel | 2,559 | 2,509 | 5,828 | 50 | 4,040 | 3,960 | 9,200 | 80 |
| Crushed stone | 28 | 19 | - | 9 | 48 | 32 | - | 16 |
| TOTAL . . . . | 4,141 | 4,008 | 11,881 | 133 | 6,073 | 5,882 | 17,007 | 191 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recircu-lated | Consumed | Intake | Discharged | Recircu-lated | Consumed |
| Coal | 2,678 | 2,550 | 10,640 | 128 | 3,161 | 3,010 | 12,811 | 151 |
| Sand and gravel | 5,869 | 5,753 | 13,364 | 116 | 12,385 | 12,140 | 28,204 | 245 |
| Crushed stone | 71 | 47 | - | 24 | 152 | 101 | - | 51 |
| TOTAL . . . . | 8,618 | 8,350 | 24,004 | 268 | 15,698 | 15,251 | 41,014 | 447 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recircu-lated | Consumed |
| Coal | 2,804 | 2,670 | 11,592 | 134 |
| Sand and gravel | 23,731 | 23,261 | 54,041 | 470 |
| Crushed stone | 264 | 176 | - | 88 |
| TOTAL . . . . | 26,799 | 26,107 | 65,633 | 692 |

TABLE 32. - Illinois River Basin South Plan Area 5B - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Coal | 1,783 | 2,281 | 3,097 | 3,752 | 3,021 | 183,430 | 173,270 |
| Petroleum | (1/) | (1/) | (1/) | (1/) | (1/) | (1/) | (2/) |
| Sand and gravel | 242 | 382 | 549 | 1,148 | 2,159 | 56,815 | (2/) |
| Crushed stone | 50 | 97 | 145 | 310 | 540 | 14,995 | (2/) |
| Dimension stone | (1/) | (1/) | (1/) | (1/) | (1/) | (1/) | (2/) |
| TOTAL . . . . | 2,075 | 2,760 | 3,791 | 5,210 | 5,720 | 255,240 | 173,270 |

1/ Insignificant usage with respect to the plan area's total land use.
2/ No estimate ~~have~~ has been made.

Future production of sand and gravel in the plan area is projected to increase about ninefold by 2020 to 112 million tons annually, and will require a cumulative total of 3,039 million tons for the 1960-2020 projection period. Reserves of sand and gravel are more than adequate to meet the projected demands several times over, and the magnitude of these reserves have been examined only to the extent that they are adequate for these demands. Most of the plan area is covered with glacial drift containing large amounts of sand and gravel.

New water requirements for 1960 in Plan Area 5B for sand and gravel were 2,559 million gallons, 62 percent of the plan area's total water needs, and nearly all of this water was discharged. In addition, 5,828 million gallons were recirculated to meet processing requirements.

Future new water requirements for sand and gravel are projected to increase more than ninefold by 2020 to 23,731 million gallons annually, about 90 percent of the plan area's total 2020 new water needs, and nearly all of this water will be discharged. In addition, 54,041 million gallons will be recirculated to meet processing requirements.

Land requirements for 1960 in Plan Area 5B for sand and gravel were 242 acres, 12 percent of the plan area's total land needs. Future land requirements are projected to increase about ninefold by 2020 to 2,159 acres annually, about 38 percent of the plan area's 2020 total land needs, and will require a cumulative area of 56,815 acres for the 1960-2020 projection period. Possible land reclamation was not estimated.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 5B was 8,390,234 tons with a value of $11,425,276, ranking third in and representing about 9 percent of the plan area's total mineral value.

Future crushed stone production in Plan Area 5B is projected to increase more than tenfold by 2020 to 88 million tons annually and will require a cumulative total of 2,453 million tons for the 1960-2020 projection period. Reserves of crushed stone in the plan area are more than adequate to meet the demands several times over.

New water requirements for 1960 in Plan Area 5B for crushed stone were 28 million gallons, less than 1 percent of the plan area's total new water needs. This volume is relatively insignificant.

Future water requirements are projected to increase about ninefold by 2020 to 264 million gallons annually, a volume insignificant compared ~~to~~ with the plan area's total 2020 new water needs.

Land requirements for 1960 in Plan Area 5B for crushed stone were 50 acres, 2 percent of the plan area's total land needs. Future land requirements are projected to increase more than tenfold by 2020 to 540 acres annually, less than one-tenth the plan area's total 2020 land needs and will require a cumulative area of 14,995 acres for the 1960-2020 projection period. No estimates were made of possible reclaimed acreage.

c. Bituminous Coal. Bituminous coal production for 1960 in Plan Area 5B was 14,102,642 tons with a value of $56,806,769, ranking first in and representing 47 percent of the plan area's total mineral value.

Future coal production in Plan Area 5B is projected to increase nearly twofold by 2020 to 26 million tons after reaching a high point of 30 million tons in 2000, and will require a cumulative total of 1,514 million tons for the 1960-2020 projection period. Reserves of coal in the plan area are estimated to be 46,137 million tons, more than adequate many times over to meet the projected demands.

New water requirements for 1960 in Plan Area 5B for coal were 1,554 million gallons, 38 percent of the plan area's total new water needs, and nearly all of this was discharged. In addition, 6,053 million gallons were recirculated to meet processing requirements. Future water requirements for coal are projected to increase nearly twofold by 2020 to 2,084 million gallons annually, about 10 percent of the plan area's total 2020 new water needs. The new water needs for coal are expected to increase proportional to production because coal washing (or beneficiation) is now practiced throughout the plan area. No expected changes are anticipated that would radically affect the water ratios.

Land requirements for 1960 in Plan Area 5B for coal operations were 1,783 acres, 86 percent of the plan area's total land needs. Through 1964 in the plan area, about 77,000 acres ~~have~~ been disturbed by coal mining, and about 49,000 acres ~~have~~ been reclaimed. Future land requirements for coal are projected to increase with production nearly twofold by 2020 to 3,021 acres annually, about one-half of the plan area's total 2020 land needs, and will require a cumulative total area of 183,430 acres for the 1960-2020 projection period, with 173,270 acres to be reclaimed for other uses. After the year 2000, land requirements will decrease ~~due~~ to an anticipated decline in production, as the high point in production is projected to take place in 2000 with 30 million tons annually.

d. <u>Petroleum</u>. Petroleum production for 1960 in Plan Area 5B was 2,164,000 barrels of crude oil with a value of $6,405,224, ranking fourth in and representing about 5 percent of the plan area's total mineral value.

Future petroleum production in Plan Area 5B is projected to decrease one-half by 1970 to ~~one~~ 1 million barrels annually until nearly 2000, then decline thereafter, and will require a cumulative volume of 50 million barrels for the 1960-2020 projection period. Reserves of petroleum, pro-rated on the basis of crude oil production, were estimated at 17 million barrels of crude, with minor amounts of natural gas and natural gas liquids. Even though petroleum reserves are indicated not to be adequate, the probability of additional discoveries, along with stripper production from present oil pools, may satisfy most of the projected demands through 2020.

New water, potable and saline, requirements for 1960 in Plan Area 5B for petroleum were about 59 million gallons. Secondary (waterflood) recovery projects used 41 million gallons of water, mostly saline, and drilling operations used nearly 18 million gallons of potable water. Future new water requirements for petroleum are projected to decline slowly until about 1970 when, after this date, water requirements will be about ~~one~~ 1 million gallons annually, and most of this water will be used in secondary recovery projects.

e. Clay and Shale. The clay and shale industry accounted for 3.1 percent of the total mineral value in the plan area. Water and land use has not been determined for the clay and shale industry. Its requirements are insignificant.

f. Limestone and Limestone Products. Limestone and its products accounted for 20.7 percent of the total mineral value in the plan area. Water and land use has not been determined for these minerals.

21. PLAN AREA 6 - KASKASKIA RIVER BASIN

General location - Southern Illinois, (figure 12).

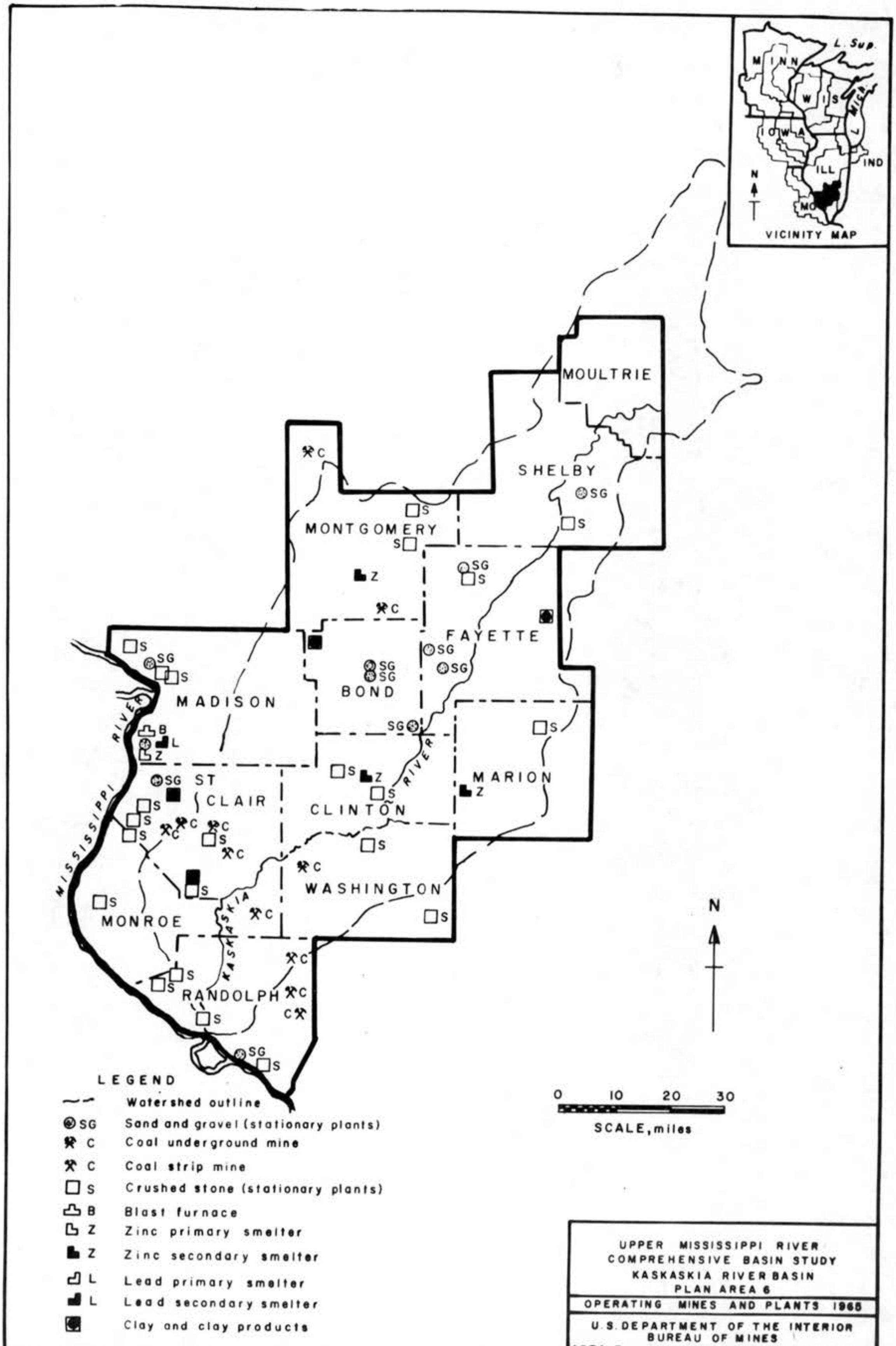
Area - 12 counties, 6,942 square miles, 6.4 percent urbanized.

Population - 713,929 total, 62.6 percent urban.

Plan Area 6 lies in the Kaskaskia River watershed and extends in a northeasterly direction from the Mississippi River.

Mineral production for 1960 in the Kaskaskia River Basin, Plan Area 6, was valued at $119,182,216, table 33, ranking third in and representing 15 percent of the Basin's total mineral value. Within the plan area, petroleum was by far the most important commodity, representing about 64 percent of the plan area's total mineral value; coal, about 30 percent, and crushed stone, nearly 6 percent.

Future mineral production in Plan Area 6 for all commodities, except petroleum, is projected to increase fourfold to sevenfold by 2020, table 34. Petroleum will decline sharply after 1970, coal will decline slightly after 2000, and the decline in coal will probably be reflected by increased use of atomic power for electric power generation. Reserves of all commodities, except petroleum, are more than adequate to meet the projected demands. Figure 12 shows the locations of mine and permanent plants operating in the plan area in 1965.


VICINITY MAP
L. Sup.
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RANDOLPH
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KASKASKIA RIVER
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0 10 20 30
SCALE, miles
LEGEND
Watershed outline
SG Sand and gravel (stationary plants)
C Coal underground mine
C Coal strip mine
S Crushed stone (stationary plants)
B Blast furnace
Z Zinc primary smelter
Z Zinc secondary smelter
L Lead primary smelter
L Lead secondary smelter
Clay and clay products
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
KASKASKIA RIVER BASIN
PLAN AREA 6
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 33. - Kaskaskia River Basin, mineral production in Plan Area 6, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale........................short tons.. | 128,243 | $212,486 |
| Coal (bituminous)............................do.... | 9,257,306 | 35,313,112 |
| Petroleum..............thousand 42-gallon barrels.. | 25,573 | 75,700,895 |
| Sand and gravel........................short tons.. | 980,625 | 918,735 |
| Stone (crushed and broken)...................do.... | 4,639,975 | 7,036,872 |
| Stone (dimension)............................do.... | 27 | 116 |
| Total.......................................... | --------- | $119,182,216 |

TABLE 34. - Kaskaskia River Basin Plan Area 6 - Projected mineral production and employment (thousand short tons, except as noted, and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Coal | 12,300 | 2,300 | 16,300 | 2,300 | 19,100 | 2,000 | 17,200 | 1,600 | 969,000 |
| Petroleum | 1/ 15 | 965 | 1/ 3 | 250 | 1/ 1.5 | 125 | 1/ 1.5 | 125 | 1/ 300.5 |
| Sand and gravel | 1,392 | 72 | 1,875 | 80 | 3,400 | 106 | 5,091 | 126 | 166,529 |
| Crushed stone | 7,905 | 485 | 11,740 | 589 | 21,633 | 762 | 32,284 | 828 | 1,034,339 |
| Dimension stone | (2/) | 1 | (2/) | 1 | (2/) | 1 | (2/) | 1 | 5 |
| TOTAL . . . | X X X | 3,823 | X X X | 3,220 | X X X | 2,994 | X X X | 2,680 | X X X X X |

1/ Million barrels.
2/ Less than 1,000 short tons.

New water requirements for 1960, exclusive of that used in petroleum production, in Plan Area 6, were 516 million gallons, most of which were discharged. In addition, 4,225 million gallons ~~were~~ recirculated to meet processing requirements. The petroleum industry required an additional 2,975 million gallons, both potable and saline, in its operations. The principal sources of water in descending order of importance are: ground, or subsurface water, water that is pumped in conjunction with mineral extraction--especially oil pumping that produces saline water, lakes, and streams.

Future water requirements for all commodities, except petroleum, are projected to increase more than twofold by 2020 to 1,330 million gallons annually (table 35), with sand and gravel and coal taking almost all of them, and most of the water will be discharged. In addition, 8,431 million gallons will be recirculated to meet processing requirements. In the petroleum industry, new water requirements will decrease as oil production declines. The principal sources of water will probably be lakes, ground or subsurface water, and streams.

Land requirements for 1960 in Plan Area 6 for all mineral commodities, exclusive of the petroleum and dimension stone industries, were 620 acres, coal taking 90 percent. Through 1964, as shown by the Bureau of Mines strip mine survey, 16,000 acres of land have been disturbed by mining operations, and about 10,000 acres have been reclaimed for other purposes.

TABLE 35. - Kaskaskia River Basin Plan Area 6 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | 418 | 228 | 4,142 | 190 | 541 | 295 | 5,417 | 246 |
| Sand and gravel | 89 | 88 | 83 | 1 | 134 | 132 | 124 | 2 |
| Crushed stone | 9 | 9 | - | - | 16 | 16 | - | - |
| TOTAL . . . . | 516 | 325 | 4,225 | 191 | 691 | 443 | 5,541 | 248 |



| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | 717 | 391 | 7,250 | 326 | 840 | 458 | 8,666 | 382 |
| Sand and gravel | 182 | 180 | 169 | 2 | 333 | 330 | 309 | 3 |
| Crushed stone | 23 | 23 | - | - | 43 | 43 | - | - |
| TOTAL . . . . | 922 | 594 | 7,419 | 328 | 1,216 | 831 | 8,975 | 385 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Coal | 757 | 413 | 7,960 | 344 |
| Sand and gravel | 508 | 503 | 471 | 5 |
| Crushed stone | 65 | 65 | - | - |
| TOTAL . . . . | 1,330 | 981 | 8,431 | 349 |

Future land requirements in Plan Area 6 are projected to increase more than twofold by 2020 to 1,471 acres annually (table 36), and will require a cumulative area of 83,310 acres for the 1960-2020 projection period, with 65,988 acres of the latter to be reclaimed for other uses.

a. Sand and Gravel. Sand and gravel production for 1960 in Plan Area 6 was 980,625 tons with a value of $918,735, ranking fourth in and representing less than 1 percent of the plan area's total mineral value.

Future sand and gravel production in Plan Area 6 is projected to increase about fivefold by 2020 to 5 million tons annually, and will require a cumulative total of 166 million tons for the 1960-2020 projection period. Reserve deposits of sand and gravel in the plan area are more than adequate many times over to meet the projected demands, and the quantity of the deposits were examined only to the extent that the tonnages would meet the projected needs.

New water requirements for 1960 in Plan Area 6 for sand and gravel were 89 million gallons, less than one-fifth the plan area's total new water needs, and almost all of this was discharged. In addition, 83 million gallons ~~were~~ recirculated to meet processing needs. Future new water requirements are projected to increase about fivefold by 2020 to 508 million gallons annually, less than one-third of the plan area's 2020 total water needs. Almost all of this water will be discharged.

Land requirements for 1960 in Plan Area 6 for sand and gravel were 19 acres, 3 percent of the plan area's total land needs. Future land requirements are projected to increase about fivefold by 2020 to 96 acres annually, and will require a cumulative area of 3,165 acres for the

TABLE 36. - Kaskaskia River Basin Plan Area 6 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Coal | 554 | 881 | 1,285 | 1,413 | 1,046 | 69,575 | 65,988 |
| Petroleum | (1/) | (1/) | (1/) | (1/) | (1/) | (1/) | - |
| Sand and gravel | 19 | 27 | 36 | 65 | 96 | 3,165 | (2/) |
| Crushed stone | 47 | 82 | 119 | 222 | 329 | 10,570 | (2/) |
| Dimension stone | (3/) | (3/) | (3/) | (3/) | (3/) | - | - |
| TOTAL . . . . | 620 | 990 | 1,440 | 1,700 | 1,471 | 83,310 | 65,988 |

1/ Insignificant land use.
2/ No estimates ~~were~~ made.
3/ Less than ~~two~~ 2 acres per year.

1960-2020 projection period. Possible reclaimed acreage was not estimated.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 6 was 4,639,975 tons with a value of $7,036,872, ranking third in and representing about 6 percent of the plan area's total mineral value.

Future crushed stone production in Plan Area 6 is projected to increase more than sixfold by 2020 to 32 million tons annually, and will require a cumulative total of 1,034 million tons for the 1960-2020 projection period. Reserves of stone for crushed stone and stone products in the plan area are more than adequate by many times to meet the projected demands.

New water requirements for 1960 in Plan Area 6 for crushed stone were 9 million gallons, insignificant compared to the plan area's total new water needs; nearly all of this water was discharged.

Future new water requirements are projected to increase about sevenfold by 2020 to 65 million gallons annually, still insignificant compared to the plan area's total 2020 new water needs; all of the 2020 water will be discharged.

Land requirements for 1960 in Plan Area 6 for crushed stone operations were 47 acres, less than 8 percent of the plan area's total land needs. Future land requirements are projected to increase about sevenfold by 2020 to 329 acres annually, 22 percent of the plan area's total 2020 land needs, and will require a cumulative area of 10,570 acres for the 1960-2020 projection period. Possible reclaimed acreage was not estimated.

c. Petroleum. Petroleum production for 1960 in Plan Area 6 was 25,573,000 barrels of crude oil with a value of $75,700,895, ranking first in and representing about 64 percent of the plan area's total mineral value.

Future petroleum production in Plan Area 6 is projected to decline rapidly from 15 million barrels annually in 1960 to 3 million barrels annually by 1980, thereafter dwindling steadily to a minimal production. Reserves of petroleum estimated at the beginning of the projection period were 186 million barrels, estimated on a pro-rated basis of crude oil production, with minor amounts of natural gas and natural gas liquids, and of course, will be inadequate to sustain present rates of production. Even though reserves of petroleum are indicated to be inadequate, it is possible that additional future oil discoveries, along with stripper production from present oil pools, may satisfy some of the projected demands through 2020.

Water requirements for 1960 in Plan Area 6 for petroleum were the greatest for any mineral commodity in the plan area and amounted to 2,974 million gallons of both potable and saline waters.

Future water requirements in Plan Area 6 are projected to decrease as petroleum production declines. Between 1970-1980 and thereafter, only a fraction of the 1960, 2,974 million gallons of water will be required annually, and most of the water probably will be used in secondary oil recovery projects.

Land requirements for petroleum in Plan Area 6 are considered insignificant. Future land requirements will also be insignificant;

large areas of land are not required and, as wells are abandoned, the areas are reclaimed and restored to their former uses.

d. Coal. Coal production for 1960 in Plan Area 6 was 9,257,306 tons with a value of $35,313,112, ranking second in and representing nearly 30 percent of the plan area's total mineral value.

Future coal production in Plan Area 6 is projected to increase about twofold by 2000 to 19 million tons annually, then decline slightly by 2020 to 17 million tons annually, and will require a cumulative total of 969 million tons for the 1960-2020 projection period. Reserves of coal are estimated to be 29,687 million tons, more than thirtyfold the projected cumulative production, and therefore, more than adequate to meet the projected demands.

New water requirements for 1960 in Plan Area 6 for coal were 418 million gallons, more than 80 percent of the plan area's total new water needs, and about half of this water was discharged. In addition, 4,142 million gallons were recirculated to meet processing requirements.

Future water requirements for 1960 are projected to increase nearly twofold by 2020 to 757 million gallons annually. In addition, 7,960 million gallons of water will be recirculated in 2020 to meet processing requirements. Coal washing or beneficiation is practiced throughout the plan area, and no anticipated changes are foreseen that would radically affect the water ratio. Coal is the major user of water in the plan area taking about one-half of the total.

Land requirements for 1960 in Plan Area 6 for coal were 554 acres, 89 percent of the plan area's total land needs. Future land requirements are projected to increase nearly threefold by 2020 to 1,413 acres annually, then decrease by 2020 to 1,046 acres annually, and will require a cumulative area of 69,575 acres, most of which may be reclaimed, for the 1960-2020 projection period.

e. Miscellaneous. Miscellaneous clay, shale, and dimension stone accounted for 0.2 percent of the $119,182,216.

Due to the confidential status of the miscellaneous minerals, water and land use were not estimated. However, the amount of water and land used is considered to be insignificant.

## 22. PLAN AREA 7 - BIG MUDDY RIVER BASIN

General location - Southern Illinois, (figure 13).

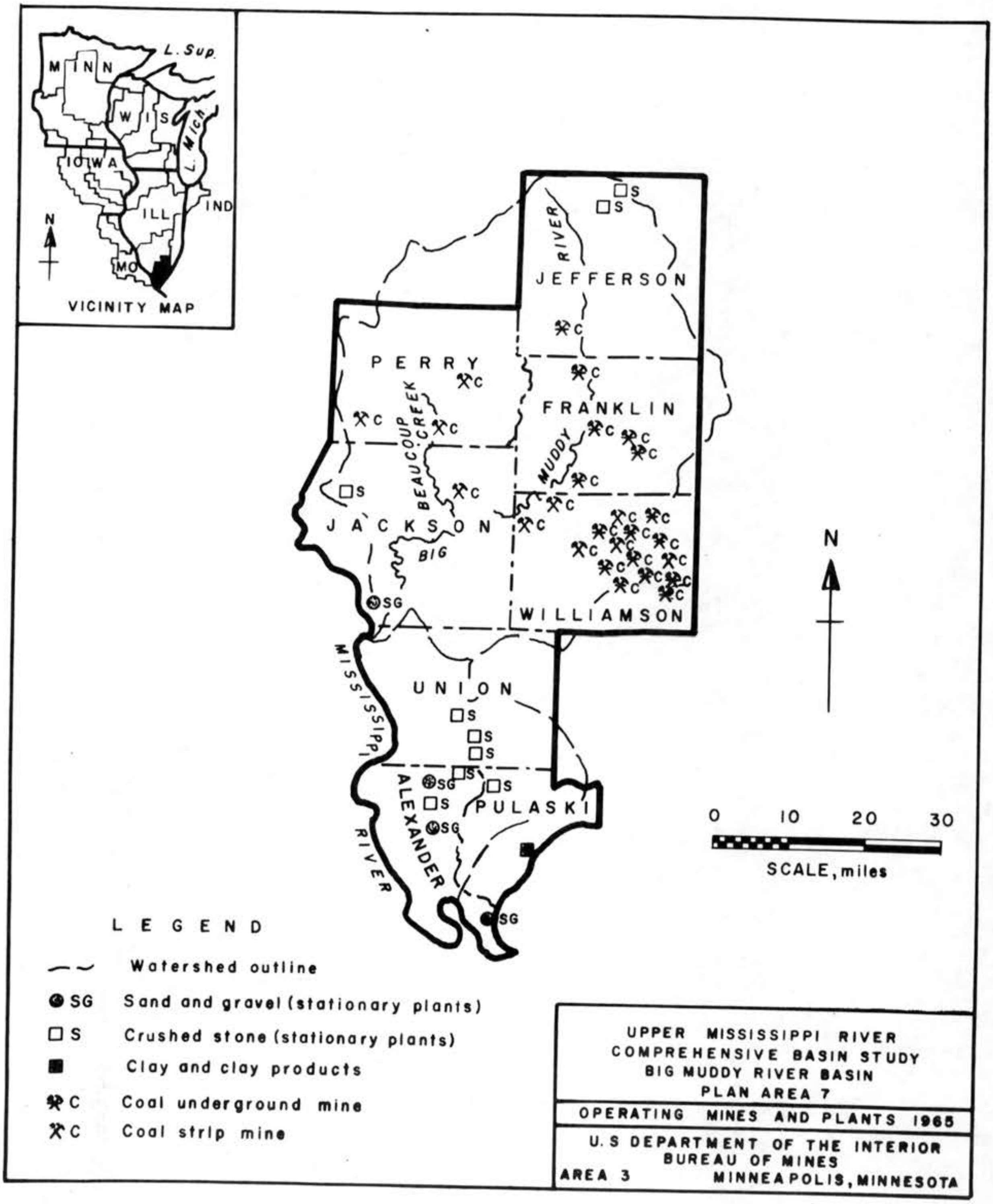
Area - 8 counties, 3,323 square miles, 5.4 percent urbanized.

Population - 223,244 total, 48.5 percent urban.

Plan Area 7 lies in the Big Muddy River watershed. It extends in a northeasterly direction along the southern edge of Illinois.

Mineral production in the Big Muddy River Basin, Plan Area 7, for 1960 was valued at $85,861,834, representing 11 percent of and ranking fifth in the Basin's total mineral production value, (table 37). Within the plan area, coal production value ranked first with 81 percent of the total, petroleum second with about 16 percent, and crushed stone third with nearly 3 percent.

Projected mineral production in the plan area is expected to increase through 2020 except for petroleum, (table 38). Petroleum will decline sharply after 1970 and coal will decline slightly after 2020.



VICINITY MAP
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ILL
MO
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L. Sup.
L. Mich.
N
JEFFERSON
PERRY
FRANKLIN
JACKSON
WILLIAMSON
UNION
ALEXANDER
PULASKI
RIVER
BEAUCOUP CREEK
MUDDY
BIG
MISSISSIPPI RIVER
0 10 20 30
SCALE, miles
LEGEND
Watershed outline
SG Sand and gravel (stationary plants)
S Crushed stone (stationary plants)
Clay and clay products
C Coal underground mine
C Coal strip mine
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
BIG MUDDY RIVER BASIN
PLAN AREA 7
OPERATING MINES AND PLANTS 1965
U. S DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3
MINNEAPOLIS, MINNESOTA

TABLE 37. - Big Muddy River Basin, mineral production in Plan Area 7, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale........................short tons.. | 10,247 | $148,581 |
| Coal (bituminous)............................do.... | 17,491,843 | 69,828,958 |
| Petroleum..............thousand 42-gallon barrels.. | 4,485 | 13,275,152 |
| Sand and gravel........................short tons.. | 320,577 | 203,371 |
| Stone (crushed and broken)...................do.... | 1,458,127 | 2,302,457 |
| Stone (dimension)............................do.... | 2,564 | 103,315 |
| Total............................................ | ---------- | 1/$85,861,834 |

1/ Incomplete total. Excludes the value of tripoli to avoid disclosing individual company confidential data.

TABLE 38. - Big Muddy River Basin Plan Area 7 - Projected mineral production and employment (thousand short tons, except as noted, and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Coal | 22,400 | 4,000 | 29,600 | 4,000 | 34,800 | 3,500 | 31,500 | 3,000 | 1,766,000 |
| Petroleum | 1/ 2.5 | 360 | 1/1 | 100 | 1/ .5 | 50 | 1/ .5 | 50 | 1/ 77.5 |
| Sand and gravel | 455 | 24 | 613 | 26 | 1,111 | 35 | 1,663 | 41 | 54,425 |
| Crushed stone | 2,484 | 152 | 3,688 | 185 | 6,797 | 240 | 10,143 | 260 | 324,978 |
| Dimension stone | 4 | 23 | 6 | 25 | 11 | 34 | 18 | 44 | 532 |
| TOTAL . . . | X X X | 4,559 | X X X | 4,336 | X X X X | 3,859 | X X X X | 3,395 | X X X X X X |

1/ Million barrels.

Figure 13 shows the locations of mines and permanent plants operating in Plan Area 7 in 1965.

New water requirements for 1960 in Plan Area 7, exclusive of the petroleum industry, were 2,409 million gallons, discharged water was 2,304 million gallons, and consumed water was 105 million gallons. In addition, 8,488 million gallons were recirculated to meet the processing requirements. An additional 109 million gallons of water, both potable and saline, were used by petroleum production operations. The principal sources of water, listed in descending order of importance, are lakes; water pumped in conjunction with mineral production--especially oil pumping which produces saline water; streams; and ground or subsurface water.

Future new water requirements for the mineral industry are projected to increase with production and nearly double by 2020 to 4,730 million gallons annually. Table 39 shows the projected water requirements for each mineral, except petroleum. Coal will use nearly all of the water. In the petroleum industry, water needs will decrease as oil production declines. The principal sources of water will probably continue to be lakes, streams, and ground or subsurface water.

Land requirements for 1960 for the mineral industry, exclusive of the petroleum industry, were 784 acres, with coal taking almost all with 769 acres. The Bureau of Mines strip mine survey shows that 42,800 acres of land have been affected by the mineral industry through 1964 and, of this, about 24,000 acres have been reclaimed.

Projected land requirements are expected to increase nearly twofold from 784 acres in 1960 to 1,372 acres in 2020, table 40, coal

TABLE 39. - Big Muddy River Basin Plan Area 7 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | 2,314 | 2,210 | 8,456 | 104 | 2,979 | 2,845 | 10,995 | 134 |
| Sand and gravel | 95 | 94 | 32 | 1 | 142 | 140 | 47 | 2 |
| TOTAL . . . . | 2,409 | 2,304 | 8,488 | 105 | 3,121 | 2,985 | 11,042 | 136 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Coal | 3,937 | 3,759 | 14,675 | 178 | 4,629 | 4,420 | 17,600 | 209 |
| Sand and gravel | 193 | 191 | 64 | 2 | 354 | 349 | 118 | 5 |
| TOTAL . . . . | 4,130 | 3,950 | 14,739 | 180 | 4,983 | 4,769 | 17,718 | 214 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Coal | 4,190 | 4,001 | 16,251 | 189 |
| Sand and gravel | 540 | 533 | 180 | 7 |
| TOTAL . . . . | 4,730 | 4,534 | 16,431 | 196 |

TABLE 40. - Big Muddy River Basin Plan Area 7 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Coal | 769 | 1,223 | 1,640 | 1,781 | 1,278 | 89,075 | 84,095 |
| Petroleum | (1/) | (1/) | (1/) | (1/) | (1/) | (1/) | (2/) |
| Sand and gravel | 6 | 9 | 12 | 21 | 32 | 1,040 | (2/) |
| Crushed stone | 9 | 15 | 22 | 42 | 62 | 1,975 | (2/) |
| Dimension stone | (1/) | (1/) | (1/) | (1/) | (1/) | (1/) | (2/) |
| TOTAL . . . . | 784 | 1,247 | 1,674 | 1,844 | 1,372 | 92,090 | 84,095 |

1/ Insignificant with respect to plan area.
2/ No estimates ~~were~~ made ~~on reclaimed land.~~

taking about 93 percent. For the 1960-2020 period the cumulative acreage needed will be 84,095 acres, with coal taking ~~about~~ all.

a. Coal. Coal production for 1960 in Plan Area 7 was 17,491,843 tons with a value of $69,828,958, representing about 81 percent of and ranking first in the total mineral value.

Reserves of coal have been estimated ~~to be~~ at 16,713.5 million tons, a reserve of large excess quantity, as compared ~~to~~ with a cumulative projected demand of 1,766 million tons for the 1960-2020 period. The annual demand for coal over the projection period will increase slightly then decline after 2020.

New water requirements for 1960 in Plan Area 7 were 2,314 million gallons (almost all of the water used by the mineral industry in the plan area), discharged water was 2,210 million gallons, and consumed water was 104 million gallons. In addition, 8,456 million gallons of water ~~were~~ was recirculated in its processing operations.

By 2020, new water requirements for coal will nearly double to 4,190 million gallons and will increase as production increases. Coal washing or beneficiation is practiced throughout the area and uses much water and in 2020 will recirculate 16,251 million gallons of water in processing operations. No foreseeable changes are anticipated that would radically affect the water ratio.

Land requirements in 1960 were 784 acres or 98 percent of the total land used in the plan area.

By 2020, land requirements will increase with production and will nearly double in 2020, decreasing slightly thereafter as a result of declining production, table 40. Land reclamation will increase during the projection period.

b. Sand and Gravel. Sand and gravel production for 1960 in Plan Area 7 was 320,577 tons with a value of $203,371, representing 0.2 percent of and ranking fourth in total mineral value.

Projected demands of sand and gravel in 2020 will increase about fivefold to 1,660,000 tons annually with a cumulative need of 54,425,000 tons for the 1960-2020 period. Reserves are adequate to meet these demands and the deposits were examined and estimated only to this extent. Most of the plan area is covered with glacial drift which contains large amounts of sand and gravel.

New water requirements in 1960 were 25 million gallons, only 4 percent of the plan area's total water needs. Projected water needs for sand and gravel will increase nearly fourfold to 540 million gallons annually in 2020 but will be only about 11 percent of the plan area's 2020 total.

Land requirements in 1960 were only 6 acres or less than 1 percent of the plan area's total land needs. By 2020 the needs will increase about fivefold to 32 acres, but for the 1960-2020 period will require a cumulative 1,040 acres. This is only about 1 percent of the plan area's total cumulative needs.

c. Petroleum. Petroleum production for 1960 in Plan Area 7 was 4,485,000 barrels of crude with a value of $13,275,152, representing about 15 percent of and ranking second in total mineral value.

Projected petroleum production will decline because of inadequate oil reserves, and by 1980 will fall to less than one-half of the 1960 production. Petroleum reserves at the beginning of 1960, pro-rated on the basis of crude oil production, were estimated at 41.5 million barrels of crude oil with minor quantities of natural gas and natural gas liquids. Even though petroleum reserves are indicated not to be adequate, it is probable that additional discoveries along with stripper production from present oil pools may satisfy some of the projected demands through 2020.

The petroleum industry for 1960 in Plan Area 7 used an estimated 107 million gallons of water, mostly saline. The projected water needs of the future are expected to decline slowly until about 1970 when, after this date, the water needs will be about 1 million gallons annually.

Land required by the petroleum industry is considered to be insignificant and no estimates were made. The small area needed is partly dependent upon the number of active wells.

d. Crushed Stone. Crushed stone production for 1960 in Plan Area 7 was 1,458,127 tons with a value of $2,302,457, ranking third in and representing less than 3 percent of the plan area's total mineral value.

Projected crushed stone production will increase about sevenfold in 2020 to 10 million tons annually, and requirements for the 1960-2020 period will be a cumulative 324 million tons. Known stone reserves of the plan area will meet the projected demands many times over.

Water required by the stone industry is insignificant and no estimates were made. No projected estimates of future water needs were made as the stone in the plan area will be crushed and beneficiated by a dry process.

Land requirements for stone are small, though the second largest in the plan area, with 9 acres in 1960, representing about 1 percent of the total. Projected requirements are expected to increase about sevenfold to 62 acres in 2020, and for the 1960-2020 projection period will need a cumulative 1,975 acres.

e. Miscellaneous. Miscellaneous clay, shale, and dimension stone accounted for 0.3 percent of the $85,861,834.

Water and land use for miscellaneous minerals are insignificant in the plan area, due principally to the small quantities produced.

## 23. PLAN AREA 8 - MERAMEC RIVER BASIN

General location - Southeastern Missouri, figure 14.

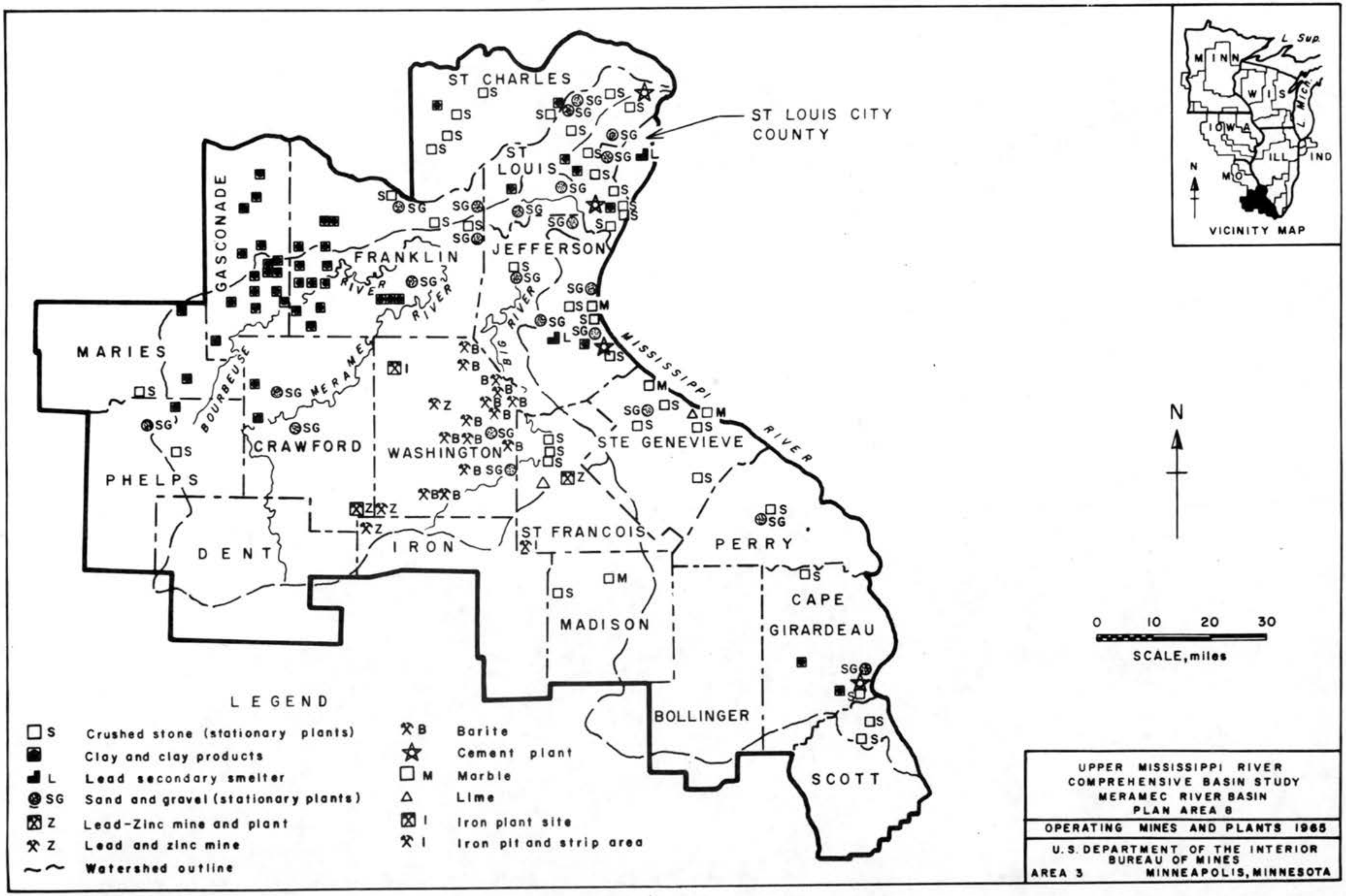
Area - 19 counties, 10,812 square miles, 4.4 percent urbanized.

Population - 1,864,398 total, 84 percent urban.

Plan Area 8 consists of all of the counties of the Meramec watershed.

Mineral production for 1960 in the Meramec River Basin, Plan Area 8, was valued at $103,133,012, ranking fourth in and representing 12 percent of the Basin's total mineral value, table 41. Within the plan area, lead ranked first with about 25 percent of the plan area's total mineral value, crushed stone second with 8 percent, and sand and gravel third with about 7 percent. Iron ore and cement remain undisclosed because of confidentiality.

The industry in the future in Plan Area 8 is expected to display continued growth, about threefold, more or less, by 2020, for all mineral commodities except barite, table 42. Reserves are adequate




UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
MERAMEC RIVER BASIN
PLAN AREA 8

OPERATING MINES AND PLANTS 1965

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 41. - Meramec River Basin, mineral production in Plan Area 8, 1960

| Mineral | 1960 | |
| --- | --- | --- |
| | Quantity | Value |
| Barite..................................short tons.. | 180,702 | $2,587,820 |
| Clays and shale 1/.........................do.... | 803,447 | 3,234,514 |
| Clay produced for use in mfg. cement.........do.... | 398,302 | 398,302 |
| Copper......................................do.... | 1,087 | 697,854 |
| Lead........................................do.... | 111,948 | 26,195,832 |
| Sand and gravel.............................do.... | 6,171,952 | 7,482,805 |
| Silver.....................................ounces.. | 15,594 | 14,113 |
| Stone (crushed and broken) 2/..........short tons.. | 5,795,033 | 8,373,751 |
| Limestone for use in mfg. cement and lime....do.... | 4,472,431 | 4,472,431 |
| Stone (dimension)...........................do.... | 9,706 | 447,684 |
| Zinc........................................do.... | 2,821 | 727,818 |
| Value of items that cannot be disclosed: Cement (portland and masonry), cobalt, iron ore, lime, and nickel.......................................... | --------- | 48,500,088 |
| Total.......................................... | --------- | $103,133,012 |

1/ Excludes clay produced for use in manufacturing cement.
2/ Excludes limestone produced for use in manufacturing cement and lime.

TABLE 42. - Meramec River Basin Plan Area 8 - Projected mineral production and employment (thousand short tons, except as noted, and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Iron ore | 1/ 5,000 | 2,000 | 1/ 10,000 | 4,000 | 1/ 12,000 | 5,000 | 1/ 14,000 | 6,000 | 1/ 581,200 |
| Lead | 400 | 3,750 | 475 | 3,900 | 650 | 4,850 | 900 | 6,000 | 33,625 |
| Zinc | 8 | (3/) | 9 | (3/) | 13 | (3/) | 18 | (3/) | 670 |
| Sand and gravel | 8,763 | 455 | 11,807 | 503 | 21,402 | 668 | 32,053 | 792 | 1,048,371 |
| Crushed stone 2/ | 17,495 | 1,073 | 25,981 | 1,302 | 47,876 | 1,687 | 71,448 | 1,833 | 2,289,069 |
| Dimension stone | 16 | 87 | 21 | 97 | 41 | 127 | 67 | 151 | 2,017 |
| Barite | 300 | 600 | 300 | 600 | | | | | |
| TOTAL . . . | X X X | 7,965 | X X X | 10,402 | X X X | 12,332 | X X X | 14,776 | X X X X |

1/ Thousand long tons.
2/ Includes limestone use in manufacturing cement and lime.
3/ Included in lead employment figure.

for all commodities, except for barite. Figure 14 shows the locations of mines and permanent plants operating in Plan Area 8 in 1965.

New water requirements for 1960 in Plan Area 8 were 8,904 million gallons, discharged water was 8,739 million gallons, and consumed water was 165 million gallons. In addition, 5,293 million gallons were recirculated to meet processing requirements.

During the 1960-2020 projection period new water requirements are expected to increase more than fourfold, table 43, sand and gravel operations accounting for more than half of the increase. By 2020, recirculated quantities are expected to be nearly 14 times as great as the 1960 recirculated water, primarily due to projected iron ore industry requirements.

Land requirements for 1960, excluding those of clay and shale, were 408 acres in Plan Area 8. Future requirements, excluding clay and shale, are projected to increase threefold by 2020 to 1,289 acres, table 44. The cumulative 1960-2020 land requirements are projected to be 38,052 acres. Surface mining operators, including those of clay and shale, disturbed 11,500 acres through 1964. Data on areas reclaimed are not available.

a. Lead and Zinc. Lead metal production for 1960 in Plan Area 8 represented 45 percent of the Nation's mine output. The tonnage was 111,948 tons with a value of $26,196,000, ranking first in and representing about 25 percent of the plan area's total mineral value. Zinc metal production for 1960 was 2,821 tons and accounted for less than 1 percent of the plan area's total mineral value. Although zinc is an important commodity within the Basin, in the Meramec plan area it is a byproduct of lead mining, as are copper, silver, cobalt, and nickel.

TABLE 43. - Meramec River Basin Plan Area 8 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Iron ore | 92 | 46 | 888 | 46 | 1,920 | 950 | 18,490 | 970 |
| Lead and zinc | 1,419 | 1,415 | 709 | 4 | 5,620 | 5,606 | 2,809 | 14 |
| Sand and gravel | 3,689 | 3,636 | 2,479 | 53 | 5,529 | 5,450 | 3,716 | 79 |
| Crushed stone 1/ | 115 | 63 | 21 | 52 | 192 | 105 | 35 | 87 |
| Barite | 3,589 | 3,579 | 1,196 | 10 | 1,296 | 1,285 | 3,888 | 11 |
| TOTAL . . . . | 8,904 | 8,739 | 5,293 | 165 | 14,557 | 13,396 | 28,938 | 1,161 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Iron ore | 3,840 | 1,900 | 36,980 | 1,940 | 4,608 | 2,280 | 44,376 | 2,328 |
| Lead and zinc | 6,666 | 6,650 | 3,333 | 16 | 9,132 | 9,109 | 4,565 | 23 |
| Sand and gravel | 7,525 | 7,418 | 5,056 | 107 | 13,775 | 13,578 | 9,256 | 197 |
| Crushed stone 1/ | 286 | 156 | 52 | 130 | 527 | 287 | 96 | 240 |
| Barite | 1,296 | 1,285 | 3,888 | 11 | - | - | - | - |
| TOTAL . . . . | 19,613 | 17,409 | 49,309 | 2,204 | 28,042 | 25,254 | 58,293 | 2,788 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Iron ore | 5,376 | 2,660 | 51,772 | 2,716 |
| Lead and zinc | 12,644 | 12,613 | 6,321 | 31 |
| Sand and gravel | 21,034 | 20,734 | 14,134 | 300 |
| Crushed stone 1/ | 786 | 429 | 143 | 357 |
| Barite | - | - | - | - |
| TOTAL . . . . | 39,840 | 36,436 | 72,370 | 3,404 |

1/ Includes limestone use in manufacturing cement and lime.

TABLE 44. - Meramec River Basin Plan Area 8 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Barite | 114 | 124 | 124 | - | - | 4,543 |
| Lead-zinc | 47 | 169 | 200 | 274 | 379 | 14,195 |
| Sand and gravel | 75 | 110 | 150 | 270 | 400 | 2,700 |
| Crushed stone 1/ | 71 | 120 | 179 | 330 | 492 | 15,757 |
| Dimension stone | 1 | 1 | 1 | 3 | 4 | 122 |
| Iron ore | 100 | 5 | 10 | 12 | 14 | 735 |
| TOTAL . . . . | 408 | 529 | 664 | 889 | 1,289 | 38,052 |

1/ Includes limestone use in manufacturing cement and lime.

Future production of lead in the plan area is projected to increase about eightfold by 2020 to 900,000 tons annually, and a cumulative total of 33,625,000 tons for the 1960-2020 projection period is required. Reserves of lead are adequate to meet the projected demands.

The recently discovered Viburnum Trend, about two-thirds of which lies outside of Plan Area 8, has a width from a few hundred feet up to two miles and a length of about 45 miles. The fifteen miles or so in Plan Area 8 cut across part of Crawford, Washington, Dent, and Iron Counties. Other lead ore areas include Indian Creek in Washington County, Fredericktown and Higdon in Madison County, and Annapolis in Iron County. These areas vary in size but are considerably smaller than the Old Lead Belt or the Viburnum Trend.

The Viburnum Trend and smaller areas such as Indian Creek and Higdon have a potential of one billion tons of ore reserves with upwards of 30 million tons of recoverable lead and considerable quantities of zinc and copper (119). Reserves in the Old Lead Belt area have been maintained at about 40 million tons of ore or about one million tons of lead metal. Undiscovered reserves in the Old Lead Belt are considered small in comparison to the potential of the Viburnum Trend.

New water requirements for 1960 in Plan Area 8 for processing lead and zinc ores were 1,419 million gallons or 16 percent of the plan area's total water needs. Nearly all of the new water was derived from abandoned mines.

Projected new water requirements will increase ninefold by 2020 to 12,644 million gallons, table 43, accounting for 32 percent of the plan area's 2020 total water needs. Abandoned mines will continue to be an important source of water in the future.

Land requirements for 1960 for lead and zinc were 47 acres or nearly 12 percent of the plan area's total area needs. This acreage was estimated as follows: lead-zinc concentrates output represents about 3 percent by weight of total ore material mined. Assuming tailings wastes averaging ~~one and one-half~~ tons per cubic yard are discarded in piles averaging 50 feet in height, land use area for 1960 is then calculated to be 47 acres. The mining companies owned and leased 66,429 acres in the vicinity of lead-zinc producing areas. The Old Lead Belt of St. Francois County, which has yielded to date over 8 million tons of lead metal, covers an area of about 50 square miles.

Future land requirements in Plan Area 8 are projected to increase eightfold by 2020 to 379 acres, representing 30 percent of the plan area's total land needs, table 44, and the cumulative acreage required over the 1960-2020 period will be 14,195 acres, or about 40 percent of the plan area's total cumulative land needs. The center of land requirements will shift from the Old Lead Belt, where production is expected to show a continued decline in the future, to the new Viburnum Trend which is relatively undeveloped. Large tracts of Federal land have been leased in this area and no land use problems are anticipated. Data ~~is~~ not available concerning total land disturbed by lead-zinc producers through 1964.

b. Sand and Gravel. Sand and gravel production, including some silica sand, for 1960 in Plan Area 8 was 6,171,952 tons with a value of $7,482,805, ranking second in and representing about 7 percent of the plan area's total mineral value.

Future sand and gravel projected requirements are expected to increase fivefold by 2020 to about 32 million tons annually, and a cumulative 1 billion tons is needed for the 1960-2020 projection period. Reserves of sand and gravel are greater than the plan area's projected demands. The Meramec River alluvial deposits are one of the most important sand and gravel sources in the area and the river's product has been in great demand in the St. Louis area where it has brought a better price than local sand and gravel from the Mississippi River. The Meramec River sand and gravel is coarser, more angular, and better suited for construction needs than the Mississippi.

New water requirements in 1960 for sand and gravel were the highest of all mineral commodities in the plan area with 3,689 million gallons, or 41 percent of the total. Discharged water was 3,636 million gallons, consumed water was 53 million gallons and, in addition, 2,479 million gallons were recirculated. Streams were the principal sources of new water supply and waters discharged back to streams were generally laden with particles of silt and clay size.

Future new water requirements in Plan Area 8 for sand and gravel will increase nearly sixfold by 2020 to an annual need of 21,034 million gallons, the largest demand by a mineral commodity in the plan area, table 43. Streams will be the source of water for this demand. Silica sand producers are expected to supplement their water requirements from wells and lakes.

Land requirements for 1960 in Plan Area 8 were 60 acres, but including silica sand operations totalled 75 acres, the latter representing about 20 percent of the total land needs. These land needs are minimal. Most operations are located on the banks of the Meramec and Mississippi Rivers from which sand and gravel is taken by draglines and pumps. A major exception to this procedure is the production of sand by underground mining in Jefferson County. About 30 operators produced sand and gravel during 1960. A total of about 500 acres of land ~~have~~ has been disturbed through 1964, but during the same period, silica sand producers disturbed only 55 acres.

Future land requirements will increase more than fivefold by 2020 to 400 acres annually, representing about one-third the plan area's total land needs in 2020, and a cumulative total of 2,700 acres will be needed for the 1960-2020 period (table 44). The cumulative needs are estimated assuming that each year 20 percent of the land occupied is abandoned and/or exhausted by both silica and sand and gravel producers. Producers probably could meet most of the future demands of sand and gravel by increasing the present size of their operating sites. However, some sites will be abandoned and new ones selected as various river deposits are exhausted and new ones developed.

c. Crushed Stone. Crushed stone production for 1960, including limestone for cement and lime, totalled 10,267,464 tons with a value of $12,846,182 or 12 percent of the value of all minerals produced in Plan Area 8. Nearly all of this was limestone, dolomite, and sandstone. Chats (waste rock from the lead, zinc, and iron mines) were used in limited amounts as road metal and for agricultural limestone.

Future crushed stone and limestone requirements are projected to increase about sevenfold by 2020 to about 71 million tons, and will require a cumulative total of more than 2 billion tons for the 1960-2020 projection period. Reserves in the plan area for these demands are several times greater and more than adequate to meet them, as strata suitable for crushed stone and limestone exist throughout much of Plan Area 8.

New water requirements for 1960 were only 1 percent of the total intake for the plan area, and though crushed stone tonnage exceeded that of sand and gravel, it required less processing water than the latter. Nearly all of the water used by crushed stone operations was taken from nearby streams. Projected water requirements are relatively small and are expected to be satisfied mostly by local streams.

Land requirements for 1960 in Plan Area 8 were 71 acres, about 17 percent of total land needs. This was estimated assuming an average quarrying depth of 60 feet. Through 1964, about 1,100 acres in the plan area had been disturbed by sandstone, limestone, and dolomite operations. St. Louis County accounted for the major portion of stone production; however, owing to zoning restrictions in St. Louis

County, adjoining Jefferson County is assuming greater importance as a producer.

Future land requirements for crushed stone are projected to increase sevenfold by 2020 to 492 acres, and will require a cumulative area of 15,757 acres over the 1960-2020 projection period, the latter acreage accounting for about 41 percent of the plan area's total accumulative area.

Rapid urban development in recent years has encroached upon various quarries and reduced St. Louis County's potential output of limestone for cement and lime and crushed stone for construction. As a result, limestone quarries in nearby Jefferson County have enjoyed increasingly greater demand from consumers in St. Louis. Future urban development will make it necessary for quarries to be located at increasingly greater distances from the urban center.

d. Dimension Stone. Production of dimension granite for 1960 in Plan Area 8 was 9,706 tons with a value of $447,684, which accounted for less than 1 percent of the plan area's total value of all minerals combined. Most of the rough monument stone produced is shipped to New England where it is in demand as a contrasting stone with the gray granites of Vermont and other New England States.

Future dimension stone requirements are projected to increase sevenfold by 2020 to 67,000 tons annually, and will require a cumulative total of 2 million tons for the 1960-2020 projection period. Reserves of this stone are considered unlimited and, of course, will satisfy all future demands.

Water requirements in quarrying, cutting, and polishing are relatively insignificant and have not been estimated either for 1960 or for future projections.

Land requirements for dimension stone for 1960 in Plan Area 8 and for future projections are relatively insignificant. For 1960, slightly more than one-half acre of land was required, assuming a quarrying depth of only 10 feet and that 50 percent of the quarried material was wasted. Only 8 acres of land have been disturbed through 1964, and for the projection period, 1960-2020, a cumulative area of 122 acres will be needed.

e. Iron Ore. Iron ore production data for 1960 in Plan Area 8 was withheld to avoid disclosing individual company confidential data. However, production in the plan area was small compared to the 1964 output of 1,116,000 long tons, which marked the commencement of pelletizing at Pea Ridge.

Future iron ore production is projected to increase by 2020 to 14 million tons annually, and will require a cumulative total of 581 million tons for the 1960-2020 projection period. Reserves are considered adequate to meet these demands. Deep-seated Precambrian age deposits in Crawford, Dent, Franklin, Iron, St. Francois, and Washington Counties may contain as much as ~~one~~ 1 billion tons of ore (119). Reserves of limonitic ores in southeastern Missouri total less than 1.4 million tons. Probabilities for the discovery of additional iron ore deposits are considered good.

In the plan area's iron ore industry, new water requirements and discharged waters for 1960 were insignificant at 1 percent, and were less than those of any other mineral producer. Most of the water was obtained from mines, and some from streams and lakes.

Future water requirements in Plan Area 8 will increase greatly from 92 million gallons in 1960 to 5,376 million gallons in 2020, the latter accounting for about 13 percent of the plan area's 2020 total. Mines, lakes, and streams will probably continue as sources of water supply.

Land requirements in 1960 for iron ore were 100 acres, about 25 percent of the plan area's total. Underground operations accounted for most of the acreage, using it for waste material dumps, tailings ponds, and new plant sites. Surface mining of iron ore disturbed only 86 acres through 1964. Data are not available estimating total land disturbed by underground mining operations through 1964.

Future annual land requirements are projected to decrease by 2020 to one-seventh the 1960 needs, and the cumulative acreage needed for the 1960-2020 projection period will be 735 acres, assuming ~~one~~ 1 acre of waste disposal per ~~one~~ 1 million tons of ore produced annually plus 150 acres for plants and offices, most of which were established or planned by 1966 and reflected in the 1960 figure. This cumulative area is insignificant compared to the plan area's total mineral land requirements. Nearly all of the projected area needed will be used by underground mining operations.

f. Barite. Barite production for 1960 in Plan Area 8 was 180,702 tons with a value of $2,587,820, or less than 3 percent of the plan area's total mineral value. This output was about two-thirds of the 300,000 tons for the 1954-1964 average.

Future production of barite in Plan Area 8 is projected to decline to and become zero by 1990 because of exhaustion of its reserves, which were estimated at 11 million tons in 1960.

Water use in the barite industry for 1960 was second only to sand and gravel requirements. New water intake was 3,589 million gallons or 40 percent of the plan area's total needs. More than half of the water used was from lakes, with the remainder from wells and streams.

Projected water needs will reach a peak in 1980 with 1,296 million gallons annually, but after this date the needs will decline sharply unless new barite reserves are discovered.

Land requirements for 1960 were 114 acres, based on an output of 2,421 tons of barite quarried to a depth of 20 feet, and accounted for about 25 percent of the plan area's total land area. Approximately 7,150 acres of land ~~have~~ had been disturbed through 1964. The cumulative land needs for barite for the 1960-1990 life period will be 4,543 acres.

g. Other Minerals. In the category of other minerals for 1960 in Plan Area 8 are clays, shale, and the Basin's entire output of silver, copper, cobalt, and nickel, with the metals derived as by-products from lead-zinc ores. Clay and shale production totaled 1,201,749 tons with a value of $3,632,816 which accounted for more than 3 percent of the total value of all minerals produced in the plan area during 1960. Silver output was 15,594 ounces and copper

1,087 tons. Silver and copper combined accounted for less than 1 percent of the total value of all minerals. Nickel and cobalt are included with cement, iron ore, and lime, all of which has a combined value of $48,500,088 or 47 percent of the 1960 total.

Water requirements for the production of clays and shale are insignificant. Water requirements of byproducts are included in those calculated for lead and zinc.

No estimates are available concerning land use requirements of clay and shale producers during 1960.

Byproduct metals, such as copper, silver, cobalt, and nickel will continue to be produced with lead and zinc; however, no estimates of reserves of these metals have been made.

Estimates of clay and shale reserves are not available. In regard to clay, however, it has been estimated (84) that an area of 516 square miles in the plan area is underlain by potential clay horizons. These are found in Crawford, Franklin, Gosconade, Maries, and Phelps Counties. Several types of clay are produced, including diaspore for superduty refractories. In recent years the quantities mined have exceeded the rate of their discovery.

Though water requirements are insignificant, land use requirements are relatively large because clay deposits average only five feet in thickness and are scattered and variable in areal extent. Through 1964, clay producers have disturbed 2,400 acres. Future producers can be expected to have a wide range of land use problems in maintaining industry growth.

Shale producers reportedly disturbed only 200 acres through 1964. However, most of the plan area's producers are located in St. Louis County where urban development can be expected to encroach upon shale quarries.

## 24. PLAN AREA 9 - SALT RIVER BASIN

General location - Northeast Missouri (figure 15).

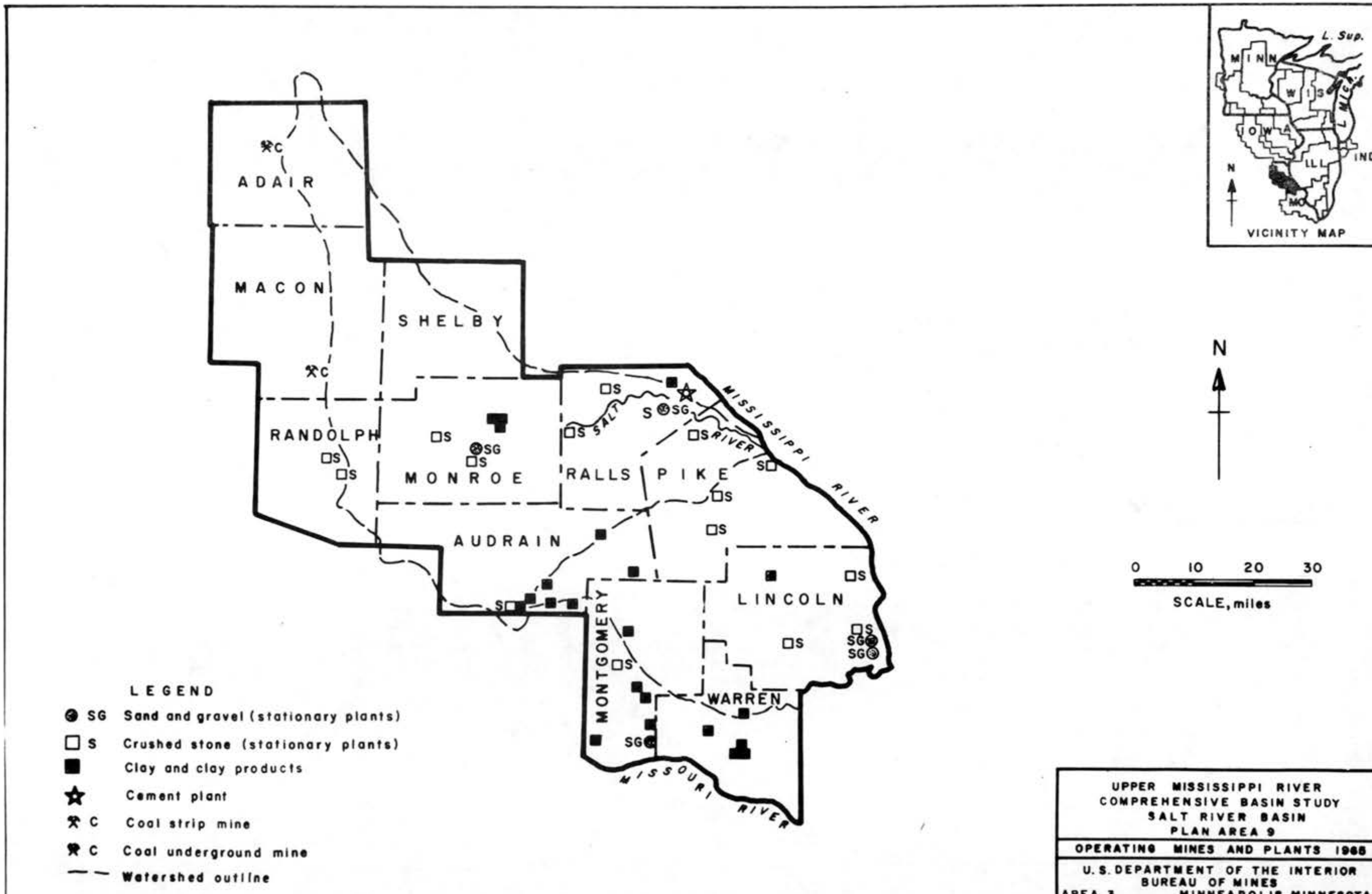
Area - 11 counties, 6,848 square miles, 2.7 percent urbanized.

Population - 163,836 total, 33 percent urban.

The plan area is in the watershed of the Salt River.

Mineral production for 1960 in the Salt River Basin, Plan Area 9, was valued at $7,061,079, ranking 13th in and representing less than one percent of the Basin's total mineral value (table 45). The value of cement and limestone used in cement was excluded from the plan area's total to avoid disclosing company confidential information. Coal ranked first in value in the plan area (about 43 percent of total), clays and shales second (about 28 percent), and crushed stone third (about 27 percent).

Future production in Plan Area 9 is projected to increase about fourfold by 2020 in all commodities except coal, which will remain unchanged (table 46). Reserves of minerals exceed projected demands, sand and gravel many times and crushed stone several times. Because of the limited coal reserves, coal mining may presumably continue for about 50 years. Figure 15 shows the locations of mines and permanent plants operating in the plan area in 1965.




UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
SALT RIVER BASIN
PLAN AREA 9

OPERATING MINES AND PLANTS 1965

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 45. - Salt River Basin, mineral production in Plan Area 9, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale........................short tons... | 559,737 | $1,949,185 |
| Coal (bituminous)..............................do.... | 657,720 | 3,032,013 |
| Sand and gravel................................do.... | 200,568 | 136,568 |
| Stone (crushed and broken) 1/..................do.... | 1,438,445 | 1,943,313 |
| Total........................................ | ---------- | 2/ $7,061,079 |

1/ Excludes limestone produced for use in manufacturing cement.
2/ Incomplete total. Excludes the values for portland and masonry cement, and the value of limestone produced for use in manufacturing cement, to avoid disclosing individual company confidential data.

TABLE 46. - Salt River Basin Plan Area 9 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Sand and gravel | 284 | 15 | 383 | 16 | 694 | 22 | 1,040 | 26 | 33,312 |
| Crushed stone | 3,106 | 191 | 4,613 | 231 | 8,500 | 300 | 12,684 | 325 | 406,395 |
| Coal | 700 | 200 | 700 | 200 | 700 | 200 | - | - | 28,000 |
| TOTAL . . . | X X X | 406 | X X X | 447 | X X X | 522 | X X X | 351 | X X X X X |

New water requirements for 1960 in Plan Area 9 were 201 million gallons, coal taking more than one-half; discharged water was 182 million gallons and consumed water was 19 million gallons. In addition, 435 million gallons ~~were~~ was recirculated to meet processing requirements. The principal water sources were streams and lakes.

Future water requirements are projected to increase more than twofold by 2020 to 516 million gallons annually, table 47, with sand and gravel taking all since coal will have been exhausted before the end of the projection period.

Land requirements for mineral production for 1960 in Plan Area 9 were 104 acres, with coal using about three-fourths. Through 1964, surface mining operations have disturbed 10,500 acres. Future land needs are projected to increase less than twofold by 2020, with crushed stone requiring about 75 percent, table 48. Cumulative land needs for the 1960-2020 projection period will be 8,726 acres with 2,280 acres estimated to be reclaimed.

a. Sand and Gravel. Sand and gravel production for 1960 in Plan Area 9 was 200,568 tons with a value of $136,568, ranking fourth in and accounting for less than 2 percent of the plan area's total mineral value. This tonnage was produced from six counties.

Future production of sand and gravel in the plan area is projected to increase fivefold by 2020 to more than 1 million tons annually, and will require a cumulative total of 33 million tons for the 1960-2020 projection period. Reserves of sand and gravel are more than adequate to meet the projected demands and total at least 800 million tons, roughly 25 times projected demand.

TABLE 47. - Salt River Basin Plan Area 9 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 91 | 89 | - | 2 | 136 | 133 | - | 3 |
| Coal | 110 | 93 | 435 | 17 | 110 | 93 | 439 | 17 |
| TOTAL . . . . | 201 | 182 | 435 | 19 | 246 | 226 | 439 | 20 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 185 | 181 | - | 4 | 338 | 331 | - | 7 |
| Coal | 110 | 93 | 444 | 17 | 110 | 93 | 453 | 17 |
| TOTAL . . . . | 295 | 274 | 444 | 21 | 448 | 424 | 453 | 24 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 516 | 506 | - | 10 |
| Coal | - | - | - | - |
| TOTAL . . . . | 516 | 506 | - | 10 |

TABLE 48. - Salt River Basin Plan Area 9 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Sand and gravel | 8 | 11 | 15 | 28 | 42 | 1,307 | (1/) |
| Crushed stone | 20 | 33 | 50 | 91 | 136 | 4,379 | (1/) |
| Coal | 76 | 76 | 76 | 76 | - | 3,040 | 2,280 |
| TOTAL . . . . | 104 | 120 | 141 | 195 | 178 | 8,726 | 2,280 |

1/ ~~Not estimated.~~

New water requirements for 1960 in Plan Area 9 for sand and gravel were 91 million gallons, about one-half of the total plan area needs. Future water needs are projected to increase more than fivefold by 2020 to 516 million gallons annually representing all of the plan area's water for mineral needs.

Land requirements for 1960 in Plan Area 9 for sand and gravel were 8 acres, about 20 percent of the plan area's total needs. Future land needs are projected to increase fivefold by 2020 to 42 acres annually, and will require a cumulative area of 1,307 acres for the 1960-2020 projection period.

b. Bituminous Coal. Coal production for 1960 in Plan Area 9, for both strip and underground mines, totalled 657,720 tons with a value of $3,032,013, ranking first in and representing about 43 percent of the plan area's total mineral value. Mining was concentrated in Adair, Ralls, and Randolph Counties in 1960, but by 1965 mining had ceased in Ralls and Randolph Counties.

Future coal production is projected to remain unchanged at about 700,000 tons annually and the limited coal reserves indicate about 50 years more of mining. Available information indicates a coal reserve of about 70 million tons, half of which may be recovered by present mining methods.

New water requirements for 1960 in Plan Area 9 for coal were 110 million gallons, representing half of the plan area's total water needs. Future projected needs will remain unchanged until 2000; thereafter water requirements will decrease with decline of coal production. These projections are based on the assumption of the need of 150 gallons of new water per ton of coal produced and that this ratio will be maintained during the projection period.

Land requirements for 1960 in Plan Area 9 for coal were 76 acres, about 75 percent of the plan area's total. Through 1964, 8,340 acres of land have been disturbed by strip mining operations. Future needs will remain unchanged through 2000, but for the 1960-2020 projection period a cumulative area of 3,040 acres will be needed, and of this, 2,280 acres may be reclaimed.

c. Crushed Stone. Crushed stone production for 1960 in Plan Area 9, excluding limestone used in cement manufacturing, was 1,438,445 tons with a value of $1,943,313, ranking third in and representing about 27 percent of the plan area's total mineral value. All ~~eleven~~ 11 counties of the plan area participated in this production.

Future crushed stone production is projected to increase nearly ninefold by 2020 to 12.6 million tons annually, and will require a cumulative production of 406 million tons for the 1960-2020 projection period. Reserves of stone are more than adequate to meet the demands and were estimated to exceed 1 billion tons, several times the demand of the projection period.

New water requirements by the stone industry were reported insignificant by the producers. Over the projection period water requirements are assumed to be minimal and will not burden the plan area water supply.

Land requirements for 1960 in Plan Area 9 for crushed stone were 20 acres, less than 20 percent of the plan area's total. Through 1965, 800 acres of land ~~have~~ had been utilized by stone quarrying. Future requirements are projected to increase nearly sevenfold by

2020 to 136 acres, more than 75 percent of the 2020 total, and will require a cumulative area of 4,379 acres over the 1960-2020 projection period or about half of the plan area's cumulative total. Of the 4,379 acres, 2,280 acres may be reclaimed.

d. Other. About 560,000 tons of clay were mined in the plan area in 1960, nearly one-fourth of the State's total output. Most of the material was fire clay for use in manufacturing refractories.

Cement, produced in Ralls County, like clay is covered in Appendix P, Part II, as a major portion of its labor force is used in manufacturing.

25. PLAN AREA 10 - FOX, WYACONDA, FABIUS RIVER BASINS

General location - Northeastern Missouri, figure 16.

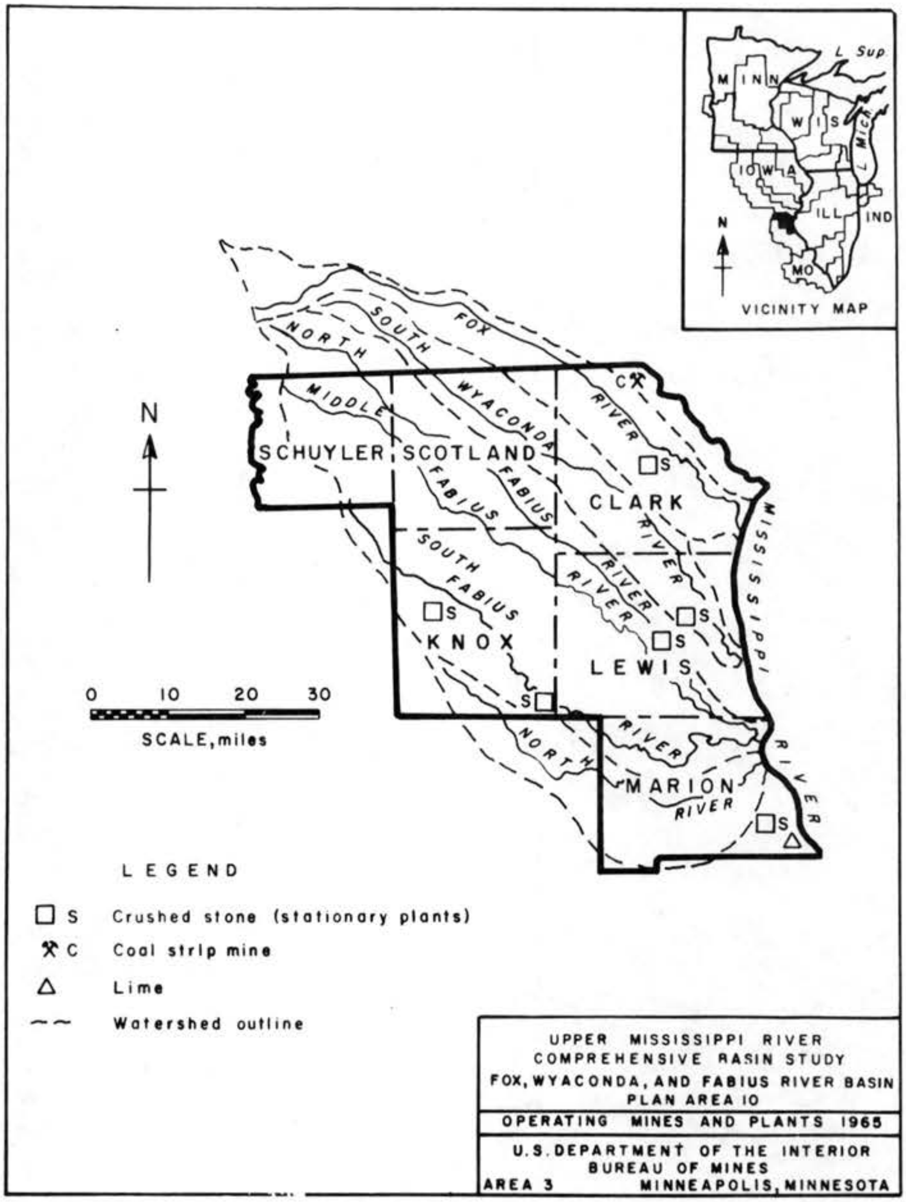
Area - 6 counties, 2,713 square miles, 2.9 percent urbanized.

Population - 67,325 total, 38 percent urban.

The watershed of the plan area includes the drainage basins of the Fox, Wyaconda, and Fabius Rivers.

Mineral production for 1960 in the Fox, Wyaconda, and Fabius River Basins, Plan Area 10, was valued at $2,441,735, less than 1 percent of the Basin's total mineral value, table 49. Within the plan area, crushed stone value ranked first with 58 percent of the plan area's total mineral value, for the combined values of coal, lime, sand and gravel, and limestone for use in lime manufacturing, about 39 percent, and for clay used in cement manufacturing, about 3 percent.

Future mineral production in the plan area is projected to increase nearly tenfold by 2020, table 50. Reserves are adequate for all



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RIVER
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RIVER
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SCALE, miles
LEGEND
S Crushed stone (stationary plants)
C Coal strip mine
Lime
Watershed outline
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
FOX, WYACONDA, AND FABIUS RIVER BASIN
PLAN AREA 10
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 49. - Fox, Wyaconda, and Fabius River Basins, mineral production in Plan Area 10, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clay produced for use in mfg. cement....short tons.. | 77,650 | $77,650 |
| Stone (crushed and broken) 1/..................do.... | 811,771 | 1,412,032 |
| Value of items that cannot be disclosed: Bituminous coal, lime, sand and gravel, and limestone for use in manufacturing lime............................ | ------- | 952,053 |
| Total............................................. | ------- | $2,441,735 |

1/ Excludes limestone produced for use in manufacturing lime.

TABLE 50. - Fox, Wyaconda, and Fabius River Basins Plan Area 10 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Sand and gravel | 725 | 38 | 977 | 42 | 1,772 | 55 | 2,653 | 66 | 86,759 |
| Crushed stone | 1,450 | 89 | 2,153 | 108 | 3,967 | 140 | 5,920 | 152 | 189,671 |
| TOTAL . . . | X X X | 127 | X X X | 150 | X X X | 195 | X X X | 218 | X X X X |

mineral commodities to meet their projected demands through 2020. Figure 16 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water requirements for 1960 in Plan Area 10 were considered insignificant and not tabulated. Future water needs, however, will increase by 2020 to 324 million gallons of new water annually, with sand and gravel using about 83 percent of the 2020 total, (table 51).

Land requirements for 1960 in Plan Area 10 were 24 acres, almost equally divided in use between sand and gravel and crushed stone. Surface operations ~~have~~ disturbed 1,128 acres through 1964; data on areas reclaimed are not available. Future needs are projected to increase more than fivefold by 2020 to 138 acres, and will require a cumulative area of 4,465 acres for the 1960-2020 projection period, table 52).

a. <u>Sand and Gravel</u>. Sand and gravel production tonnages and values for 1960 in Plan Area 10 are unavailable because of confidentiality of this commodity. Future production is projected to increase more than fourfold by 2020 to 2.6 million tons annually and a cumulative tonnage of 86.7 million tons will be needed for the 1960-2020 projection period. Reserves of sand and gravel total at least 249 million tons and are more than adequate to meet demands.

New water requirements for 1960 for sand and gravel are insignificant and no quantities are reported. However, future water needs will grow and by 2000, 177 million gallons annually will be required; by 2020 the forecast is for 265 million gallons annually. This increased water is anticipated because of more restrictive specifications for the product, requiring more washing. Enough water is

TABLE 51. - Fox, Wyaconda, and Fabius River Basins Plan Area 10 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 Intake | 1960 Discharged | 1960 Recirculated | 1960 Consumed | 1970 Intake | 1970 Discharged | 1970 Recirculated | 1970 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | - | - | - | - | - | - | - | - |
| Crushed stone | - | - | - | - | - | - | - | - |
| TOTAL . . . . | - | - | - | - | - | - | - | - |

| Commodity | 1980 Intake | 1980 Discharged | 1980 Recirculated | 1980 Consumed | 2000 Intake | 2000 Discharged | 2000 Recirculated | 2000 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | - | - | - | - | 177 | 171 | 417 | 6 |
| Crushed stone | - | - | - | - | 39 | 33 | 20 | 6 |
| TOTAL . . . . | - | - | - | - | 216 | 204 | 437 | 12 |

| Commodity | 2020 Intake | 2020 Discharged | 2020 Recirculated | 2020 Consumed |
|---|---|---|---|---|
| Sand and gravel | 265 | 257 | 625 | 8 |
| Crushed stone | 59 | 50 | 30 | 9 |
| TOTAL . . . . | 324 | 307 | 655 | 17 |

TABLE 52. - Fox, Wyaconda, and Fabius River Basins Plan Area 10 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Sand and gravel | 12 | 18 | 24 | 44 | 66 | 2,140 |
| Crushed stone | 11 | 18 | 26 | 49 | 72 | 2,325 |
| Others | 1 | | | | | |
| TOTAL . . . . | 24 | 36 | 50 | 93 | 138 | 4,465 |

expected to be available in the plan area for these needs. For these reasons, 100 gallons of new water per ton of product ~~were~~ was used in estimating annual water requirements for the year 2000 and after.

Land requirements for sand and gravel for 1960 in Plan Area 10 were 12 acres, half of the plan area's total. Past sand and gravel operations ~~have~~ had disturbed about 900 acres of land through 1964. Future requirements are projected to increase more than fivefold by 2020 to 66 acres annually, and will need a cumulative area of 2,140 acres for the 1960-2020 projection period.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 10 was 811,771 tons with a value of $1,412,032, ranking first in and representing about 58 percent of the plan area's total value. Future production is projected to increase about sevenfold by 2020 to 5.9 million tons annually and need a cumulative tonnage of 189 million tons for the 1960-2020 projection period. Reserves of stone total about 485 million tons and will be more than adequate to meet demands.

New water requirements for 1960 in Plan Area 10 for crushed stone are considered insignificant and will continue so until 2000, as determined by the Bureau of Mines 1962 water canvass of producers. However, future water needs from 2000 on may require significant quantities of water, 59 million gallons annually in 2020, owing to more restrictive specifications for finished products requiring more washing. For water estimates, 10 gallons of new water per ton of material produced ~~were~~ was assumed.

Land requirements for 1960 for crushed stone operations was 11 acres, slightly less than half of the plan area's total. Stone operations have disturbed about 200 acres through 1964. Future land needs are projected to increase nearly sevenfold to 72 acres annually and will require a cumulative area of 2,325 acres for the 1960-2020 projection period.

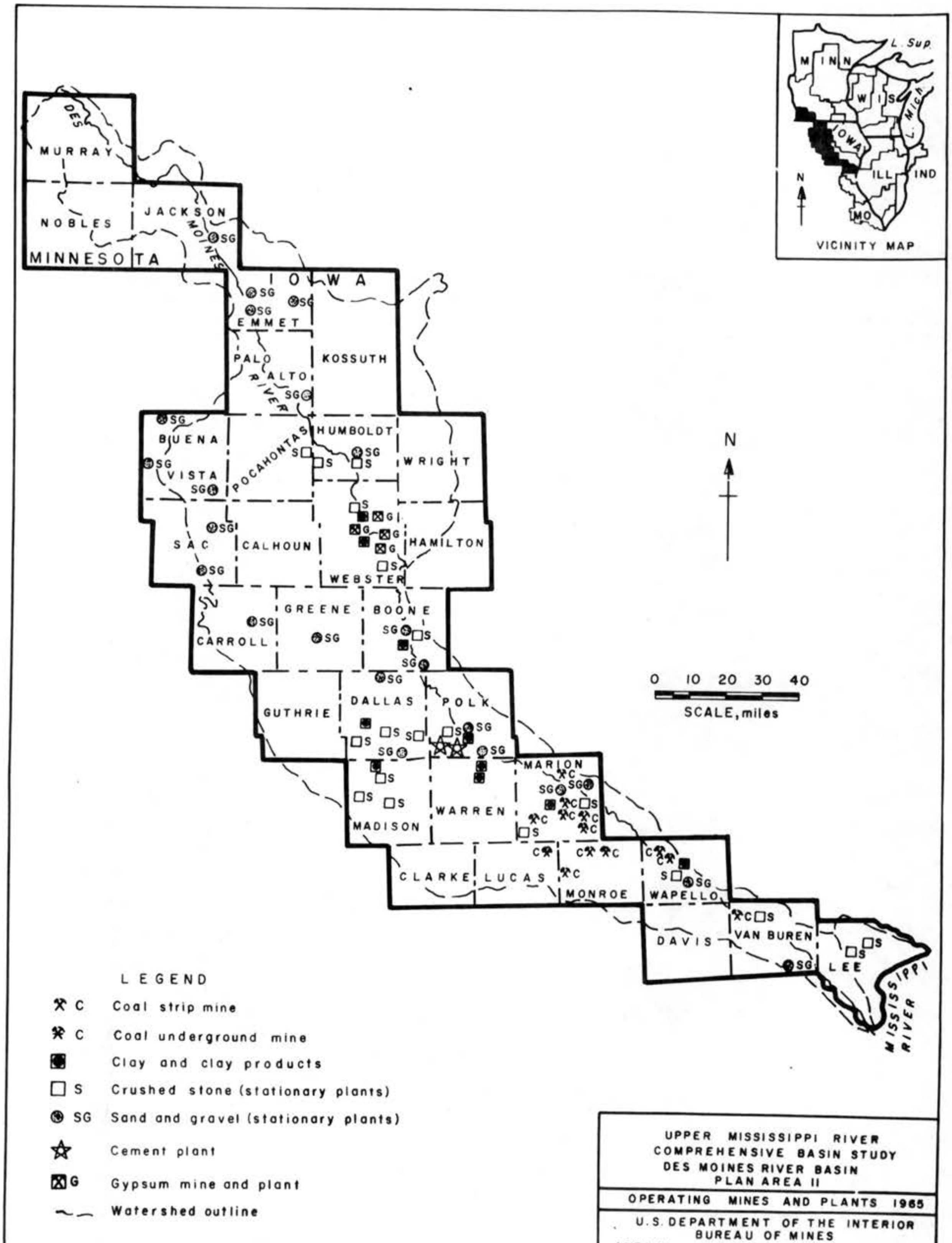
## 26. PLAN AREA 11 - DES MOINES RIVER BASIN

General location - Western Iowa and southwestern Minnesota (figure 17).
Area - 30 counties, 17,123 square miles, 4.1 percent urbanized.
Population - 845,148 total, 56 percent urban.

The plan area is predominantly within the watershed of the Des Moines River.

Mineral production for 1960 in the Des Moines River Basin, Plan Area 11, was valued at $33,488,585, ranking ninth in and representing 4 percent of the Basin's total mineral value (table 53). Within the plan area, the undisclosed commodities of cement, gypsum, and clay and limestone used in cement manufacturing, combined, ranked first with about 59 percent of the plan area's total mineral value; sand and gravel was second with 17 percent, crushed stone third with about 15 percent, and coal fourth with 8 percent of the total.

Future production of mineral commodities in Plan Area 11 are projected to increase more than fivefold by 2020, table 54, except for coal which will rise slightly until 2000, then decline thereafter. Reserves of all mineral commodities are adequate to meet 2020 projected demands. Figure 17 shows the locations of mines and permanent plants operating in the plan area in 1965.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EMMET
PALO ALTO
KOSSUTH
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
SAC
CALHOUN
WEBSTER
HAMILTON
CARROLL
GREENE
BOONE
GUTHRIE
DALLAS
POLK
MADISON
WARREN
MARION
CLARKE
LUCAS
MONROE
WAPELLO
DAVIS
VAN BUREN
LEE
MISSISSIPPI RIVER
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SCALE, miles
LEGEND
C Coal strip mine
C Coal underground mine
Clay and clay products
S Crushed stone (stationary plants)
SG Sand and gravel (stationary plants)
Cement plant
G Gypsum mine and plant
Watershed outline
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
DES MOINES RIVER BASIN
PLAN AREA II
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 53. - Des Moines River Basin, mineral production in Plan Area 11, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale 1/......................short tons.. | 280,691 | $454,701 |
| Coal (bituminous)...........................do.... | 752,007 | 2,676,065 |
| Sand and gravel.............................do.... | 6,242,451 | 5,687,161 |
| Stone (crushed and broken) 2/...............do.... | 3,742,332 | 4,985,022 |
| Value of items that cannot be disclosed: Cement (portland and masonry), gypsum, and clay and limestone produced for use in manufacturing cement..... | --------- | 19,685,636 |
| Total........................................ | --------- | $33,488,585 |

1/ Excludes clay produced for use in manufacturing cement.
2/ Excludes limestone produced for use in manufacturing cement.

TABLE 54. - Des Moines River Basin Plan Area 11 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Coal | 1,000 | 300 | 1,200 | 300 | 1,400 | 300 | 1,200 | 100 | 72,000 |
| Sand and gravel | 3,935 | 569 | 11,927 | 624 | 19,652 | 755 | 28,198 | 866 | 976,029 |
| Crushed stone | 6,924 | 461 | 9,446 | 517 | 15,755 | 603 | 23,066 | 643 | 777,508 |
| TOTAL . . . | X X X | 1,330 | X X X | 1,441 | X X X | 1,658 | X X X | 1,609 | X X X X |

New water requirements for 1960 for the plan area's mineral industries were 610 million gallons, discharged water was 589 million gallons, and consumed water was 21 million gallons. In addition, 1,392 million gallons were recirculated to meet the processing requirements.

Future new water requirements in Plan Area 11 are projected to increase about fivefold by 2020 to 3,182 million gallons annually (table 55), with sand and gravel taking nearly all.

Land requirements for 1960 in Plan Area 11 were 385 acres, with sand and gravel and coal requiring most of the acreage. Through 1964, surface operations have disturbed 21,400 acres. Data on reclaimed areas are not available. Future land requirements are projected to increase nearly fourfold by 2020 to 1,439 acres annually, and will require a cumulative area of 54,140 acres for the 1960-2020 projection period (table 56). Of the 54,140 acres, 10,520 acres may be reclaimed. Sand and gravel will be the major land user.

a. <u>Sand and Gravel</u>. Sand and gravel production for 1960 in Plan Area 11 was 6,242,451 tons with a value of $5,687,161, ranking second in and representing about 17 percent of the plan area's total mineral value.

Future production is projected to increase more than fourfold by 2020 to 28 million tons annually, and will require a cumulative total of 976 million tons for the 1960-2020 projection period. Reserves of sand and gravel total about 3.8 billion tons and are more than adequate to meet demands.

TABLE 55. - Des Moines River Basin Plan Area 11 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 581 | 564 | 1,377 | 17 | 920 | 893 | 2,180 | 27 |
| Crushed stone | 29 | 25 | 15 | 4 | 49 | 42 | 24 | 7 |
| TOTAL . . . . | 610 | 589 | 1,392 | 21 | 969 | 935 | 2,204 | 34 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 1,241 | 1,205 | 2,939 | 36 | 2,065 | 2,005 | 4,891 | 60 |
| Crushed stone | 66 | 57 | 33 | 9 | 110 | 94 | 55 | 16 |
| TOTAL . . . . | 1,307 | 1,262 | 2,972 | 45 | 2,175 | 2,099 | 4,946 | 76 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recirculated | Consumed |
| Sand and gravel | 3,021 | 2,933 | 7,156 | 88 |
| Crushed stone | 161 | 138 | 81 | 23 |
| TOTAL . . . . | 3,182 | 3,071 | 7,237 | 111 |

TABLE 56. - Des Moines River Basin Plan Area 11 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Coal | 124 | 177 | 211 | 229 | 189 | 12,025 | 10,520 |
| Sand and gravel | 181 | 260 | 346 | 571 | 819 | 28,305 | (1/) |
| Crushed stone | 58 | 80 | 110 | 184 | 269 | 9,110 | (1/) |
| Other | 22 | 37 | 48 | 94 | 162 | 4,700 | (1/) |
| TOTAL . . . . | 385 | 554 | 715 | 1,078 | 1,439 | 54,140 | 10,520 |

1/ No estimate has been made.

New water requirements for 1960 in Plan Area 11 were 581 million gallons or about 96 percent of the plan area's total needs. Discharged water was 564 million gallons and consumed was 17 million gallons. In addition, 1,377 million gallons were recirculated to meet processing requirements. Currently, about one-half of the water used by the sand and gravel industry is obtained from lakes and the other half from streams.

Future new water requirements for sand and gravel are projected to increase about fivefold by 2020 to 3,021 million gallons annually. Sources of water for operations presumably will continue to be lakes and streams as there is no present evidence to indicate otherwise.

Land requirements for 1960 in Plan Area 11 for sand and gravel were 181 acres or 47 percent of the total area required by mineral producers in Plan Area 11. Through 1964, about 9,400 acres of land have been disturbed in the plan area by sand and gravel operations. Future land needs are projected to increase more than fourfold by 2020 to 819 acres annually, and will require a cumulative area of 28,305 acres for the 1960-2020 projection period.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 11 was 3,742,332 tons with a value of $4,985,022, ranking third in and representing 15 percent of the plan area's total mineral value.

Future production is projected to increase about sixfold by 2020 to 23 million tons annually, and will require a cumulative total of 777 million tons for the 1960-2020 projection period. Since stone reserves total in excess of 937 million tons, stone demands will easily be met.

New water requirements for 1960 for crushed stone were 29 million gallons or about 5 percent of the plan area's total mineral water needs. Sources of water were 75 percent from streams and 25 percent from wells. Future requirements are projected to increase more than fivefold by 2020 to 161 million gallons annually, only about 5 percent of the plan area's 2020 total needs. Sources of water in 2020 are presumed to be the same as those of 1960, as there is no evidence indicating otherwise.

Land requirements for 1960 in Plan Area 11 for crushed stone were 58 acres, or 15 percent of the plan area's total mineral land needs. Through 1964, about 2,900 acres of land were disturbed by stone operations. Future requirements are projected to increase nearly fivefold by 2020 to 269 acres annually, and will require a cumulative area of 9,110 acres for the 1960-2020 projection period. Future reclaimed acreage was not estimated.

No problems nor conflicts are presently identifiable concerning water, land, or reserves that would obstruct fulfillment of projected demands by the stone industry.

c. Bituminous Coal. Coal production for 1960 in Plan Area 11 was 752,007 tons with a value of $2,676,065, ranking fourth in and representing 8 percent of the plan area's total mineral value.

Future coal production is projected to increase nearly twofold by 2000 to 1.4 million tons annually but will decline to 1.2 million tons annually by 2020. The cumulative tonnage for the 1960-2020 projection period will be 72 million tons. Reserves of coal, including all classes of reserves, total about 4,056 million tons, much more than adequate to meet all demands.

New water requirements for 1960 in Plan Area 11 for coal are zero, since no water was used in beneficiation, and none is estimated to be used in any future production.

Land requirements for 1960 for coal were 124 acres or 32 percent of the plan area's total mineral land needs. Through 1964, about 7,100 acres of land in the plan area ~~were~~ disturbed by coal operations. Future land requirements are projected to increase about half again by 2020 to 189 acres annually and will require a cumulative area of 12,025 acres for the 1960-2020 projection period. Of the 12,025 acres, 10,520 will be reclaimed.

d. <u>Other Minerals</u>. Approximately 69 percent of the plan area's total mineral value in 1960 was obtained from the production of clay and shale, cement, gypsum, and clay and limestone for use in manufacturing cement. No new water intake was used in the production of these commodities. Land used during the year for producing these commodities is estimated at 6 percent of total land used by all plan area mineral producers.

Reserves of gypsum, shale, and limestone produced for use in manufacturing cement are indicated to be available in sufficient quantities to meet projected demands for period 1960-2020.

Water requirements for these various operations in the plan area were judged to be minor and no projections were made.

Land requirements for these commodities for the period 1960-2020 are estimated at 4,700 acres. Collectively, the various mineral producers in the plan area, through year 1964, have used about 2,000 acres of land.

No problems are presently identifiable concerning land, water, or reserves that would restrict the capacity of these producers in meeting anticipated future demands.

## 27. PLAN AREA 12 - SKUNK RIVER BASIN

General location - Southeastern Iowa, figure 18.

Area - 8 counties, 4,308 square miles, 4.5 percent urbanized.

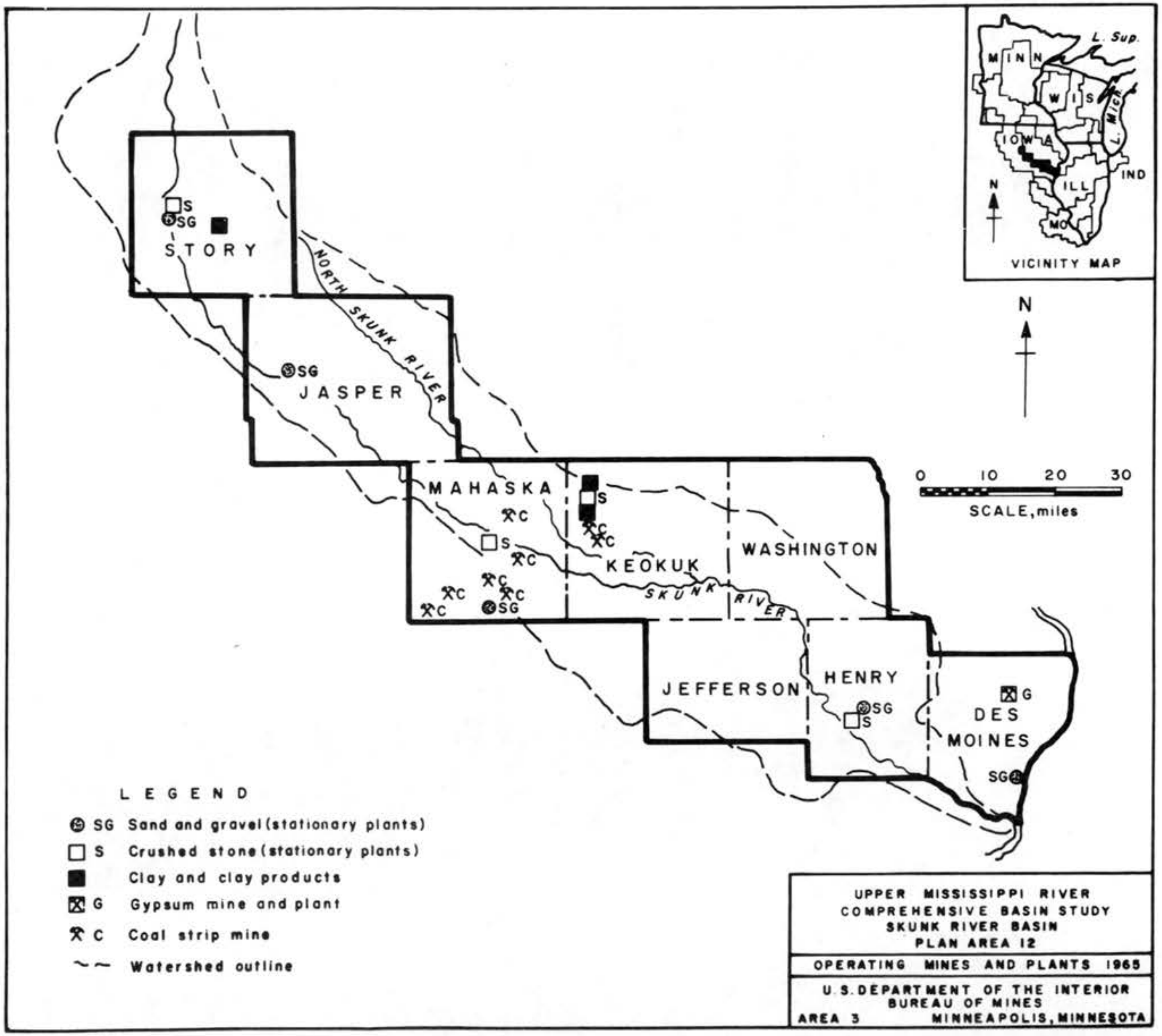
Population - 221,719 total, 51 percent urban.

The plan area is predominantly in the Skunk River watershed.

Mineral production for 1960 in the Skunk River Basin, Plan Area 12, was valued at $3,664,729, excluding the value of gypsum, ranking 15th in and representing less than 1 percent of the Basin's total mineral value, table 57. Within the plan area crushed stone ranked first (about 50 percent) in the plan area's total mineral value, sand and gravel second (about 25 percent), and coal third (about 23 percent).

Future production of mineral commodities in Plan Area 12 is projected to increase about fivefold by 2020, table 58, except for coal which will increase about threefold by 1980 and remain constant thereafter. Reserves of minerals are adequate to meet the projected demands. Figure 18 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water required for 1960 by the plan area's mineral industries was 123 million gallons, discharged water was 121 million gallons, and consumed water was 2 million gallons. In addition, 685 million gallons of water ~~were~~ was recirculated to meet processing requirements.



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SG Sand and gravel (stationary plants)
S Crushed stone (stationary plants)
Clay and clay products
G Gypsum mine and plant
C Coal strip mine
Watershed outline
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
SKUNK RIVER BASIN
PLAN AREA 12
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 57. - Skunk River Basin, mineral production in Plan Area 12, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale........................short tons.. | 32,233 | $67,584 |
| Coal (bituminous)..........................do.... | 257,793 | 850,767 |
| Sand and gravel............................do.... | 868,614 | 908,722 |
| Stone (crushed & broken)...................do.... | 1,518,209 | 1,837,719 |
| Total........................................ | --------- | 1/$3,664,792 |

1/ Incomplete total. Excludes the value of gypsum to avoid disclosing individual company confidential data.

TABLE 58. - Skunk River Basin Plan Area 12 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Coal | 500 | 100 | 700 | 100 | 700 | 100 | 700 | (1/) | 38,000 |
| Sand and gravel | 1,216 | 78 | 1,633 | 86 | 2,713 | 104 | 3,946 | 120 | 134,911 |
| Crushed stone | 2,196 | 144 | 3,044 | 164 | 5,121 | 193 | 7,507 | 206 | 251,819 |
| TOTAL . . . | X X X | 322 | X X X | 350 | X X X | 397 | X X X | 326 | X X X X X |

1/ Less than 100.

Future new water requirements in Plan Area 12 are projected to increase sixfold by 2020 to 744 million gallons (table 59), with sand and gravel taking nearly all of the new water.

Land requirements for 1960 in Plan Area 12 for mineral production were 106 acres, with coal using more than half. Through 1964, surface operations ~~have~~ had disturbed a total of about 6,000 acres. Future land requirements are projected to increase about fourfold by 2020, to 398 acres annually (table 60), with sand and gravel the largest user, taking nearly half. The cumulative area needed over the 1960-2020 projection period will be 16,110 acres, with 6,315 acres to be reclaimed.

a. <u>Sand and Gravel</u>. Sand and gravel production for 1960 in Plan Area 12 was 868,614 tons with a value of $908,722, ranking second in and representing about 25 percent of the plan area's total mineral value.

Future production of sand and gravel is projected to increase nearly fivefold by 2020 to 3.9 million tons annually, and will require a cumulative total of about 135 million tons for the 1960-2020 projection period. Reserves of sand and gravel of 250 million tons are available and are more than adequate to meet projected demands.

New water requirements for 1960 in Plan Area 12 for sand and gravel were 123 million gallons, which was all of the water used in the plan area. Nearly all of this water was discharged but the recirculated water to meet processing needs was large, 685 million gallons. Most of the new water is obtained from wells and the remainder from lakes. Future new water requirements for sand and gravel are projected to increase more than fivefold by 2020 to 669 million gallons annually, about 90 percent of the plan area's 2020 total. There is no

TABLE 59. - Skunk River Basin Plan Area 12 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 Intake | 1960 Discharged | 1960 Recirculated | 1960 Consumed | 1970 Intake | 1970 Discharged | 1970 Recirculated | 1970 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | 123 | 121 | 685 | 2 | 198 | 194 | 1,102 | 4 |
| Crushed stone | - | - | - | - | - | - | - | - |
| TOTAL . . . . | 123 | 121 | 685 | 2 | 198 | 194 | 1,102 | 4 |



| Commodity | 1980 Intake | 1980 Discharged | 1980 Recirculated | 1980 Consumed | 2000 Intake | 2000 Discharged | 2000 Recirculated | 2000 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | 269 | 264 | 1,494 | 5 | 451 | 443 | 2,507 | 8 |
| Crushed stone | - | - | - | - | 51 | 43 | 25 | 8 |
| TOTAL . . . . | 269 | 264 | 1,494 | 5 | 502 | 486 | 2,532 | 16 |

| Commodity | 2020 Intake | 2020 Discharged | 2020 Recirculated | 2020 Consumed |
|---|---|---|---|---|
| Sand and gravel | 669 | 657 | 3,718 | 12 |
| Crushed stone | 75 | 64 | 38 | 11 |
| TOTAL . . . . | 744 | 721 | 3,756 | 23 |

TABLE 60. - Skunk River Basin Plan Area 12 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Required | Reclaimed |
| Coal | 56 | 93 | 130 | 130 | 130 | 7,060 | 6,315 |
| Sand and gravel | 30 | 49 | 65 | 108 | 158 | 5,355 | (1/) |
| Crushed stone | 20 | 32 | 45 | 75 | 110 | 3,695 | (1/) |
| TOTAL . . . . | 106 | 174 | 240 | 313 | 398 | 16,110 | 6,315 |

1/ Not estimated.

present evidence indicating what the sources of water will be through the projection years to 2020, but it would be reasonable to assume that the sources will be much the same as the current ones.

Land requirements for 1960 in Plan Area 12 for sand and gravel were 30 acres or 28 percent of the total land used by 211 plan area mineral producers. Through 1964, a total of 700 acres of land have been disturbed by the collective sand and gravel operations in the plan area. Future land needs are projected to increase about fivefold by 2020 to 158 acres, 40 percent of the plan area's total 2020 needs, and will require a cumulative area of 5,355 acres for the 1960-2020 projection period. Data was unavailable to estimate possible reclaimed acreage.

Water requirements, land use, or reserves should not restrict the sand and gravel industry from meeting the projected demands through 2020.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 12 was 1,518,209 tons with a value of $1,837,719, ranking first in and representing about 50 percent of the plan area's total mineral value.

Future production of crushed stone is projected to increase fivefold by 2020 to 7.5 million tons annually, and will require a cumulative total of 251 million tons for the 1960-2020 projection period. Reserves of stone indicated exceed 448 million tons, more than adequate to meet the plan area demands easily.

New water requirements for 1960 for crushed stone were zero and no water needs are anticipated until 2000, when future projections indicate 51 million gallons will be needed, and in 2020, 75 million gallons will be needed, with the latter about 10 percent of the plan area's total 2020 needs. The projected gallonages were estimated assuming 10 gallons of new water per ton of stone.

Land requirements for 1960 in Plan Area 12 for crushed stone were 20 acres or 18 percent of the plan area's total mineral land needs. Through 1964, past stone operations have disturbed about 1,250 acres of land. Future land requirements are projected to increase more than fivefold by 2020 to 110 acres annually, and will require a cumulative area of 3,695 acres for the 1960-2020 projection period. Future reclaimed acreage was not estimated because data was unavailable.

No problems nor conflicts are presently identifiable concerning water, land, or reserves that would obstruct fulfillment of projected demands by the stone industry.

c. <u>Bituminous Coal</u>. Coal production for 1960 in Plan Area 12 was 257,793 tons with a value of $850,767, ranking third in and representing 23 percent of the plan area's total mineral value.

Future coal production requirements in Plan Area 12 are projected to increase severalfold by 2000 to 700,000 tons annually, then hold constant through 2020. A cumulative tonnage of 38 million tons will be required for the 1960-2020 projection period. Reserves of coal, including all classes of reserves, in the plan area total about 994 million tons and are more than adequate to meet all projected demands.

New water requirements for 1960 for coal in the plan area are zero, since water is not used as the coal is not washed. Future coal production will be unwashed, thus no future new water is estimated.

Land requirements for 1960 for coal production were 56 acres, more than half of the plan area's total needs. Through 1964, coal operations in Plan Area 12 disturbed a land area of 3,755 acres. Future land needs are projected to increase more than twofold by 2020 to 130 acres annually, and will require a cumulative area of 7,060 acres, 6,315 acres of which will be reclaimed.

d. Gypsum. Production of gypsum in Des Moines County started in 1960 when the first shaft was completed 600 feet into the deposits underground.

## 28. PLAN AREA 13 - IOWA-CEDAR RIVER BASIN

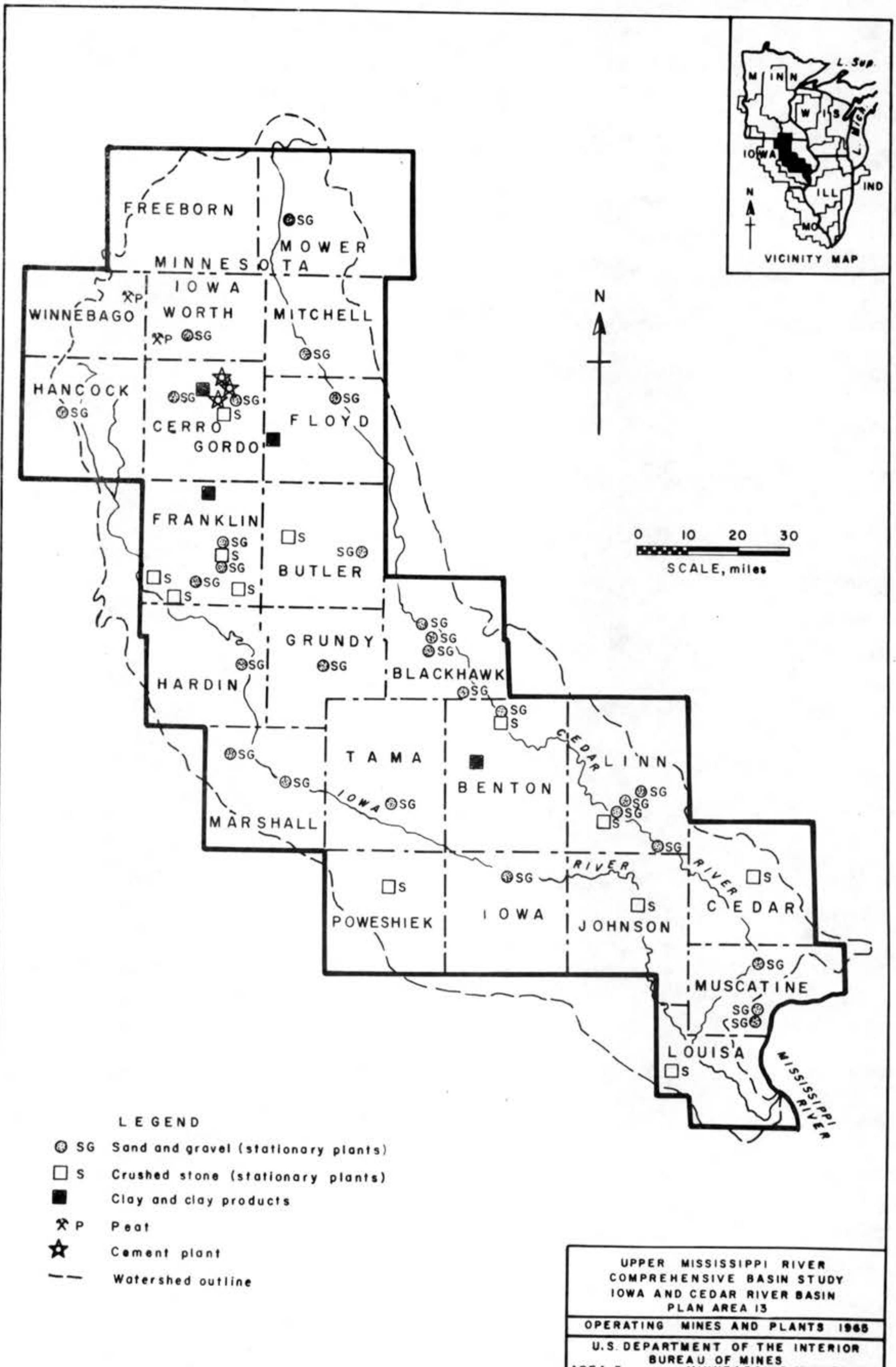
General location - Extends northwest to southeast through central Iowa and includes two counties on the south border of Minnesota, figure 19.

Area - 23 counties, 13,074 square miles, 4.4 percent urbanized.

Population - 772,474 total, 54.8 percent urban.

The plan area is in the watershed of the Iowa and Cedar Rivers.

Mineral production for 1960 in the Iowa-Cedar River Basin, Plan Area 13, was valued at $36,112,832, ranking seventh in and representing about 4 percent of the Basin's total mineral value, table 61. Within the plan area, crushed stone ranked first in value (24 percent) and sand and gravel second (about 12 percent). Undisclosed commodities of cement, peat, and clay and limestone used in cement manufacturing collectively accounted for about 64 percent of the plan area's total




UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
IOWA AND CEDAR RIVER BASIN
PLAN AREA 13

OPERATING MINES AND PLANTS 1965

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 61. - Iowa-Cedar River Basin, mineral production in Plan Area 13, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clays and shale 1/......................short tons.. | 116,563 | $174,844 |
| Sand and gravel.............................do.... | 4,854,495 | 4,178,112 |
| Stone (crushed and broken) 2/...............do.... | 6,479,594 | 8,776,830 |
| Stone (dimension)...........................do.... | 78 | 394 |
| Value of items that cannot be disclosed: Cement (portland and masonry), peat, and clay and limestone produced for use in manufacturing cement........... | --------- | 22,982,652 |
| Total.......................................... | --------- | $36,112,832 |

1/ Excludes clay produced for use in manufacturing cement.
2/ Excludes limestone produced for use in manufacturing cement.

mineral value, while dimension stone, clay, and shale collectively accounted for less than 0.5 percent.

Future production of mineral commodities in Plan Area 13 are projected to increase about four-to-sixfold by 2020, table 62, and reserves of these mineral commodities in the plan area should be sufficient to meet all projected demands. Crushed stone and sand and gravel are the principal mineral commodities. Figure 19 shows the locations of mines and permanent plants operating in Plan Area 13 in 1965.

New water required for 1960 by the plan area's mineral industries was 578 million gallons, discharged water was 550 million gallons, and consumed water was 28 million gallons. In addition, 1,034 million gallons were recirculated to meet processing requirements. Sand and gravel was the major water user taking about 95 percent of the total. Although production of crushed and broken stone is 1.6 times greater than that of sand and gravel, the latter uses about 20 times as much water in processing. Streams were the principal sources of water.

Future water requirements for the plan area's mineral industries are projected to increase about sixfold by 2020 to 3,580 million gallons, table 63, with sand and gravel taking nearly all of the water.

Land requirements for 1960 in Plan Area 13, were 233 acres, with sand and gravel taking two-thirds. Future land needs are projected to increase fivefold by 2020 to 1,160 acres annually, table 64, with sand and gravel taking 70 percent, and will require a total cumulative area of 38,516 acres for the 1960-2020 projection period. Reclaimed acreage is unknown due to unavailability of data, but disturbed land through 1964 totals about 10,000 acres.

TABLE 62. - Iowa-Cedar River Basin Plan Area 13 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Sand and gravel | 7,126 | 417 | 9,912 | 471 | 17,199 | 592 | 25,522 | 692 | 844,742 |
| Crushed stone | 11,344 | 768 | 15,727 | 877 | 26,560 | 1,042 | 39,023 | 1,118 | 1,305,225 |
| Dimension stone | (1/) | 1 | (1/) | 1 | (1/) | 1 | (1/) | 2 | 10 |
| TOTAL . . . | X X X | 1,186 | X X X | 1,349 | X X X | 1,635 | X X X | 1,812 | X X X X X X |

1/ Less than 1,000 short tons.

TABLE 63. - Iowa-Cedar River Basin Plan Area 13 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 | | | | 1970 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recircu-lated | Consumed | Intake | Discharged | Recircu-lated | Consumed |
| Sand and gravel | 550 | 529 | 956 | 21 | 919 | 884 | 1,596 | 35 |
| Crushed stone | 28 | 21 | 78 | 7 | 45 | 34 | 128 | 11 |
| TOTAL . . . . | 578 | 550 | 1,034 | 28 | 964 | 918 | 1,724 | 46 |

| Commodity | 1980 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Intake | Discharged | Recircu-lated | Consumed | Intake | Discharged | Recircu-lated | Consumed |
| Sand and gravel | 1,291 | 1,241 | 2,242 | 50 | 2,263 | 2,175 | 3,930 | 88 |
| Crushed stone | 63 | 47 | 178 | 16 | 106 | 80 | 300 | 26 |
| TOTAL . . . . | 1,354 | 1,288 | 2,420 | 66 | 2,369 | 2,255 | 4,230 | 114 |

| Commodity | 2020 | | | |
|---|---|---|---|---|
| | Intake | Discharged | Recircu-lated | Consumed |
| Sand and gravel | 3,424 | 3,291 | 5,946 | 133 |
| Crushed stone | 156 | 117 | 441 | 39 |
| TOTAL . . . . | 3,580 | 3,408 | 6,387 | 172 |

TABLE 64. - Iowa-Cedar River Basin Plan Area 13 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Sand and gravel | 154 | 225 | 315 | 546 | 810 | 26,817 |
| Crushed stone | 79 | 102 | 141 | 238 | 350 | 11,699 |
| TOTAL . . . . | 233 | 327 | 456 | 784 | 1,160 | 38,516 |

a. <u>Sand and Gravel</u>. Sand and gravel production for 1960 in Plan Area 13 was 4,854,495 tons with a value of $4,178,112, ranking second in and representing about 12 percent of the plan area's total mineral value.

Future production of sand and gravel is projected to increase more than fivefold by 2020 to 25 million tons annually, and will require a cumulative total of 844 million tons for the 1960-2020 projection period. Reserves of sand and gravel in the plan area are considered adequate to meet all projected demands. Of the 23 counties in Plan Area 13, one county was estimated to have inadequate reserves of sand and gravel to meet projected demands. Deposits in adjacent counties within the plan area are ample to offset these shortages.

New water requirements for 1960 in Plan Area 13 for sand and gravel were 550 million gallons, or nearly all of the water used by the plan area's mineral industries. Future water needs are projected to increase nearly sixfold by 2020 to 3,424 million gallons which, again, is nearly all of the water used by the plan area's mineral industries.

Land requirements for 1960 in Plan Area 13 for sand and gravel were 154 acres, or two-thirds of the total land used by the plan area's mineral industries. Through 1964, land disturbed by sand and gravel operations in the plan area were 5,514 acres. Future land needs are projected to increase more than fivefold by 2020 to 810 acres annually, and will require a cumulative total area of 26,817 acres for the 1960-2020 projection period. Data was unavailable to estimate possible reclaimed acreage.

b. <u>Crushed Stone</u>. Crushed stone production for 1960 in Plan Area 13 was 6,479,594 tons with a value of $8,776,830, ranking first in and representing 24 percent of the plan area's total mineral value.

Future production of crushed stone is projected to increase about sixfold by 2020 to 39 million tons annually, and will require a cumulative total of 1,305 million tons for the 1960-2020 projection period. Reserves of stone should be adequate to meet the projected demands. Of the 23 counties in Plan Area 13, one county was estimated to have a substantial deficiency in stone reserves but deposits in adjacent counties within the plan area are ample to offset the deficit.

New water required for 1960 in Plan Area 13 by crushed stone was 28 million gallons, insignificant compared to sand and gravel needs. Future water requirements are projected to increase about fivefold by 2020 to 156 million gallons annually, but this volume is still insignificant compared to the 2020 sand and gravel needs.

Land requirements for 1960 for crushed stone operations were 79 acres, or 34 percent of the total land needs by the plan area's mineral industries. Through 1964, 3,805 acres of land were disturbed by the plan area's mineral industries. Future land requirements for crushed stone are projected to increase more than fourfold by 2020 to 350 acres annually, and will require a cumulative area of 11,699 acres for the 1960-2020 projection period. Future possible reclaimed acreage is unestimated because of unavailability of data.

c. <u>Other Commodities</u>. The total land disturbed to date by clay, coal, peat, and iron ore mining operations amounts to less than 640 acres. Future land requirements were not estimated for these commodities.

## 29. PLAN AREA 14 - TURKEY, MAQUOKETA, WAPSIPINICON, AND UPPER IOWA RIVER BASINS

General location - Northeastern Iowa, figure 20.

Area - 14 counties, 8,375 square miles, 3.6 percent urbanized.

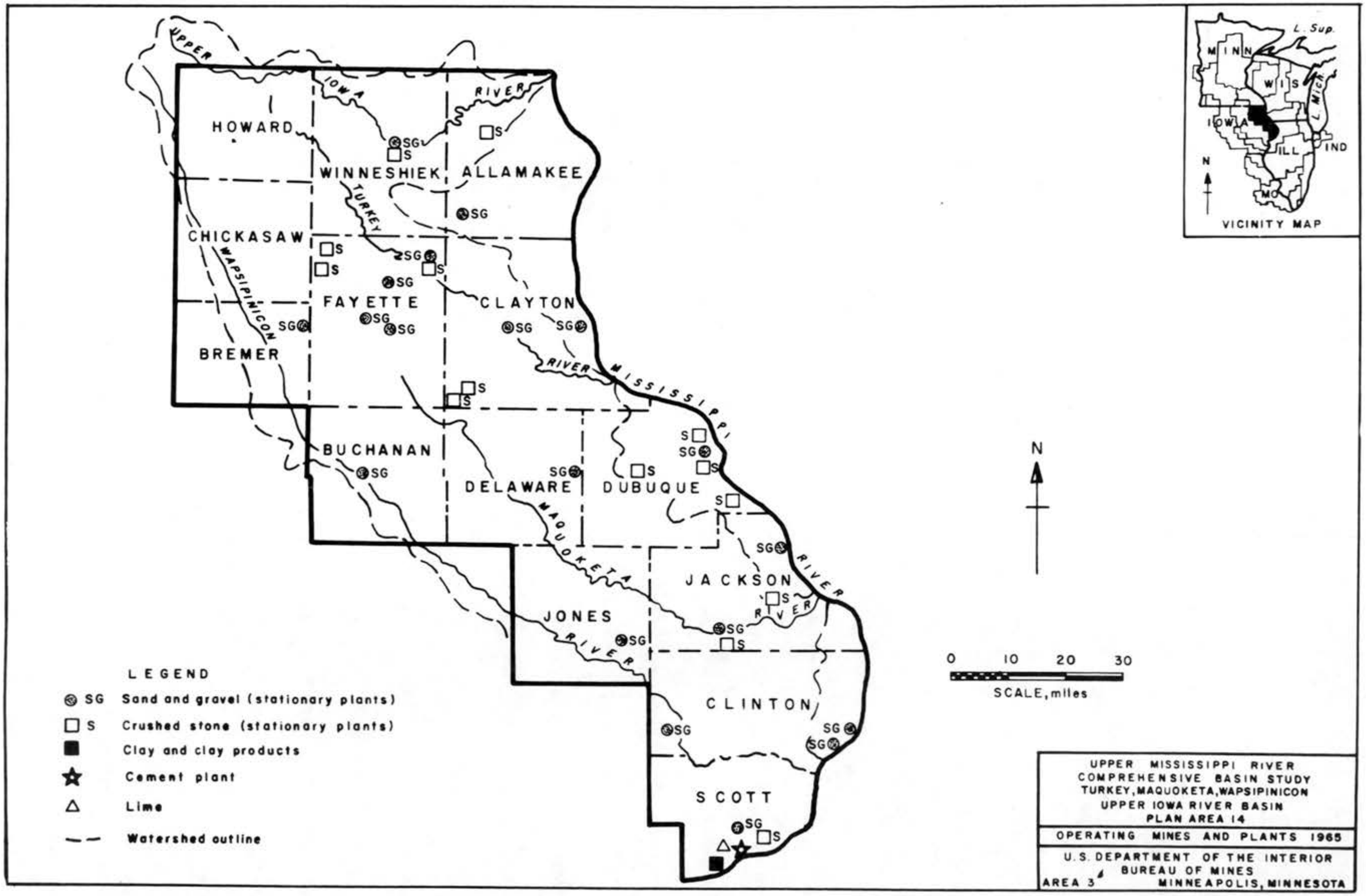
Population - 473,450 total, 54.1 percent urban.

Plan Area 14 lies predominantly in the watersheds of the Turkey, Maquoketa, Wapsipinicon, and Upper Iowa Rivers.

Mineral production for 1960 in the Turkey, Maquoketa, Wapsipinicon, and Upper Iowa River Basins, Plan Area 14, was valued at $16,476,406, ranking tenth in and representing about 2 percent of the Basin's total mineral value, (table 65). Within the plan area, crushed stone ranked first in value in the plan area (about 22 percent) and sand and gravel second (about 6 percent). Undisclosed commodities of cement, lime, and limestone used in cement manufacturing, and lime collectively accounted for about 71 percent of the plan area's total mineral value.

Future production of mineral commodities in Plan Area 14 is projected to increase about fourfold to sevenfold by 2020, (table 66). Reserves of the various commodities will be adequate to meet the projected demands several times, as determined from geological interpretations described in the literature (~~25, 26, 27, 28,~~ 29, 65, 75, 80, 94) for only the commodities of crushed stone, sand and gravel, and dimension stone for which projections were made. Figure 20 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water requirements for 1960 for the plan area's mineral industries, excluding volumes used for the undisclosed commodities, were 539 million gallons, discharged water was 530 million gallons,


HOWARD
WINNESHIEK
ALLAMAKEE
CHICKASAW
FAYETTE
CLAYTON
BREMER
BUCHANAN
DELAWARE
DUBUQUE
JACKSON
JONES
CLINTON
SCOTT
UPPER IOWA RIVER
TURKEY
WAPSIPINICON
RIVER
MISSISSIPPI RIVER
MAQUOKETA
RIVER
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VICINITY MAP
N
0 10 20 30
SCALE, miles
LEGEND
SG Sand and gravel (stationary plants)
S Crushed stone (stationary plants)
Clay and clay products
Cement plant
Lime
Watershed outline
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
TURKEY, MAQUOKETA, WAPSIPINICON
UPPER IOWA RIVER BASIN
PLAN AREA 14
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3
MINNEAPOLIS, MINNESOTA

TABLE 65. - Turkey, Maquoketa, Wapsipinicon, and Upper Iowa River Basins, mineral production in Plan Area 14, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Clay produced for use in mfg. cement....short tons.. | 90,484 | $ 90,484 |
| Sand and gravel.............................do.... | 761,108 | 1,025,117 |
| Stone (crushed and broken) 1/................do.... | 2,557,798 | 3,645,212 |
| Stone (dimension)............................do.... | 4,971 | 79,520 |
| Value of items that cannot be disclosed: Cement (portland and masonry), lime, and limestone for use in manufacturing cement and lime.............. | --------- | 11,636,071 |
| Total...................................... | --------- | $16,476,404 |

1/ Excludes limestone produced for use in manufacturing cement and lime.

TABLE 66. - Turkey, Maquoketa, Wapsipinicon, and Upper Iowa River Basins Plan Area 14 - Projected mineral production and employment (thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Sand and gravel | 1,098 | 60 | 1,465 | 66 | 2,458 | 81 | 3,607 | 94 | 122,611 |
| Crushed stone | 5,120 | 329 | 7,232 | 382 | 12,289 | 454 | 18,049 | 485 | 601,955 |
| Dimension stone | 12 | 29 | 16 | 33 | 30 | 45 | 50 | 53 | 1,496 |
| TOTAL . . . | X X X | 418 | X X X | 481 | X X X | 580 | X X X | 632 | X X X X |

and consumed water was 9 million gallons. In addition, 205 million gallons were recirculated to meet processing requirements. Crushed stone used nearly two-thirds of the new water.

Future new water requirements for the plan area's mineral industries are projected to increase more than fivefold by 2020 to 2,940 million gallons (table 67), with crushed stone taking nearly two-thirds of the 2020 water total.

Land required for 1960 in Plan Area 14 by the plan area's mineral industries, excluding acreage required by the undisclosed commodities, was 84 acres, with crushed stone taking about two-thirds. Future land needs are projected to increase more than fivefold by 2020 to 453 acres (table 68), with crushed stone again taking about two-thirds of the 2020 total, and the cumulative area required for the 1960-2020 projection period will be 15,195 acres. Possible reclaimed acreage is unestimated because of unavailability of data.

a. <u>Sand and Gravel</u>. Sand and gravel production for 1960 in Plan Area 14 was 761,108 tons with a value of $1,025,117, ranking second in and representing 6 percent of the plan area's total mineral value.

Future production of sand and gravel is projected to increase nearly fivefold by 2020 to 3.6 million tons annually, and will require a cumulative total of 122 million tons for the 1960-2020 projection period. Reserves of sand and gravel have been determined to be adequate to meet the projected demands.

New water requirements for 1960 in Plan Area 14 for sand and gravel were 197 million gallons or 37 percent of the plan area's total new

TABLE 67. - Turkey, Maquoketa, Wapsipinicon, and Upper Iowa River Basins Plan Area 14 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 Intake | 1960 Discharged | 1960 Recirculated | 1960 Consumed | 1970 Intake | 1970 Discharged | 1970 Recirculated | 1970 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | 197 | 194 | 205 | 3 | 295 | 291 | 307 | 4 |
| Crushed stone | 342 | 336 | - | 6 | 548 | 538 | - | 10 |
| TOTAL . . . . | 539 | 530 | 205 | 9 | 843 | 829 | 307 | 14 |

| Commodity | 1980 Intake | 1980 Discharged | 1980 Recirculated | 1980 Consumed | 2000 Intake | 2000 Discharged | 2000 Recirculated | 2000 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | 398 | 392 | 414 | 6 | 674 | 664 | 702 | 10 |
| Crushed stone | 774 | 759 | - | 15 | 1,315 | 1,290 | - | 25 |
| TOTAL . . . . | 1,172 | 1,151 | 414 | 21 | 1,989 | 1,954 | 702 | 35 |

| Commodity | 2020 Intake | 2020 Discharged | 2020 Recirculated | 2020 Consumed |
|---|---|---|---|---|
| Sand and gravel | 1,009 | 994 | 1,050 | 15 |
| Crushed stone | 1,931 | 1,895 | - | 36 |
| TOTAL . . . . | 2,940 | 2,889 | 1,050 | 51 |

TABLE 68. - Turkey, Maquoketa, Wapsipinicon, and Upper Iowa River Basins Plan Area 14 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Sand and gravel | 29 | 44 | 59 | 98 | 144 | 4,898 |
| Crushed stone | 54 | 87 | 123 | 210 | 308 | 10,272 |
| Dimension stone | (1/) | (1/) | (1/) | (1/) | (1/) | 25 |
| TOTAL . . . . | 84 | 132 | 183 | 309 | 453 | 15,195 |

1/ Less than 1 acre.

water needs. Future new water needs are projected to increase fivefold by 2020 to 1,009 million gallons annually, which is about one-third of the plan area's total 2020 new water needs. From present use patterns, it can be assumed that most of this water will come from streams.

Land requirements for 1960 in Plan Area 14 for sand and gravel were 29 acres or 35 percent of the plan area's total estimated mineral land needs. Future land needs are projected to increase fivefold by 2020 to 144 acres annually, and will require a cumulative area of 4,898 acres for the 1960-2020 projection period. Sand and gravel land requirement projections are based on the current land use ratio. Possible reclaimed acreage is unestimated due to unavailability of data.

b. <u>Crushed Stone</u>. Crushed and broken stone production for 1960 in Plan Area 14 was 2,557,798 tons with a value of $3,645,212, ranking first in and representing 22 percent of the plan area's total mineral value.

Future production of crushed stone is projected to increase sevenfold by 2020 to 18 million tons annually, and will require a cumulative total of about 602 million tons for the 1960-2020 projection period. Reserves are adequate to meet the projected demands.

New water requirements for 1960 in Plan Area 14 for crushed stone were 342 million gallons or 63 percent of the plan area's total water intake. Future water requirements are projected to increase more than fivefold by 2020 to 1,931 million gallons annually, which will be about 65 percent of the plan area's 2020 water needs. Of this, however, 36 million gallons are expected to be consumed and the remainder discharged to drainage.

Land requirements for 1960 for crushed stone were 54 acres or 65 percent of the total mineral land needs. Future land needs are projected to increase nearly sixfold by 2020 to 308 acres annually, and will require a cumulative area of 10,272 acres for the 1960-2020 projection period. These estimates are based on indicated thicknesses of stone strata.

c. Other Minerals. Dimension stone and clay production for 1960 accounted for about 1 percent of the total mineral value of Plan Area 14. Land and water requirements were not tabulated.

The cumulative demand for dimension stone projected for the period 1960-2020 is approximately 1.5 million tons.

The water required by the crushed stone industry is relatively insignificant and no projections were made. Dimension stone land use parameters are the same as crushed stone and the indicated cumulative total is only 25 acres for the period 1960-2020.

30. PLAN AREA 15 - CANNON, ZUMBRO, AND ROOT RIVER BASINS

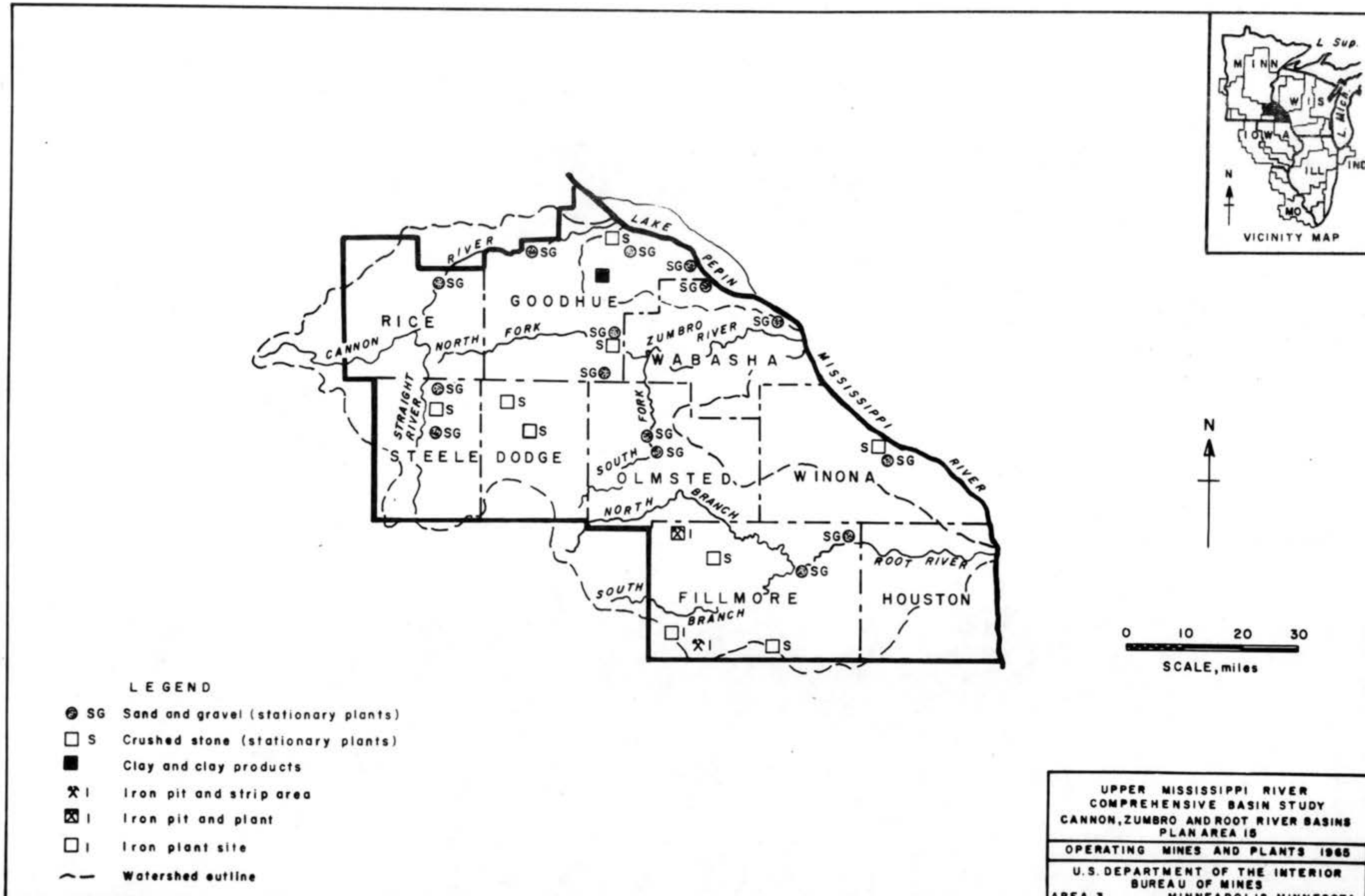
General location - Southeastern Minnesota, figure 21.

Area - 9 counties, 5,336 square miles, 4.0 percent urbanized.

Population - 274,143 total, 47.0 percent urban.

This plan area is in the watershed of the Cannon, Zumbro, and Root Rivers.

Mineral production for 1960 in the Cannon, Zumbro, and Root River Basins, Plan Area 15, was valued at $6,751,165, ranking 14th in and representing about 1 percent of the Basin's total mineral value, table 69. Within the plan area, sand and gravel accounted for about 21 percent of the plan area's total mineral value, crushed stone about 26 percent,



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VICINITY MAP
LAKE PEPIN
MISSISSIPPI RIVER
CANNON RIVER
NORTH FORK
ZUMBRO RIVER
STRAIGHT RIVER
SOUTH FORK
NORTH BRANCH
SOUTH BRANCH
ROOT RIVER
RICE
GOODHUE
WABASHA
STEELE
DODGE
OLMSTED
WINONA
FILLMORE
HOUSTON
N
0 10 20 30
SCALE, miles
LEGEND
SG Sand and gravel (stationary plants)
S Crushed stone (stationary plants)
Clay and clay products
I Iron pit and strip area
I Iron pit and plant
I Iron plant site
Watershed outline
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
CANNON, ZUMBRO AND ROOT RIVER BASINS
PLAN AREA 15
OPERATING MINES AND PLANTS 1965
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 69. - Cannon, Zumbro, and Root River Basins, mineral production in Plan Area 15, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Iron ore....................long tons.. | 461,833 | W |
| Sand and gravel.............short tons.. | 1,678,116 | $1,432,246 |
| Stone (crushed and broken)..........do.... | 1,416,482 | 1,734,683 |
| Value of items that cannot be disclosed: Clays and shale, iron ore, and dimension stone.............. | --------- | 3,584,236 |
| Total.................................. | --------- | $6,751,165 |

W Withheld to avoid disclosing individual company confidential data.

and the undisclosed commodities of clays, shale, iron ore, and dimension stone about 53 percent.

Future production of mineral commodities in Plan Area 15 are projected to increase, with sand and gravel and crushed stone from sevenfold to eightfold by 2020, except for iron ore which will demise before 1970 (in 1967, production of iron ore had practically ceased), table 70. Reserves of all commodities are adequate to meet the projected demands. Figure 21 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water required for 1960 by the plan area's mineral industries was 237 million gallons, discharged water was 202 million gallons, and consumed water was 35 million gallons. In addition, 717 million gallons were recirculated to meet processing needs. The principal users of water were the sand and gravel and dimension stone industries. The iron ore industry is expected to expire by 1970, thus eliminating its needs for water. Water sources for sand and gravel were streams (45 percent), wells (37 percent), and lakes (18 percent). The only reported source of water for dimension stone is wells.

Future new water requirements in Plan Area 15 are projected to increase more than fivefold by 2020 to 1,257 million gallons annually, table 71, with sand and gravel taking about 85 percent of the 2020 new water. Iron ore will not be a factor as this industry will demise before 1970.

Land requirements for 1960 in Plan Area 15 were about 76 acres, with sand and gravel the major user. Through 1964, about 6900 acres of

TABLE 70. - Cannon, Zumbro, and Root River Basins Plan Area 15 - Projected mineral production and employment (thousand short tons, except as noted, and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Iron ore (usable) | 1/ 400 | 50 | (2/) | | | | | | |
| Sand and gravel | 2,863 | 123 | 4,423 | 156 | 8,481 | 219 | 13,078 | 268 | 405,353 |
| Crushed stone | 2,303 | 239 | 3,485 | 300 | 6,472 | 405 | 9,822 | 533 | 309,816 |
| Dimension stone | 20 | 187 | 27 | 203 | 52 | 278 | 85 | 320 | 2,565 |
| TOTAL . . . | X X X | 599 | X X X | 659 | X X X | 902 | X X X | 1,121 | 717,734 |

1/ Thousand long tons.
2/ Mining at the indicated rate would substantially deplete reported reserves.

TABLE 71. - Cannon, Zumbro, and Root River Basins Plan Area 15 - Projected water use in the mineral industry (millions of gallons)

| Commodity | 1960 Intake | 1960 Discharged | 1960 Recirculated | 1960 Consumed | 1970 Intake | 1970 Discharged | 1970 Recirculated | 1970 Consumed |
|---|---|---|---|---|---|---|---|---|
| Iron ore | 79 | 48 | 588 | 31 | 79 | 48 | 588 | 31 |
| Sand and gravel | 128 | 125 | 113 | 3 | 221 | 215 | 195 | 6 |
| Crushed stone | 5 | 4 | 16 | 1 | 9 | 7 | 26 | 2 |
| Dimension stone | 25 | 25 | - | - | 40 | 40 | - | - |
| TOTAL . . . . | 237 | 202 | 717 | 35 | 349 | 310 | 809 | 39 |

| Commodity | 1980 Intake | 1980 Discharged | 1980 Recirculated | 1980 Consumed | 2000 Intake | 2000 Discharged | 2000 Recirculated | 2000 Consumed |
|---|---|---|---|---|---|---|---|---|
| Iron ore | - | - | - | - | - | - | - | - |
| Sand and gravel | 344 | 335 | 304 | 9 | 666 | 649 | 588 | 17 |
| Crushed stone | 14 | 11 | 39 | 3 | 26 | 20 | 73 | 6 |
| Dimension stone | 54 | 54 | - | - | 104 | 104 | - | - |
| TOTAL . . . . | 412 | 400 | 343 | 12 | 796 | 773 | 661 | 23 |

| Commodity | 2020 Intake | 2020 Discharged | 2020 Recirculated | 2020 Consumed |
|---|---|---|---|---|
| Iron ore | - | - | - | - |
| Sand and gravel | 1,047 | 1,020 | 925 | 27 |
| Crushed stone | 40 | 30 | 111 | 10 |
| Dimension stone | 170 | 170 | - | - |
| TOTAL . . . . | 1,257 | 1,220 | 1,036 | 37 |

land were disturbed by the plan area's mineral industries. Future land requirements are projected to increase nearly eightfold by 2020 to 585 acres annually (table 72) and will require a cumulative area of 18,192 acres for the 1960-2020 projection period. Of the 2020 annual acres needed, sand and gravel will take most of them. Reclaimed acreage is unknown due to unavailability of data.

a. Sand and Gravel. Sand and gravel production for 1960 in Plan Area 15 was 1,678,116 tons with a value of $1,432,246, ranking second in and representing about 21 percent of the plan area's total mineral value.

Future production of sand and gravel in Plan Area 15 is projected to increase more than tenfold by 2020 to about 13 million tons annually, and will require a cumulative total of 405 million tons for the 1960-2020 projection period. Reserves of sand and gravel are estimated to be about eight times projected requirements and will be more than adequate to meet these demands. Every county in the plan area has ample reserves to supply its needs.

New water requirements for 1960 for sand and gravel were 128 million gallons representing more than one-half of the plan area's total water needs. Nearly all of this used water was discharged. Nearly all of the plan area's mineral producers obtained their water from wells.

Future new water requirements in Plan Area 15 for sand and gravel are projected to increase more than eightfold to 1,047 million gallons annually or more than 83 percent of the plan area's 2020 new water needs.

TABLE 72. - Cannon, Zumbro, and Root River Basins Plan Area 15 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Sand and gravel | 61 | 105 | 162 | 310 | 478 | 14,824 |
| Crushed stone | 15 | 24 | 36 | 68 | 103 | 3,256 |
| Dimension stone | .5 | 1 | 1.3 | 2 | 4 | 112 |
| TOTAL . . . . | 76.5 | 130 | 199.3 | 380 | 585 | 18,192 |

Land requirements for 1960 for sand and gravel were 61 acres, or nearly 28 percent of the plan area's total mineral land needs. Through 1964, in the plan area, 1,900 acres of land were disturbed by sand and gravel operations. Future land requirements are projected to increase nearly eightfold by 2020 to 478 acres annually, about 81 percent of the plan area's total land needs, and will require a cumulative area of 14,824 acres for the 1960-2020 projection period. Data was unavailable to estimate possible reclaimed acreage.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 15 was 1,416,482 tons with a value of $1,734,683, ranking first in and representing nearly 26 percent of the plan area's total mineral value.

Future crushed stone production is projected to increase about sevenfold by 2020 to nearly 10 million tons annually, and will require a cumulative total of nearly 310 million tons for the 1960-2020 projection period. Reserves of stone are estimated to be about eight times the projected requirements and, of course, will be more than adequate to meet these demands.

New water requirements for 1960 in Plan Area 15 were relatively insignificant, requiring only five million gallons or nearly 2 percent of the plan area's total water demands. Future water requirements for crushed stone are projected to increase eightfold by 2020 to 40 million gallons annually. Water supplies are believed to be more than adequate to meet projected demands.

Land requirements for 1960 for crushed stone were 15 acres, or nearly 20 percent of the plan area's total mineral land needs.

Through 1964 in Plan Area 15, 1,150 acres were disturbed by crushed stone operations. Future land requirements are projected to increase about sevenfold by 2020 to 103 acres annually, and will require a cumulative area of 3,256 acres for the 1960-2020 projection period. Less land will be required to produce a ton of crushed stone than a ton of sand and gravel. In estimating land requirements, a maximum 50-foot mining depth was assumed for stone (and a 25-foot depth for sand and gravel).

c. <u>Dimension Stone</u>. Production and value figures for dimension stone cannot be disclosed. But water requirements for 1960 in Plan Area 15 were 25 million gallons or nearly 10 percent of all water needs by the plan area's mineral industry and land demands were only one-half acre.

Cumulative demands for dimension stone between 1960 and 2020 total 2.6 million tons. Annual rates of production will increase from 13 thousand tons in 1960 to 85 thousand tons in 2020. Stone reserves of a satisfactory quality are estimated to be eight times the projected demands.

Although rate of sand and gravel production in 2020 is over 100 times greater than dimension stone, its water requirements are only six times as large for the tonnages involved. Water intake for dimension stone in 2020 is about 2,000 gallons per ton compared to 80 gallons per ton for sand and gravel in this plan area. Total water requirements for the dimension stone industry will increase about sevenfold between 1960 and 2020. This industry discharges all of its water back to its source without recirculating it.

Less than 50 acres of land have been disturbed by the industry as of January 1, 1965. About 112 acres will be disturbed between 1960 and 2020 assuming a waste factor of 50 percent in quarrying. The annual rate of land use will range from one-half acre in 1960 to four acres in 2020.

d. Other Minerals. The amount of land disturbed in mining iron ore totaled 3,660 acres as of January 1, 1965. These operations will probably be discontinued by 1970. Very little, if any, new land will be disturbed between 1960 and 1970. Water requirements will not increase between 1960 and 1970. No water will be required after 1970.

The amount of land disturbed by peat and clay mining as of January 1, 1965, was less than 150 acres with clay mining accounting for most of the disturbed land. Estimates of peat and clay reserves were not made.

## 31. PLAN AREA 16 - MINNESOTA RIVER BASIN

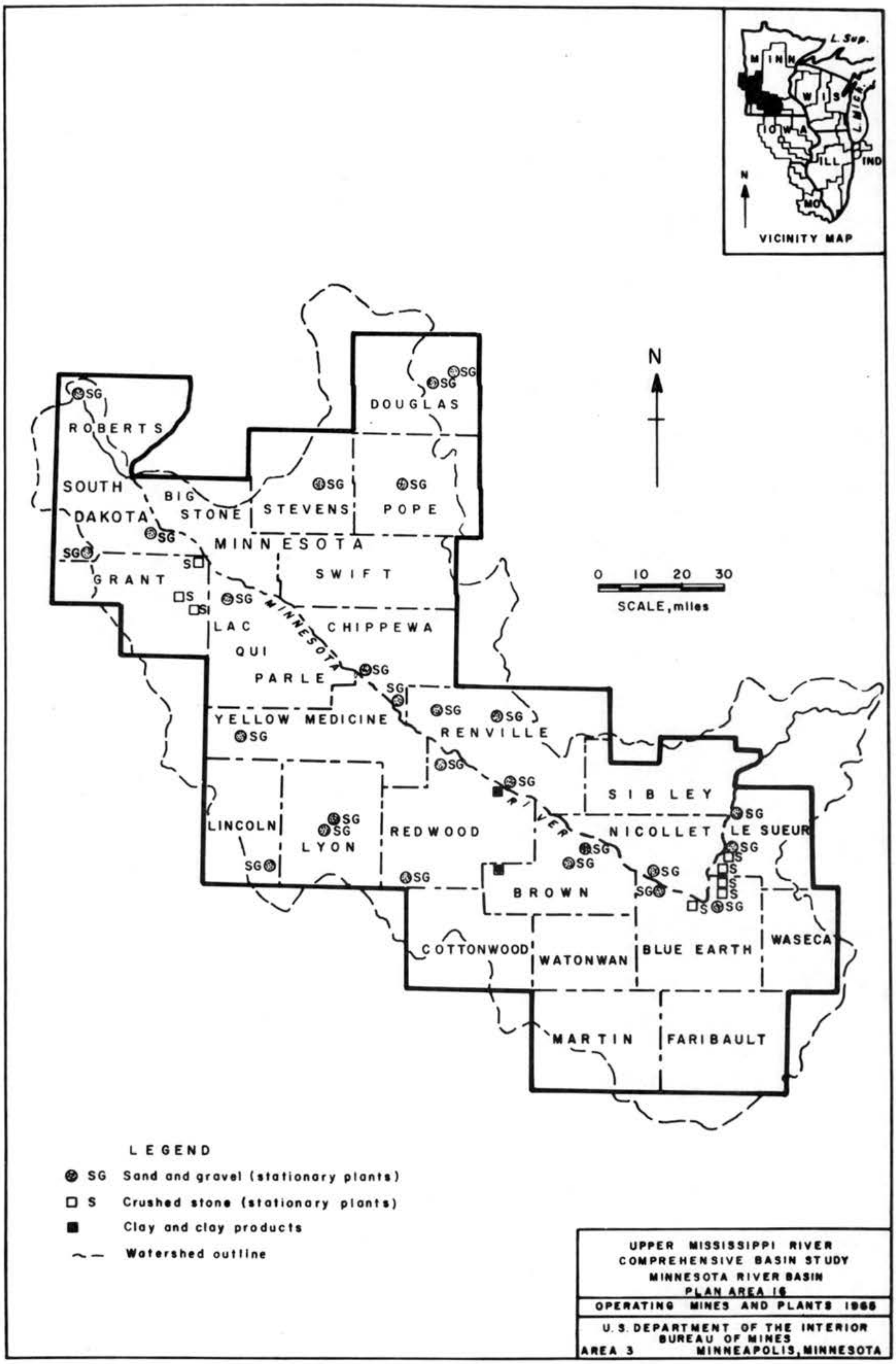
General location - Southwestern Minnesota, figure 22.

Area - 24 counties, 15,902 square miles, 3.2 percent urbanized.

Population - 442,657 total, 31.4 percent urban.

The plan area is in the watershed of the Minnesota River.

Mineral production for 1960 in the Minnesota River Basin, Plan Area 16, was valued at $10,976,948, ranking eleventh in and representing about 1 percent of the Basin's total mineral value (table 73). Within the plan area, dimension stone accounted for about 52 percent of the plan area's total mineral value, sand and gravel about 43 percent, and crushed stone about 6 percent. The values of shales and clays were excluded because of confidentiality.


VICINITY MAP
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STEVENS
POPE
DOUGLAS
MINNESOTA
GRANT
SWIFT
LAC QUI PARLE
CHIPPEWA
MINNESOTA RIVER
YELLOW MEDICINE
RENVILLE
SIBLEY
LINCOLN
LYON
REDWOOD
NICOLLET
LE SUEUR
BROWN
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
MARTIN
FARIBAULT
0 10 20 30
SCALE, miles
LEGEND
SG Sand and gravel (stationary plants)
S Crushed stone (stationary plants)
Clay and clay products
Watershed outline
UPPER MISSISSIPPI RIVER
COMPREHENSIVE BASIN STUDY
MINNESOTA RIVER BASIN
PLAN AREA 16
OPERATING MINES AND PLANTS 1966
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA 3 MINNEAPOLIS, MINNESOTA

TABLE 73. - Minnesota River Basin, mineral production in Plan Area 16, 1960

| Mineral | 1960 | |
|---|---|---|
| | Quantity | Value |
| Sand and gravel........................short tons... | 5,730,903 | $4,639,060 |
| Stone (crushed and broken)..................do..... | 577,541 | 642,672 |
| Stone (dimension)...........................do..... | 60,516 | 5,695,216 |
| Total.................................... | ------- | 1/ $10,976,948 |

1/ Incomplete total. Excludes the value of clays and shale to avoid disclosing individual company confidential data.

Future production of mineral commodities in Plan Area 16 is projected to increase about fourfold to sixfold (table 74). Reserves are estimated to be sufficient to meet the projected demands. Figure 22 shows the locations of mines and permanent plants operating in the plan area in 1965.

New water requirements for 1960 in Plan Area 16 for all mineral industries were 663 million gallons, discharged water was 648 million gallons, and consumed water was 15 million gallons. In addition, 437 million gallons was recirculated to meet processing requirements. Principal users of water were sand and gravel and dimension stone producers. The principal source of water was wells.

Future new water requirements for Plan Area 16 are projected to increase more than sixfold by 2020 to 4,333 million gallons annually (table 75), with sand and gravel and dimension stone the principal users.

Land requirements for 1960 in Plan Area 16 were 214 acres, sand and gravel using almost all of them. Through 1964 in the plan area, about 10,000 acres had been disturbed by mineral operations, sand and gravel disturbing 87 percent of this acreage. Future land requirements are projected to increase more than sixfold by 2020 to 1,322 acres annually (table 76), and will require a cumulative area of 42,919 acres for the 1960-2020 projection period. Possible reclaimed acreage was not estimated because of unavailability of data.

a. Sand and Gravel. Sand and gravel production for 1960 in Plan Area 16 was 5,730,903 tons with a value of $4,639,060, ranking second in and representing about 42 percent of the plan area's total mineral value.

TABLE 74. - Minnesota River Basin Plan Area 16 -
Projected mineral production and employment
(thousand short tons and number of employees)

| Commodity | 1970 | | 1980 | | 2000 | | 2020 | | 1960-2020 (cumulative production) |
|---|---|---|---|---|---|---|---|---|---|
| | Production | Employment | Production | Employment | Production | Employment | Production | Employment | |
| Sand and gravel | 8,996 | 393 | 13,065 | 467 | 23,857 | 624 | 35,493 | 733 | 1,152,741 |
| Crushed stone | 676 | 50 | 903 | 62 | 1,592 | 81 | 2,278 | 90 | 77,297 |
| Dimension stone | 97 | 727 | 131 | 798 | 250 | 1,087 | 407 | 1,266 | 12,310 |
| TOTAL . . . | X X X | 1,170 | X X X | 1,327 | X X X | 1,792 | X X X | 2,089 | X X X X X |

TABLE 75. - Minnesota River Basin Plan Area 16 -
Projected water use in the mineral industry
(millions of gallons)

| Commodity | 1960 Intake | 1960 Discharged | 1960 Recirculated | 1960 Consumed | 1970 Intake | 1970 Discharged | 1970 Recirculated | 1970 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | 348 | 336 | 255 | 12 | 540 | 522 | 396 | 18 |
| Crushed stone | 1 | 1 | - | - | 2 | 1 | - | 1 |
| Dimension stone | 314 | 311 | 182 | 3 | 501 | 497 | 290 | 4 |
| TOTAL . . . . | 663 | 648 | 437 | 15 | 1,043 | 1,020 | 686 | 23 |

| Commodity | 1980 Intake | 1980 Discharged | 1980 Recirculated | 1980 Consumed | 2000 Intake | 2000 Discharged | 2000 Recirculated | 2000 Consumed |
|---|---|---|---|---|---|---|---|---|
| Sand and gravel | 792 | 765 | 581 | 27 | 1,460 | 1,411 | 1,071 | 49 |
| Crushed stone | 3 | 2 | - | 1 | 5 | 3 | - | 2 |
| Dimension stone | 677 | 671 | 392 | 6 | 1,297 | 1,286 | 751 | 11 |
| TOTAL . . . . | 1,472 | 1,438 | 973 | 34 | 2,762 | 2,700 | 1,822 | 62 |

| Commodity | 2020 Intake | 2020 Discharged | 2020 Recirculated | 2020 Consumed |
|---|---|---|---|---|
| Sand and gravel | 2,215 | 2,141 | 1,624 | 74 |
| Crushed stone | 7 | 4 | - | 2 |
| Dimension stone | 2,111 | 2,093 | 1,222 | 18 |
| TOTAL . . . . | 4,333 | 4,238 | 2,846 | 94 |

TABLE 76. - Minnesota River Basin Plan Area 16 - Projected land use in the mineral industries (acres)

| Commodity | 1960 | 1970 | 1980 | 2000 | 2020 | 1960-2020 (cumulative) |
|---|---|---|---|---|---|---|
| Sand and gravel | 209 | 328 | 476 | 869 | 1,293 | 42,006 |
| Crushed stone | 4 | 5 | 6 | 12 | 17 | 557 |
| Dimension stone | 1 | 3 | 4 | 7 | 12 | 356 |
| TOTAL . . . . | 214 | 336 | 486 | 888 | 1,322 | 42,919 |

Future production of sand and gravel is projected to increase more than sixfold by 2020 to more than 34 million tons annually, and will require a cumulative total of 1,152 million tons for the 1960-2020 projection period. Reserves of sand and gravel are estimated to be six times the projected demands and will be more than adequate to meet these demands. Every county having sand and gravel production is believed to contain ample reserves.

New water requirements for 1960 for sand and gravel were 348 million gallons, 53 percent of the plan area's total new water needs. Nearly all of this water was discharged. Water sources were streams (39 percent), wells (32 percent), lakes (16 percent), and mines (12 percent).

Future water requirements are projected to increase more than sixfold by 2020 to 2,215 million gallons annually, slightly more than half of the plan area's 2020 water needs. Almost all of this water will be discharged. The new water in 2020 will undoubtedly be obtained from the same sources as in 1960.

Land requirements for 1960 for sand and gravel were 209 acres, nearly all of the plan area's land needs. Through 1964 in the plan area, about 8,800 acres of land were disturbed by sand and gravel operations. Future land requirements are projected to increase more than sixfold by 2020 to 1,293 acres annually, nearly all of the plan area's 2020 land needs, and will require a cumulative area of 42,000 acres for the 1960-2020 projection period. Data was unavailable to estimate possible reclaimed acreage.

b. Crushed Stone. Crushed stone production for 1960 in Plan Area 16 was 577,541 tons with a value of $642,672, ranking third in and representing nearly 6 percent of the plan area's total mineral value.

Future production is projected to increase fourfold by 2020 to more than 2 million tons annually, and will require a cumulative total of 77 million tons for the 1960-2020 projection period. Reserves of stone are estimated to be over ~~ten~~ 10 times the projected needs and will be more than adequate to meet the plan area's demands.

New water requirements for 1960 in Plan Area 16 for crushed stone were relatively insignificant with ~~one~~ 1 million gallons. Future new water requirements are projected to increase sevenfold by 2020 to 7 million gallons annually, still insignificant in the plan area. Because of the relatively small amount of water required, the supply is believed adequate to meet the projected demands.

Land requirements for 1960 in Plan Area 16 for crushed stone were 4 acres, less than 2 percent of the plan area's land needs. Through 1964 in the plan area, 170 acres of land were disturbed by stone operations. Future land requirements are projected to increase about fourfold by 2020 to 17 acres annually, and will require a cumulative area of 557 acres for the 1960-2020 projection period. Reclaimed acreage possible was not estimated because of unavailability of data.

c. Dimension Stone. Dimension stone production for 1960 in Plan Area 16 was 60,516 tons with a value of $5,695,216, ranking first in and representing 52 percent of the plan area's total mineral value.

Future dimension stone production is projected to increase nearly sevenfold by 2020 to 407,000 tons annually, and will require a cumulative total of 12 million tons for the 1960-2020 projection period. Reserves of stone are estimated to be 10 ten times projected cumulative demands and, of course, will easily meet any future demands. Large scale dimension stone quarries and mills operate in Plan Area 16.

New water requirements for 1960 in Plan Area 16 for dimension stone were 314 million gallons, nearly half of the plan area's total new water needs. Future water requirements are projected to increase nearly sevenfold by 2020 to 2,111 million gallons annually, again nearly half of the 2020 total water needs.

Land requirements for 1960 for dimension stone were insignificant with one acre. Through 1964, 1,100 acres of land have been disturbed by dimension stone operations. Future land requirements are projected to increase by 2020 to 12 acres annually, an area still relatively insignificant in the plan area, and will require a cumulative area of 356 acres for the 1960-2020 projection period. These land areas were estimated assuming a waste factor of 50 percent in quarrying. Reclaimed acreage possible was not estimated because of unavailability of data.

## SECTION VII
## RECOMMENDATIONS

Implementation of the following recommendations would provide accurate and detailed specific data useful in future Basin planning studies:

1. Continue gathering water use data by the mineral industry.
2. Conduct studies of water discharges by the mineral industries with particular reference to the dissolved chemical to assess better the pollution potential.
3. Conduct studies on production of construction materials in relationship to construction indexes as an aid in making projections of local demand.
4. Continue research on mine water pollution problems.
5. Periodically collect data on land use and reclamation by the mineral industries to determine trends useful in making projections of land use needs.
6. Collect, prepare, and publish information on land requirements for mineral production specifically designed to aid local communities in making realistic zoning regulations.

## SECTION VIII
## SUMMARY

The mineral industry in the Basin is an important factor in the economy of the Nation and of the Basin and a continuing healthy mineral industry is necessary to support the Nation's expanding economy. The value of mineral production in the Basin exceeded $830 million in 1960. Several commodities of national significance exist within the Basin particularly bituminous coal, iron ore, lead, zinc, and gypsum.

An adequate supply of water is essential for mining and milling operations. Although the mineral industry is a substantial user of water, actual water consumed and lost to the drainage system is minor to almost insignificant. Because of the relatively generous supply of water throughout the Basin, few mining or milling operations have a water supply problem. Pollution by discharges from mining and milling operations do occur but most cases present few technical problems which cannot be solved by application of present technology. An exception, which is a major pollution problem in some areas, is the drainage of acid water from old abandoned coal mines and old refuse piles. In many cases there are no simple solutions to these problems. They will require further study.

Historical data on land use and land reclamation related to the mineral industry is limited in many areas. It is apparent from information developed for this study that land use for construction materials in the vicinity of urban developments will present a problem in the future unless proper allowance is made for mineral reserve areas in planning such developments.

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