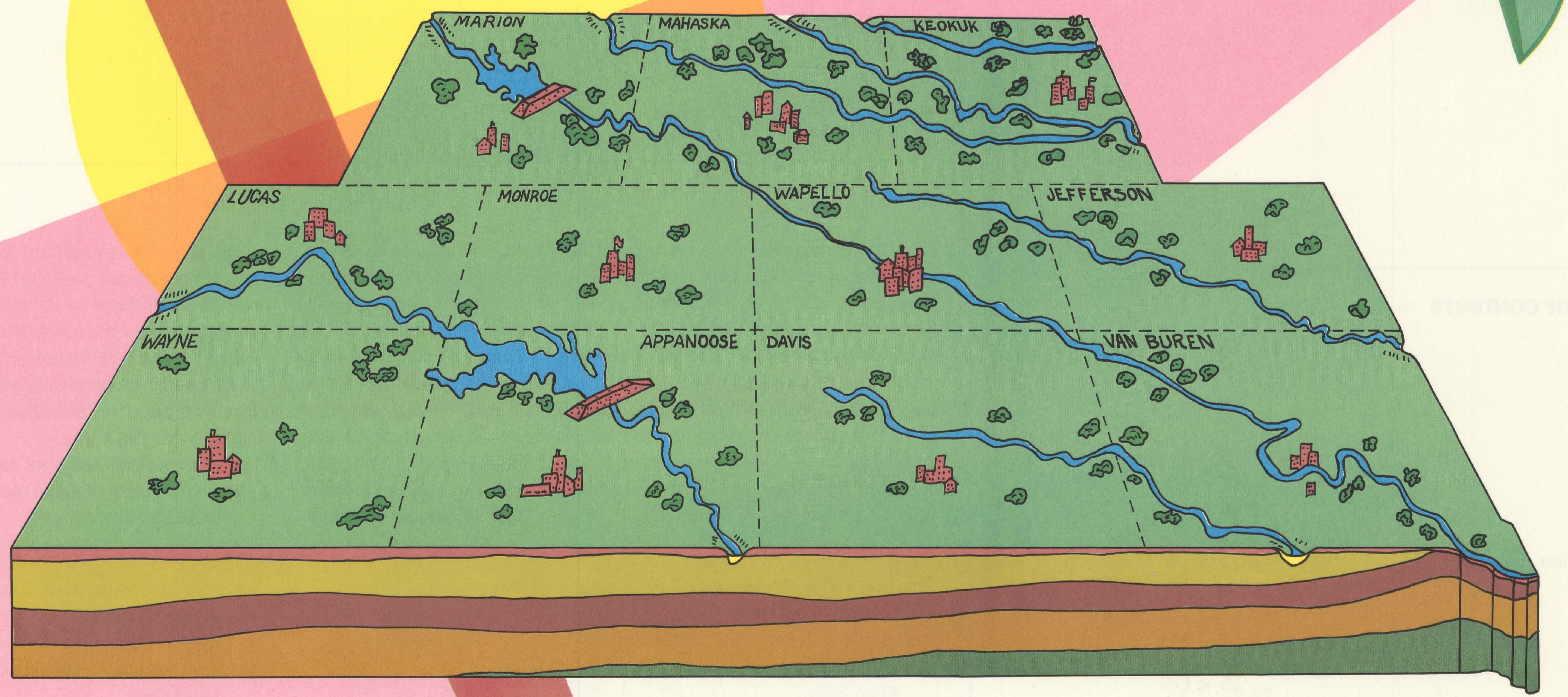
RESOURCE DEVELOPMENT
LAND-AND WATER-USE MANAGEMENT
ELEVEN-COUNTY REGION
SOUTH-CENTRAL IOWA



MISCELLANEOUS MAP SERIES 3

IOWA GEOLOGICAL SURVEY
Samuel J. Tuthill – state geologist

RESOURCE DEVELOPMENT
LAND-AND WATER-USE MANAGEMENT
SOUTH-CENTRAL IOWA
ELEVEN COUNTY REGION

Prepared by the Iowa Geological Survey
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Iowa Geological Survey
1973
Iowa City, Iowa 52240

FOREWORD

This atlas of thematic maps provides basic information for land and resource management for an Eleven-County region of south-central Iowa. These maps were produced as part of a pilot program, under a grant (14-08-0001-G-66) from the U.S. Geological Survey, EROS (Earth Resources Observation System) Program. A technical report illustrating the capability of Earth Resources Technology Satellite (ERTS) and other systems for inventory of land cover has also been prepared and is available from the Iowa Geological Survey. State and local planners, governmental agencies, and public interest organizations may use this atlas' information in making decisions on resource utilization and land-use policy. However, since this atlas is in part experimental, it may not completely satisfy the needs of resource planners. Therefore suggestions for the modification of these maps would be welcome. Please send such suggestions to this address:

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ACKNOWLEDGEMENTS

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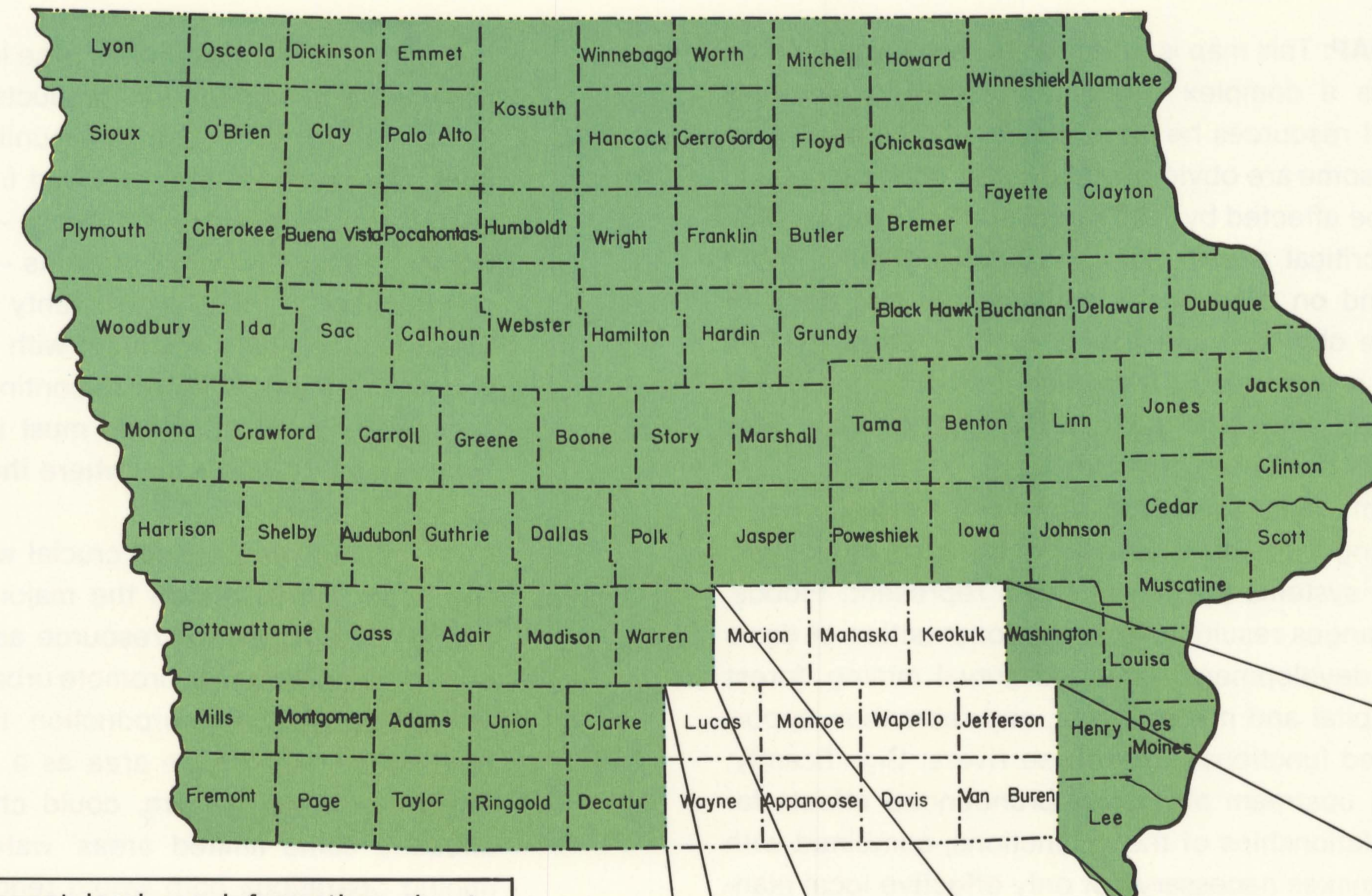
Lucas County
- Clarence Perry, County Engineer
- Bernie Aulwes, City Manager, Chariton

Wapello County
- Fred Cobbler, Farmer
- Jay Pulis, Ottumwa City Planner

Wayne County
- Ted Robinson, County Engineer



ELEVEN-COUNTY REGION

The maps throughout this atlas present land-use information about eleven counties in south-central Iowa — Appanoose, Davis, Jefferson, Keokuk, Lucas, Mahaska, Marion, Monroe, Wapello, Wayne, and Van Buren. Most of these maps describe some specific aspect of the region. Special emphasis is placed on natural resources information, especially as they are related to geology and hydrology.

In addition, there is one map, Critical Planning Areas, which summarized much of the information from other maps and focuses attention onto the areas where a complex interaction of trends, resources, and natural processes may be expected. Perhaps the atlas' greatest deficiency is in the areas of agricultural land-use, production, and management. Information of this type is best acquired from the many local, state and federal agencies involved with Iowa agriculture.

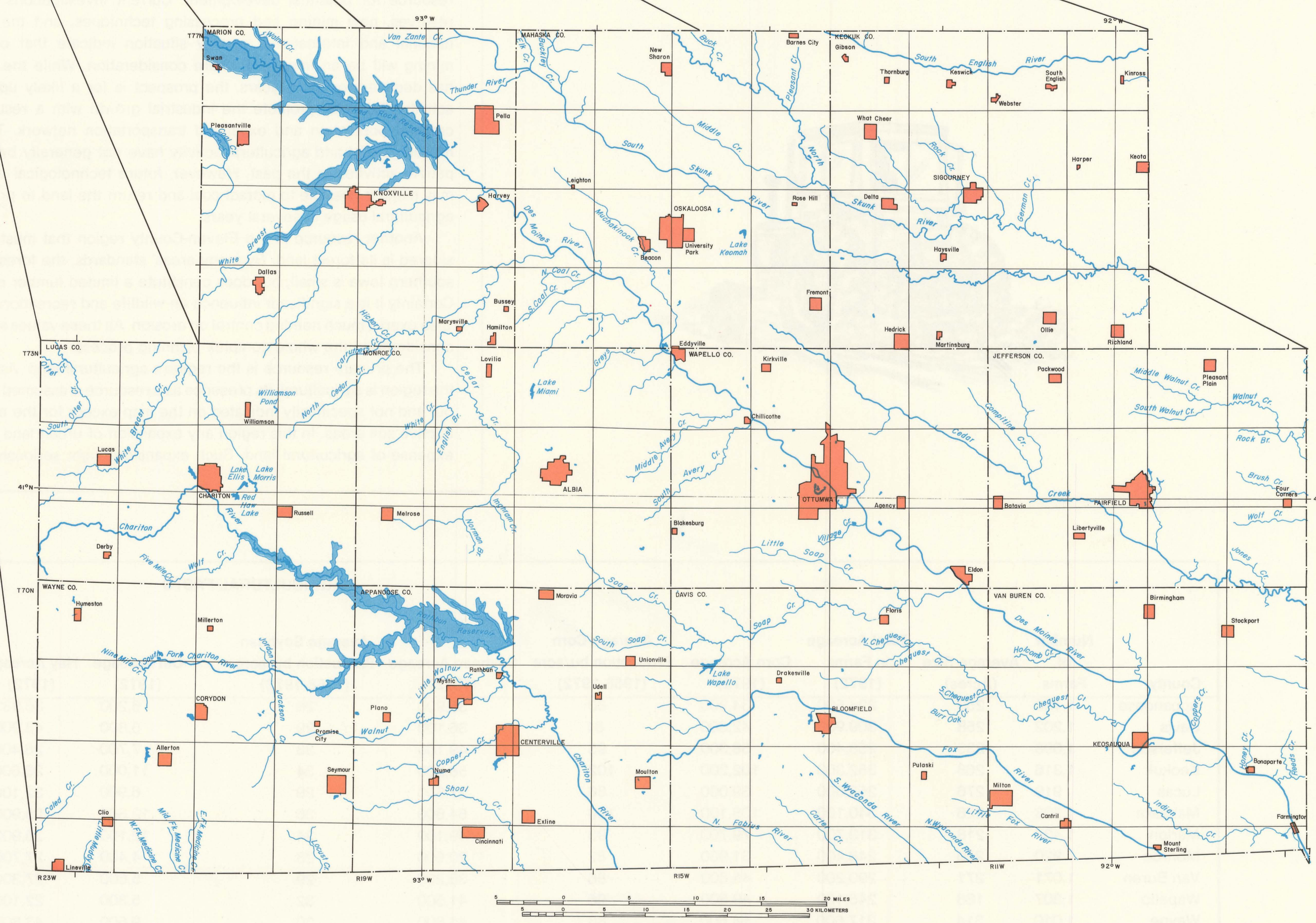
The general format of the atlas has been the presentation of maps on one page and the presentation of related text, definitions, tables, illustrations, and references on the facing page. Generally, these maps are relatively self-contained although they may relate to one or more other maps. More detailed and complete sections of the atlas involve the areas of Subsurface Geology and Water Resources. These pages are more interdependent and may necessitate more thorough reading and understanding. While some of these subjects may be somewhat technical, any careful reader should be able to understand and obtain important information from the maps and text.

The region is basically rural and extends 96 miles east-west and 63 miles north-south for a total area of 5,472 square miles. Ottumwa, in Wapello county, is the largest city (population 29,610). It provides television and news service, as well as national air and rail transportation lines to the region. Though the western counties are somewhat distant from Ottumwa, they are readily serviced by Des Moines. The counties range in population from Wapello (42,149) to Davis (8,207). The Eleven-County region has a total population of 180,177.

Most of the region makes up the already existent Iowa Planning Region 12, established by the Office of Planning and Programming. However, Marion county, which is a part of Iowa Planning Region 2, is also included in this study because of some natural similarities to the remainder of the region and the importance of Red Rock Reservoir to the communities below it along the Des Moines River.

This region has been chosen for this pilot land-use study because it reflects many of the problems facing rural Iowa. With the possible exception of the rapid expansion of urban areas onto agricultural lands, many of these problems may be more acute here. Especially troublesome has been the difficulty of obtaining high quality water supplies.

Additionally, in the recent past the region has been losing population, its coal industry declining, and railroad system curtailed. These trends, combined with the fact that the region does not contain large areas of the highest quality agricultural land present elsewhere in Iowa, have made these eleven counties some of the poorest in Iowa. The average family income is $7,258 compared with the statewide average of $9,018 (1970 figures). However, recent changes in the Eleven-County region may, when coupled with proper planning, reverse these trends. Construction of Rathbun and Red Rock reservoirs may promote tourism and the current interest in Iowa's coal may revitalize the region's coal industry.



POPULATION TRENDS

	1900	1920	1940	1960	1970
APPANOOSE	25,927	30,535	24,245	16,015	15,007
Centerville	5,256	8,486	8,413	6,629	6,531
DAVIS	15,620	12,574	11,136	9,199	8,207
Bloomfield	2,105	2,064	2,732	2,771	2,718
JEFFERSON	17,437	16,440	15,762	15,818	15,774
Fairfield	4,689	5,948	6,773	8,054	8,715
KEOKUK	24,979	20,983	18,906	15,492	13,943
Sigourney	1,952	2,210	2,355	2,387	2,319
LUCAS	16,126	15,686	14,571	10,923	10,116
Chariton	3,989	5,175	5,754	5,042	5,009
MAHASKA	34,273	26,270	26,485	23,602	22,117
Oskaloosa	9,212	9,427	11,024	11,053	11,224
MARION	24,159	24,957	27,019	25,886	26,352
Knoxville	3,131	3,523	6,936	7,817	7,755
MONROE	17,985	23,467	14,553	10,463	9,357
Albia	2,889	5,067	5,157	4,582	4,151
VAN BUREN	17,354	14,060	12,053	9,778	8,643
Keosaqua	1,117	851	1,040	1,023	1,018
WAPELLO	35,426	37,937	44,280	46,126	42,149
Ottumwa	18,197	23,003	31,570	33,871	29,610
WAYNE	17,491	15,378	13,308	9,800	8,405
Corydon	1,477	1,867	1,872	1,687	1,749
REGIONAL TOTALS	246,777	238,287	222,318	193,102	180,070

CRITICAL PLANNING MAP: This map is intended to focus attention on locations where there is a complex interaction between man, his activities, and the natural resources he uses. While all land and water resources are important, some are obviously of greater importance, and some are more likely to be affected by man's activity. This map emphasizes only these more critical areas. For individual problems, more information may be found on other maps contained in this book or new information must be obtained specifically for that problem. The map should in no way be interpreted as a compendium of the problems expected for planners, but rather as a guide to the most obvious ones in respect with the natural resources of the region.

One complex problem area involves the land along the major rivers of the region. Any planning there must reflect the intergrated biologic, geologic and hydrologic systems that these rivers represent. Floods, shallow groundwater, changes resulting from the construction of dams and levees, agricultural development, sand and gravel mining, forest management, wildlife habitat and management, and recreation opportunities are all interrelated functions along these rivers. Significantly, changes in one location upstream may have pronounced effects far downstream. The interrelationships of these functions, combined with the long distant effects, makes necessary not only effective local planning and cooperation, but also effective regional planning and cooperation.

Parts of the Eleven-County region are indicated as natural resource areas. Indicated are areas of prime agricultural soils, inferred coal reserves, and forests. These specific important resources need to be considered in planning. The apparently abundant coal reserves throughout much of the region perhaps constitute the most important natural resource for potential development. Current investigations into the reserves, new mining and processing techniques, and the present national and international energy situation indicate that coal strip mining will be an important future consideration. While the industry has declined for many years, the prospect is for a likely upsurge in activity. This may promote the industrial growth with a resulting increased population and expanded transportation network. The strip mining of coal and agricultural activity have not generally been compatible activites in the past. However, future technological advances may make it possible to extract coal and return the land to productive agricultural usage in several years.

Another resource in the Eleven-County region that must be considered is its forest land. By many areas' standards, the forest land of southern Iowa is small, but does constitute a limited lumber resource. Certainly it is a significant influence on wildlife and recreation. Forests also exert a much needed control on erosion. All these values should be considered in the whole complex planning process.

The primary resource is the region's agricultural land. As most of the region is agricultural, its presence as a resource is assumed throughout and not specifically indicated on the map except for the most productive soil areas. In this region any expansion of urban land is at the expense of agricultural land. Such expansion might seriously reduce the most important economic base in the region, and could cause slight reductions in agricultural products available for the United States.

Encircling the major communities are areas in which agricultural land may potentially be removed from crop production. In the recent past, the cities have grown in area – due to people moving to "country homes" on the municipal outskirts – but not in population. Most of the communities in the Eleven-County region have not been growing, but growth could again acclerate with increased development of tourism and coal mining. If there is continued decentralization and renewed population growth planning must insure the proper development of water supplies, especially where they may be affected by waste treatment facilities.

Planning will be most crucial where this change and growth from the larger towns affects the major water management areas on the major rivers or natural resource areas containing coal. For example, coal development may promote urbanization, both of which can remove agricultural land from production. In addition, urban growth over coal reserves eliminates the area as a possible location for a strip mine. The strip mines, in turn, could change local hydrologic conditions, affecting some limited areas' water supplies. The urbanization and mining operations both would tend to diminish forest land, reducing certain wildlife habitat areas. Because one change may set off a whole chain reaction of complex interactions, the areas where these are most likely to occur are indicated as red warning areas on the map.

These complex interactions are not restricted to the towns, however. The construction of Rathbun and Red Rock Reservoir create another impetus for change. Recreation, leisure, and beautiful home sites provide a lure for development. This development near important water bodies provides for equally as complex a planning problem.

Transportation facilities will change in response to the changes and growth within the region. Presently highways are being improved to provide safer routes for the expected influx of tourism around Red Rock and Rathbun Reservoirs. These routes may develop some associated service industries to assist the travelers. Change may also take place along railroads. In the recent past, the railroads have been declining, especially their spur lines. If coal becomes important again, or if the current energy shortage continues, the railroads may again become very important.

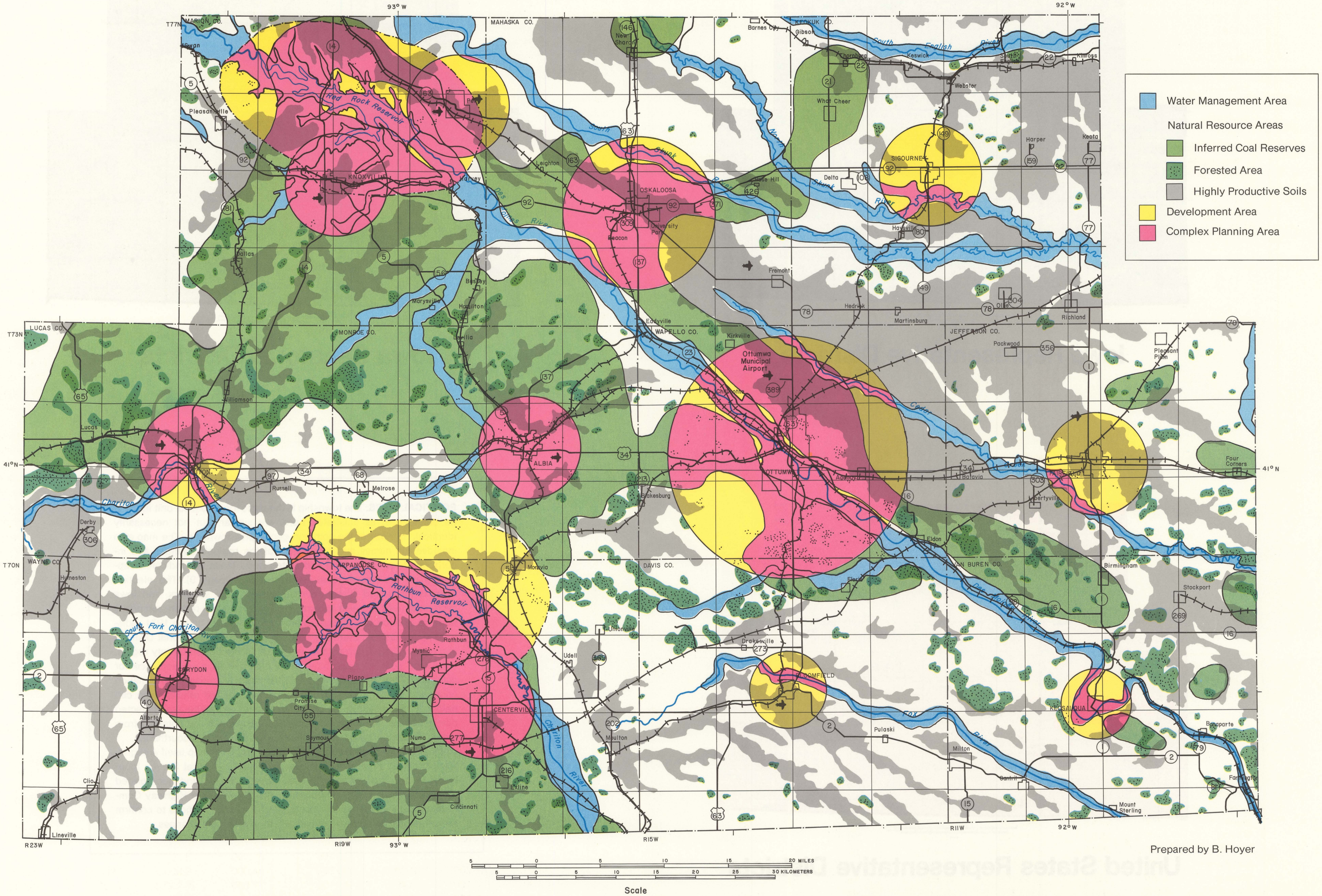
This is not **THE** Critical Planning Areas Map. This is **A** Critical Planning Areas Map. If fifty people or agencies involved in planning or managing natural resources were asked to produce a map of "Critical Planning Areas," they would produce fifty different maps. Variations would be based on the differing respective backgrounds of the people involved. However, all would reflect in some way that all natural resources together comprise a complex interrelated system. Man has many alternatives for the use of land available to him, but one use is not necessarily compatible with another. Thus, man must establish priorities, keeping in mind the complexity and interrelations of these natural systems in order both to utilize efficiently and to live as a part of his natural environment.

AGRICULTURAL FACTS

County	Number of Farms	Average Size (Acres)	Total Acreage in Farms (1972)	Corn Acreage (1972)	Average Corn Production bu/acre (1968-1972)	Soybean Acreage (1972)	Average Soybean Production bu/acre (1968-1972)	Oat Acreage (1972)	Hay Acreage (1972)	Pasture Acreage (1972)	All other acreage in farms (1972)	Hogs Marketed (1972)	Cattle Marketed (1972)	Sheep & Lambs Marketed (1972)	Poultry Raised (1972)
Appanoose	1,180	250	294,500	34,900	80	35,900	28	6,200	36,933	149,000	31,500	41,000	3,100	7,200	3,400
Davis	1,202	258	309,900	42,300	81	36,100	29	5,800	43,900	156,400	25,300	68,900	5,400	14,200	11,200
Jefferson	1,098	235	258,400	58,300	95	49,100	33	7,700	26,400	71,400	45,500	125,700	10,000	5,400	209,300
Keokuk	1,316	268	352,300	102,200	102	56,200	34	11,000	26,600	88,100	68,200	292,400	13,400	8,700	386,700
Lucas	919	276	253,600	39,000	86	27,300	29	6,900	32,100	120,800	27,300	81,900	7,400	7,800	120,200
Mahaska	1,508	226	340,100	108,100	100	64,600	36	12,800	25,900	62,900	65,800	309,800	48,100	4,900	130,700
Marion	1,437	218	313,700	79,700	93	49,100	34	12,100	26,900	84,500	61,500	202,700	16,700	12,900	71,100
Monroe	920	270	248,400	31,900	82	20,600	28	4,400	27,700	137,400	26,400	61,000	2,500	5,000	5,800
Van Buren	1,071	271	290,200	45,800	86	38,200	29	5,600	27,300	142,700	30,500	84,000	3,900	3,800	6,100
Wapello	1,307	188	245,100	49,800	96	41,500	32	5,300	22,100	85,400	41,100	77,600	8,200	3,700	19,700
Wayne	1,010	314	317,600	54,600	88	41,800	30	9,500	43,800	128,500	39,500	75,700	9,600	3,700	162,800
State	132,610	254	33,710,600	11,228,500	96	5,964,300	33	1,181,700	2,279,700	6,735,200	6,321,200	17,781,400	3,736,000	484,300	13,563,000

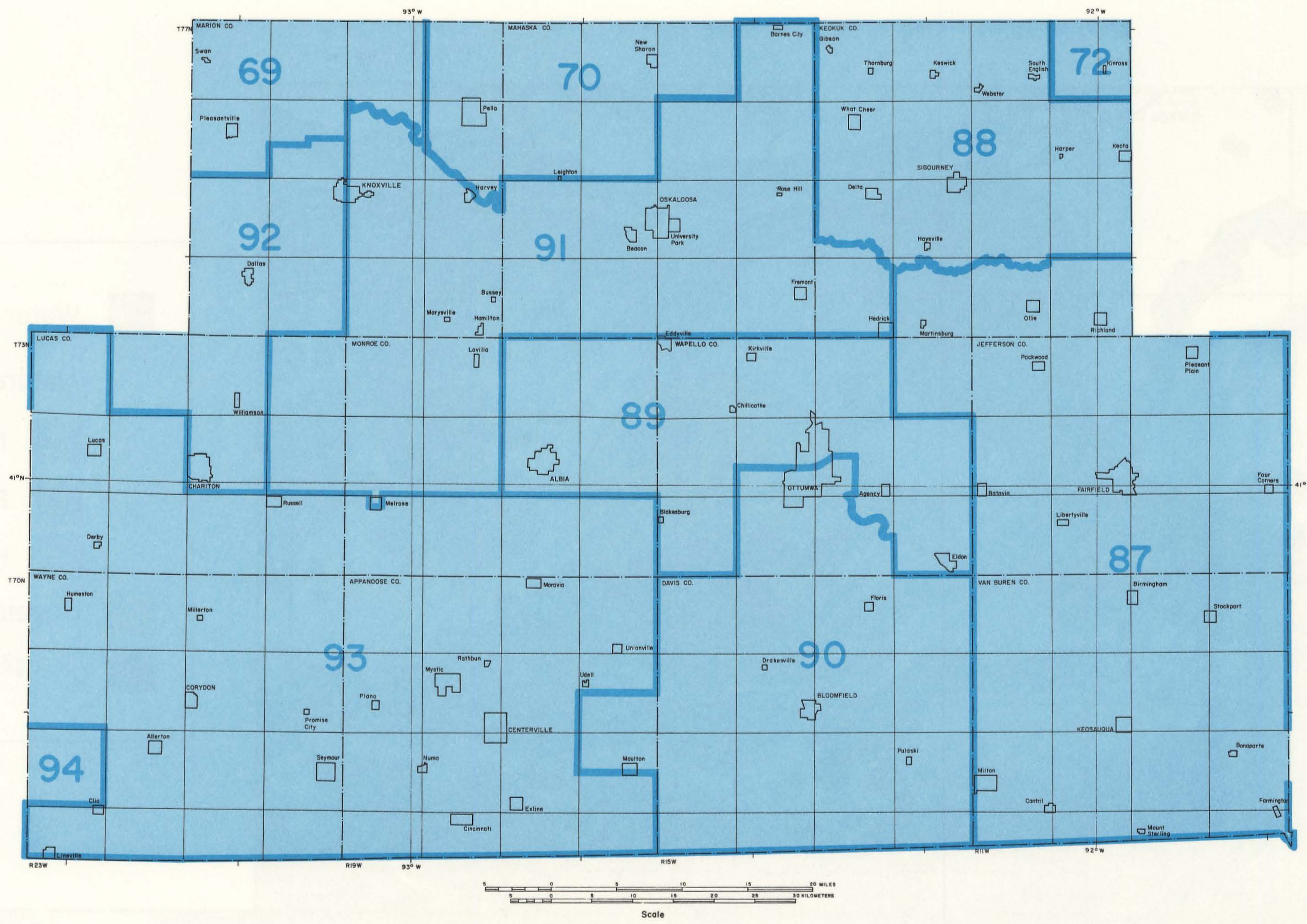
U.S. Dept of Agr., Statistical Reporting Serv., 1968-1972, Iowa Annual Farm Census.

CRITICAL PLANNING AREAS

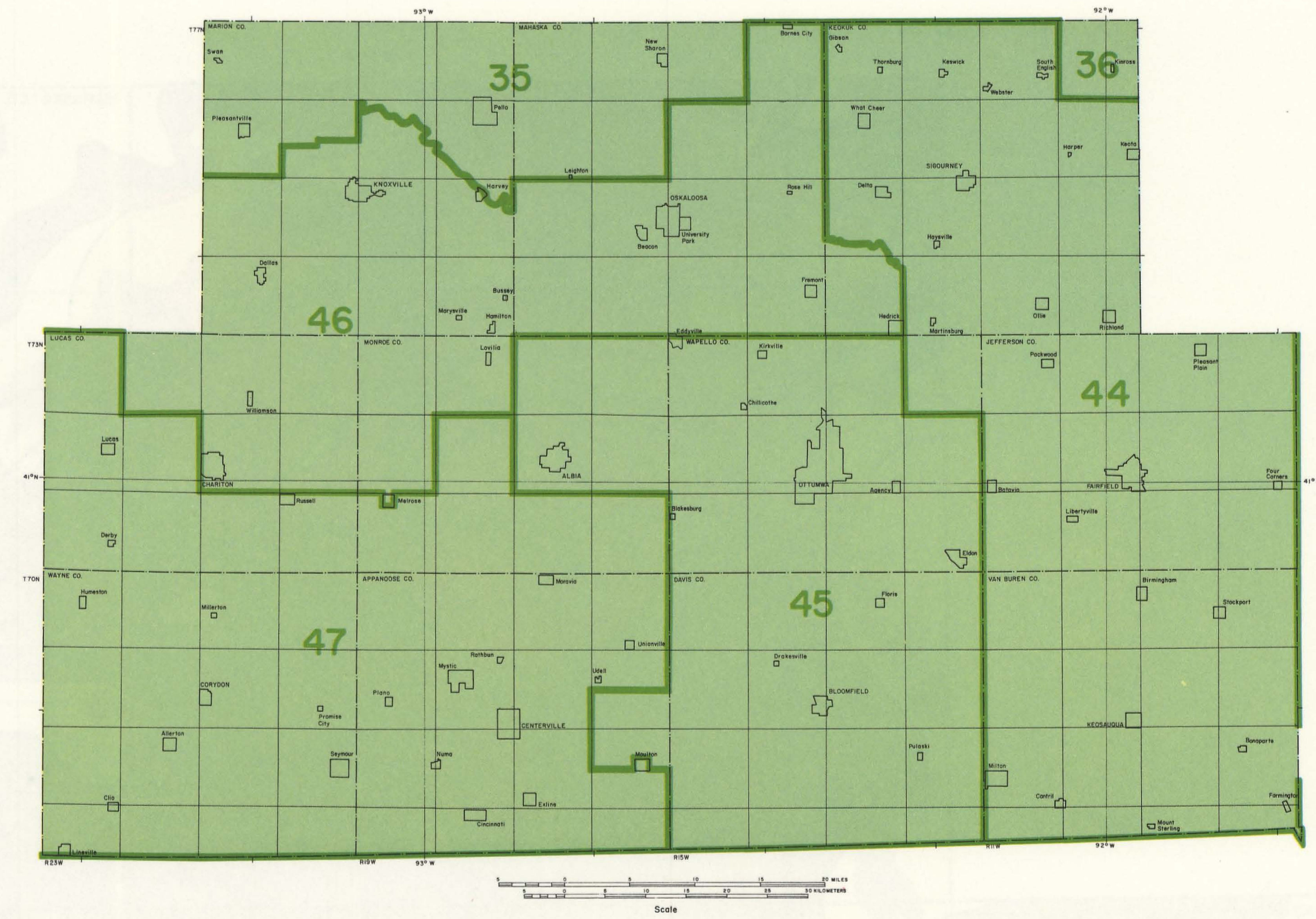


Prepared by B. Hoyer

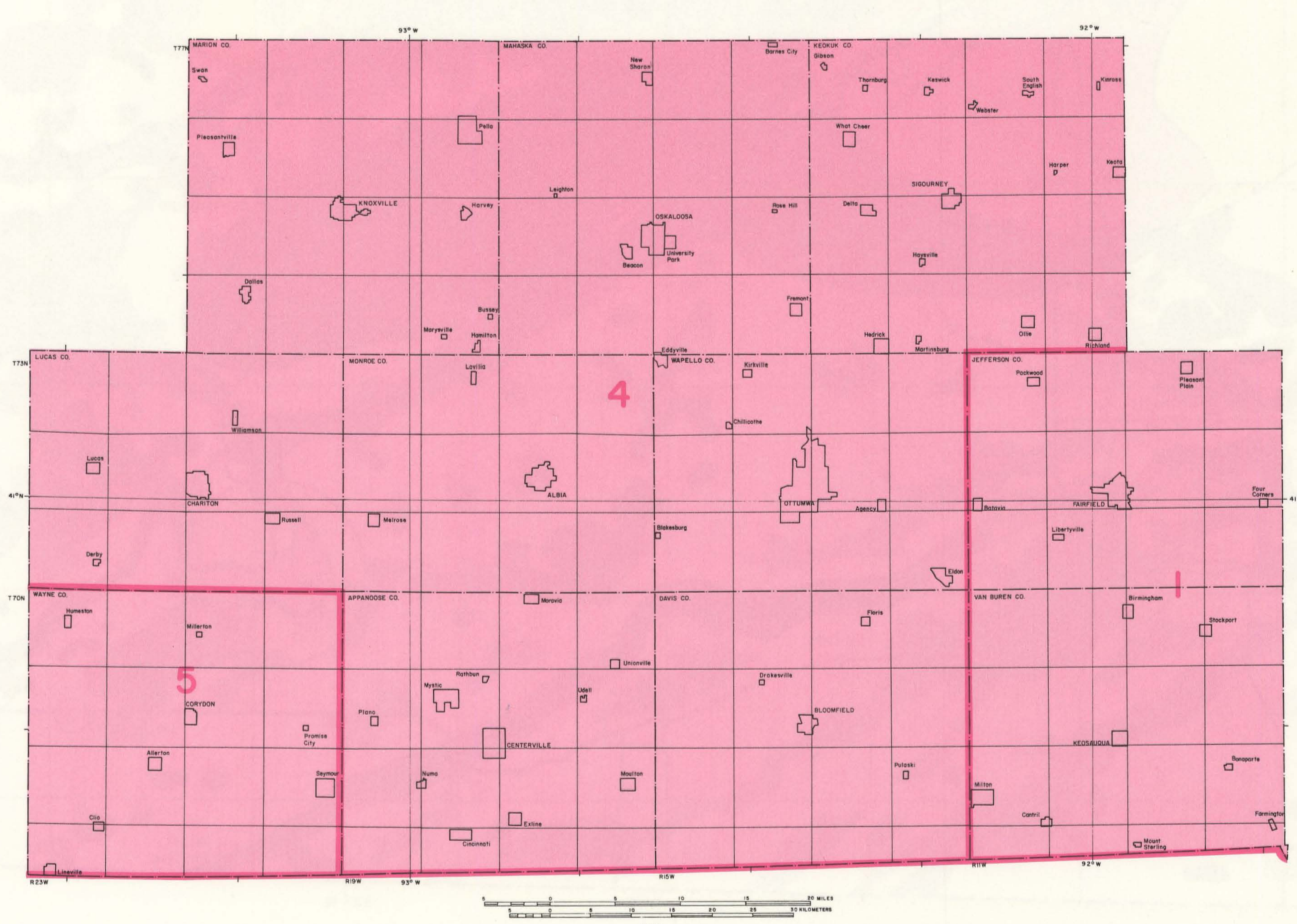
POLITICAL DISTRICTS



Iowa Representative Districts



Iowa Senatorial Districts



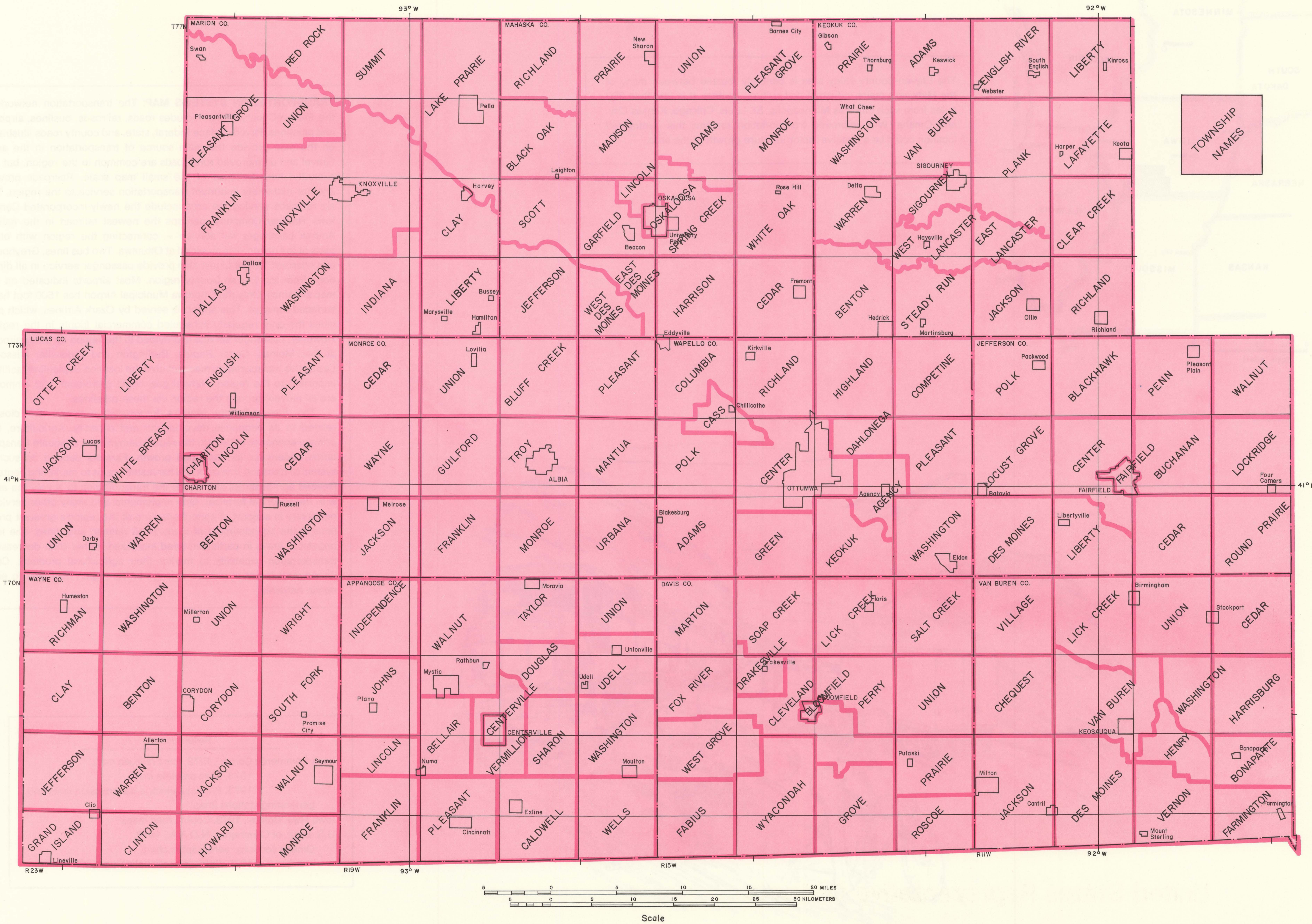
United States Representative Districts

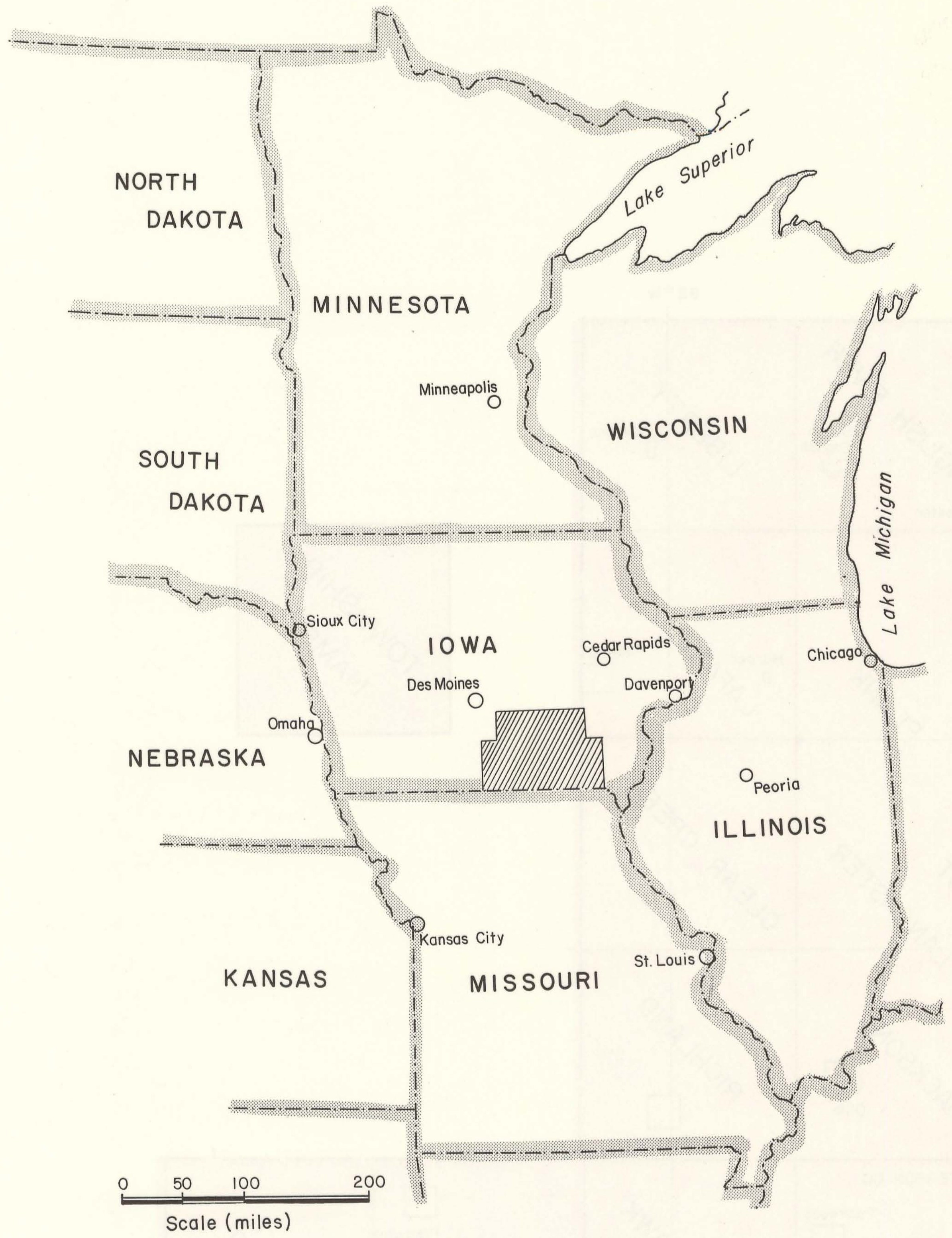
POLITICAL MAPS: The township is the basic local political unit in Iowa. Its boundaries, as illustrated here, are similar, but not necessarily identical, to those of the common geographic township. The map also includes the names and boundaries of the region's counties and incorporated towns. Federal and state-owned lands are indicated separately on the Recreational Resources map (page 9). The election districts for United States representatives, Iowa senators, and Iowa representatives are also shown. The Eleven-County region comprises portions of three U.S. Congressional districts based on the 1971 redistricting. In addition, there are portions of six State Senatorial Districts and eleven State Representative Districts in the Eleven-County region.

These political maps have been provided as a convenience for planners. Their inclusion may enable them to correlate information contained in this atlas with the respective elected officials who can help to implement any possible action. Names and addresses of elected officials of the various political districts shown may be obtained from public libraries or by contacting the appropriate county courthouse.

The county boundaries, in addition to the base map itself and grid, were obtained from Army Map Service/U.S. Geological Survey topographic maps, NK Series, 1:250,000 scale. Township and incorporated town boundaries were obtained from 1971 Iowa State Highway Commission maps. Visits were made to all of the county offices to confirm these boundaries and to obtain information on recent changes.

Political Townships





The Eleven-County study area is centrally located between many of the Midwest's major industrial and cultural centers. It is less than 300 miles from such cities as Minneapolis, St. Louis, Chicago, Kansas City, and Omaha. With improved transportation systems this centralized location could be a positive factor in future growth of the area.

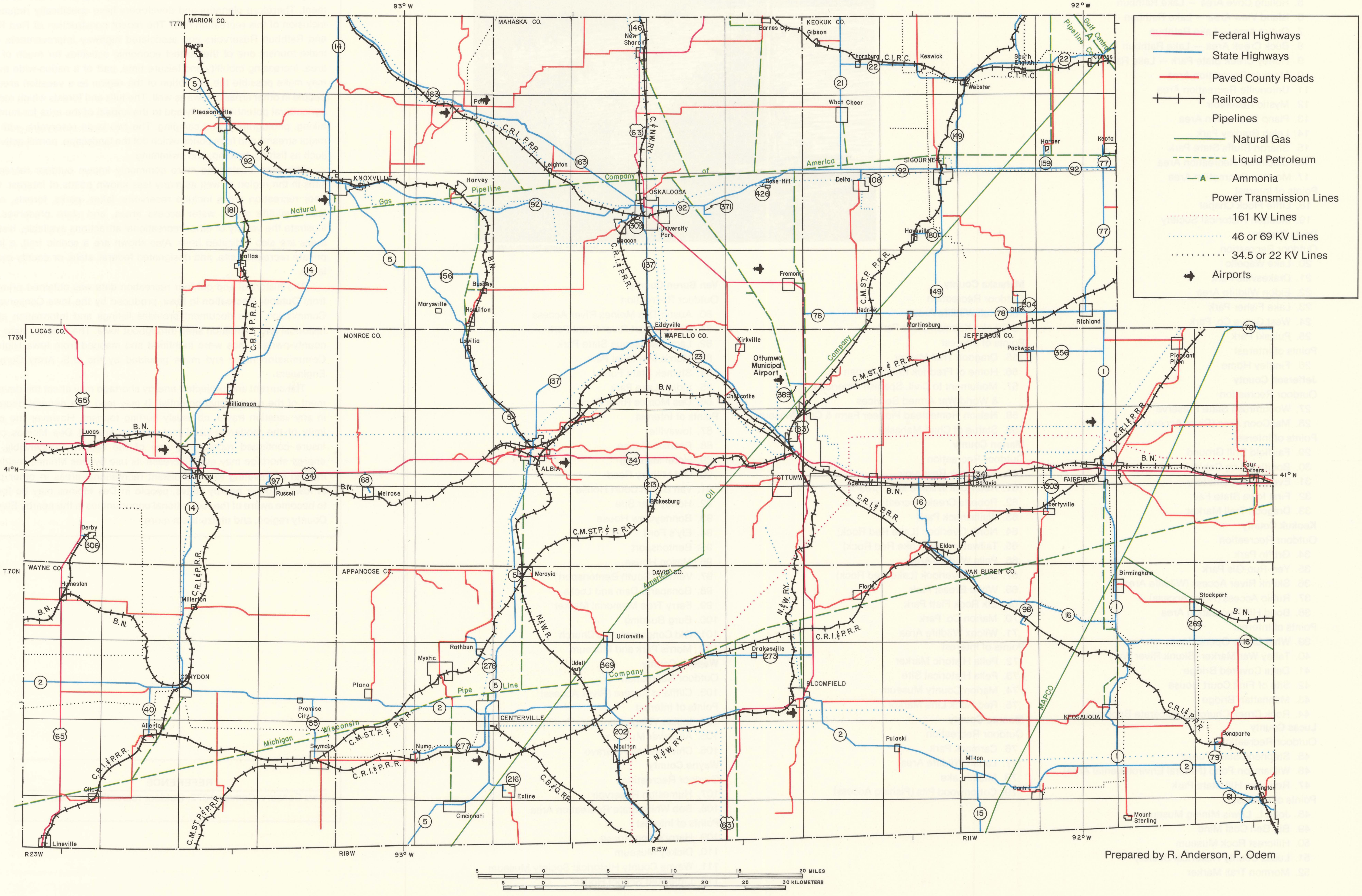
TRANSPORTATION SYSTEMS MAP: The transportation network of the Eleven-County region includes roads, railroads, buslines, airports, and pipelines. Paved-surface federal, state, and county roads illustrated on the map provide the main source of transportation in the area. Gravel and unimproved rural roads are common in the region, but are excluded here because of the small map scale. Railroads provide another extremely important transportation service to the region. The six railroads serving the area include the newly-incorporated Central Iowa Railway Company, perhaps the newest railroad in the nation. Amtrak passenger rail service — connecting the region with other parts of the nation — is provided at Ottumwa. Two bus lines, Greyhound and Missouri Transit Lines, also provide passenger service in all directions from the Eleven-County region. Most airports indicated on the map are small. Only the Ottumwa Municipal Airport has 1500 foot hard-surfaced runways. This airport is served by Ozark Airlines, which provides the only regularly scheduled commercial flights in the region. However, passenger service is provided to the region by other airports at Des Moines, Cedar Rapids, Burlington and Kirksville, Missouri. Lastly, this transportation map includes the location of pipeline facilities important to the region. Natural gas, liquid petroleum, and ammonia are all moved through the region via these pipelines.

The Eleven-County region's transportation needs are closely related to its economic development and capacity. Agriculture, the primary economic activity in the region demands an adequate transportation system for its continued growth. Farmers depend on such a system to transport livestock and harvested grains to marketing centers. Related agri-business also needs the transportation to supply the area with the essential fertilizer, farm implements, and many other services necessary in support of agriculture. One of the region's greatest problems is the abandonment of many small railroad spur lines. The less populated areas in particular, need increased, rather than decreased, transportation capability to market their agricultural products. Continued curtailment of railroad mileage in the region may lead to economic hardship.

References

Iowa Commerce Comm., 1972, Iowa railroad map.
1973, Iowa pipeline map.
1973, Principal electric transmission lines and generating stations (map).
Iowa Hwy. Comm., 1973, County road maps.
U.S. Dept. of Commerce, N.O.A.A., 1972, Omaha sectional aerographic chart.
1972, Chicago sectional aerographic chart.

TRANSPORTATION SYSTEMS



Prepared by R. Anderson, P. Odem

Revised from Outdoor Recreation in Iowa

Appanoose County
Outdoor Recreation
1. Rathbun Reservoir
2. Bridgeview Area — Lake Rathbun
3. Glenwood Area — Lake Rathbun
4. Southfork Area — Lake Rathbun
5. Rolling Cove Area — Lake Rathbun
6. Island View Area — Lake Rathbun
7. Outlet Area — Lake Rathbun
8. Buck Creek Area — Lake Rathbun
9. Honey Creek State Park — Lake Rathbun
10. Moravia Recreation Area
11. Unionville Recreation Area
12. Mystic Reservoir
13. Plano Recreation Area
14. Lelah Bradley Park
15. Sharon Bluffs State Park
16. Cincinnati Recreation Area
17. Moulton Recreation Area

Points of Interest
18. Little Flock Chapel
19. Moulton Historical Society

Davis County
Outdoor Recreation
20. Lake Wapello
21. Drakesville Park
22. Eldon Wildlife Area
23. Lake Fisher Park
24. West Grove Co. Park
25. Pulaski Park

Points of Interest
26. Findley Home

Jefferson County
Outdoor Recreation
27. Woodthrush State Preserve
28. MacCoon Area (River Access)

Points of Interest
29. Fairfield Drill Ground
30. Bonifield Log Cabin
31. Evergreen Cemetery
32. First Iowa State Fair
33. Dragoon Trail Marker

Keokuk County
Outdoor Recreation
34. Griffin Park
35. Yen-Ruo-Gis Park
36. Skunk River Access (Wildlife Area)
37. Rubio Access (River Access)
38. Bond Hill Recreation Area

Points of Interest
39. What Cheer Opera House
40. Talley War Marker (Skunk River War)
41. Delta Covered Bridge
42. Site of First Court House
43. Manhattan Bridge
44. Rock Creek Church of Separate Baptists

Lucas County
Outdoor Recreation
45. Stephens State Forest
46. Williamson Pond (Natural Environmental Area)
47. Red Haw Hill State Park

Points of Interest
48. John L. Lewis Mining Museum
49. Big Ben Coal Mine
50. Hillcrest Rock Museum
51. Lucas County Historical Society
52. Mormon Trail Marker

Mahaska County
Outdoor Recreation
53. Hull Wildlife Area
54. Lake Keomah State Park

Points of Interest
55. Dragoon Trail Marker
56. Home of Fredrick Knight Logan
57. Monument to Civil, Spanish American, & World War Armed Services
58. Nelson Homestead Pioneer Farm & Craft Museum
59. Statue of Chief Mahaska

Marion County
Outdoor Recreation
60. Red Rock Reservoir
61. Red Rock Wildlife Mgt. Area
62. Roberts Creek Recreation Area
63. Wallashuck Park
64. North Overlook (Lake Red Rock)
65. Tailwater Area (Lake Red Rock)
66. Pella Wildlife Area
67. South Overlook (Lake Red Rock)
68. White Breast Park
69. Elk Rock Flatt Park
70. Marion Co. Park
71. Wilcox Wildlife Area

Points of Interest
72. Pella Historic Marker
73. Pella Historical Site
74. Marion County Museum
75. Red Rock Line Marker

Monroe County
Outdoor Recreation
76. Carmack Park
77. Lahart Wildlife Area
78. Miami Lake
79. Cottonwood Pits (Fishing Access)

Van Buren County
Outdoor Recreation
80. Austin-Des Moines River Access
81. Bentonsport River Front Park
82. Lacy-Keosauqua State Park
83. Morris Memorial Park
84. Shimek State Forest
85. Indian Lake Park
86. Des Moines River Access

Points of Interest
87. Iowaville
88. Pearson House
89. Hotel Manning
90. Old Military Road
91. Van Buren Court House
92. Honey War Site
93. Bonneyview House
94. Ely's Ford
95. Bentonsport
96. Mason House
97. Vernon (South Bentonsport)
98. Bonaparte Dam and Locks
99. Ferry Tree Memorial Marker
100. Burg Building
101. Old Congregational Church
102. Morris Park and Museum

Wapello County
Outdoor Recreation
103. Cliffland Access (River Access)

Points of Interest
104. Indian Village Centinary Trading Post Marker
105. Airpower Museum
106. Chief Wapello's Grave

Wayne County
Outdoor Recreation
107. Humeston Reservoir
108. Bob White State Recreation Area

Points of Interest
109. Harry's Dog House
110. Dickey Museum
111. Wayne County Historical Society Museum
112. Little Red School House

RECREATIONAL RESOURCES MAP: Recreation may hold one of the greatest promises for the Eleven-County region's future development. Therefore planners and developers have specifically requested inclusion of this recreation map. The recent construction of Red Rock and Rathbun Reservoirs and associated highway improvements may make tourism one of the largest economic activities for much of this area. Increasing mobility and leisure time, part of a nation-wide trend, may make possible the promotion of the region as a vacation area for people in other areas of Iowa as well. The hills and forests which reduce agricultural potential actually add to the appeal of the area for hunting, hiking, photography, and camping. The two large reservoirs, with the major streams and farm ponds which dot the landscape, permit activities such as fishing, boating, and swimming.

This map locates the more commonly known outdoor recreation sites in the region as well as many less known points of interest. Outdoor recreation areas include reservoirs, lakes, parks, forests, overlooks, wildlife areas, water access areas, and state preserves. To illustrate the variety of other recreational attractions available, historic areas are also indicated here. Also shown are a scenic trail, a large private recreation site, and designated federal, state, or county-owned lands.

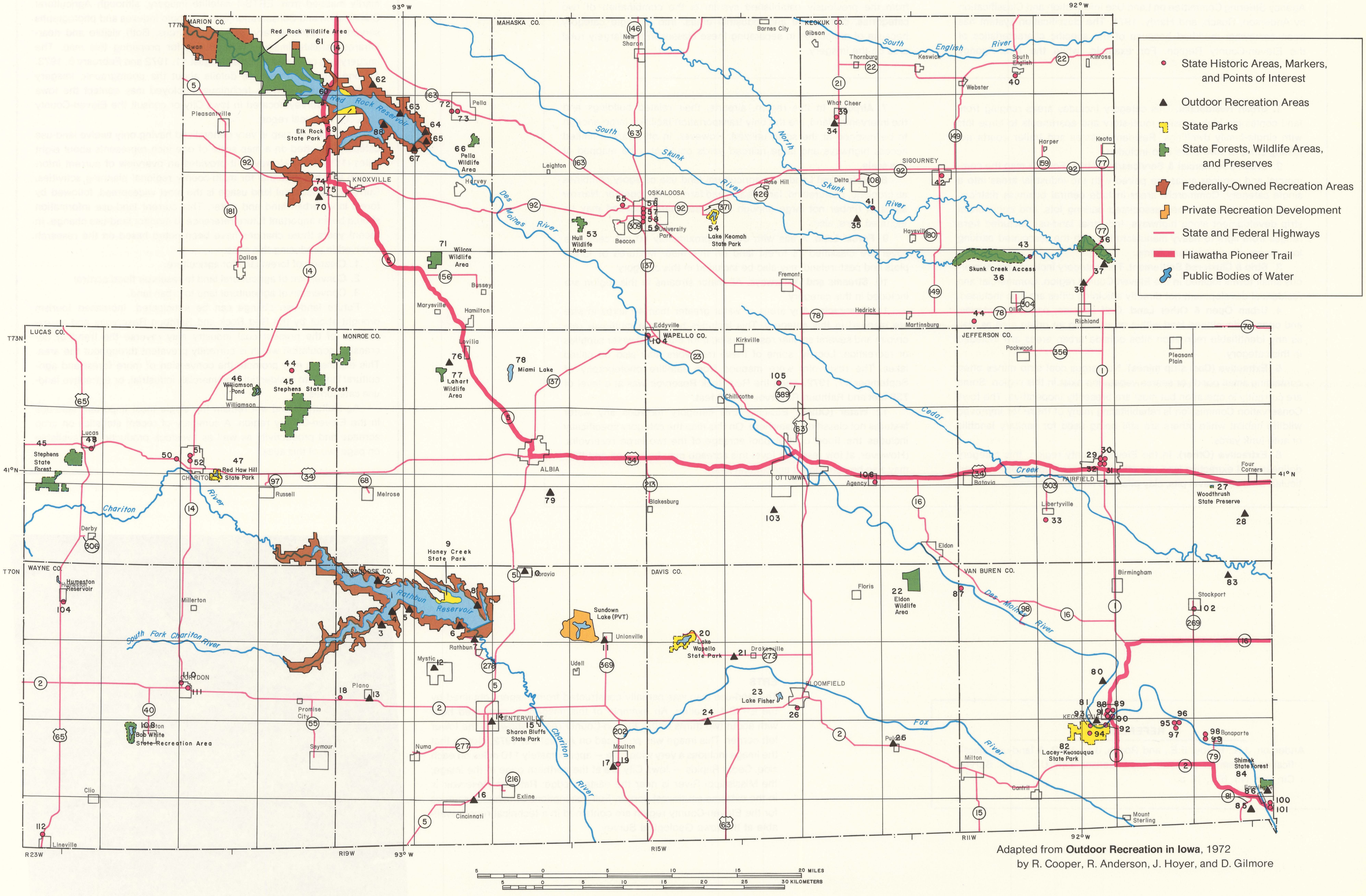
The historical and outdoor recreation data was obtained primarily from **Outdoor Recreation in Iowa**, produced by the Iowa Conservation Commission. This document provides listings and information about historical and recreation sites throughout Iowa. The federal, state, and county-owned lands were identified and mapped from Iowa Highway Commission maps and maps provided by the U.S. Army Corps of Engineers.

The current and projected energy shortage may affect the development of the recreational potential. It may lead to a general decrease in any vacation travel, obviously hurting tourism. However the proximity of the moderate-sized metropolitan area of Des Moines could insure continued recreational use of the region. Conceivably, the energy shortage may even increase its use by Des Moines residents. Instead of traveling to more distant recreational areas in other parts of Iowa or other nearby states, people in Des Moines may be forced to become aware of the recreational opportunities in the nearby Eleven-County region, and utilize them more.

REFERENCE

Iowa Conserv. Comm., 1972, Outdoor recreation in Iowa, v. 5.

RECREATIONAL RESOURCES



Adapted from **Outdoor Recreation in Iowa**, 1972
by R. Cooper, R. Anderson, J. Hoyer, and D. Gilmore

Land-Use Categories:

This map presents current land-use as mapped from 1972-73 ERTS-1 (Earth Resources Technology Satellite) imagery. In all, twelve categories of land-use were identified. These categories were derived from a land-use classification system developed for the federal Inter-Agency Steering Committee on Land Use Information and Classification by Anderson, Roach, and Hardy, 1971. The classification system has been somewhat modified because of the specific characteristics of the Eleven-County Region. For example, while the Inter-Agency Steering Committee's system does not include a category for coal strip mines, this category was added because of the distinctive appearance of the strip mines on the imagery and their extensive occurrence and importance for the Eleven-County region. Another change from the previously established system is the combination of two categories, commercial and industrial areas, into a single category because of difficulties in separating these classes in this largely rural area on the imagery.

1. **Urban Residential**. This category includes areas ranging from land containing high density, multi-story and apartments to large lots with single-family dwellings. Residential areas and trailer courts adjoining cities or towns are also included.

2. **Urban Commercial & Services/Industrial**. For this map the commercial and services areas are paired with the industrial areas into a single category. Commercial areas include central business districts, shopping centers, and their associated parking lots, and commercial strip development along highways. Industrial land-use included here ranges from light to heavy manufacturing with the associated parking lots, power plants, and tank farms.

3. **Strip & Clustered Settlement**. This category includes the numerous small towns located in the Eleven-County region. Commercial and residential development not directly adjoining cities are also included.

4. **Urban Open & Other Land**. Golf courses, parks, cemetaries, and open undeveloped land within or adjoining an urban area as well as any identifiable recreation sites outside urban areas are included in this category.

5. **Extractive (Coal strip mines)**. Numerous coal strip mines often containing small ponds or sparse vegetation exist in this region. Some are currently in operation but most are presently inoperative. The Iowa Conservation Commission is rehabilitating many of these for improved wildlife habitat while others are still being used for sanitary landfills or auto junk yards.

6. **Extractive (Other)**. In the Eleven-County region, this category delineates all extractive land-use other than coal strip mines — in particular, sand and gravel pits, clay pits, and limestone quarries.

7. **Airports**. In this region, airports, their related buildings and the intervening land, are the only transportation facilities large enough to be mapped at the scale utilized. However, in other areas limited access highways and large railroad yards could also be mapped at this scale.

8. **Agricultural Land**. The agricultural land use category combines all cropland, pastureland, farmsteads, and farm ponds together. Narrow strips of timber not large enough to be separately mapped may be included here, also.

9. **Forest Land**. Areas with over approximately 40 per cent tree cover are classified as forest land on this map. Mixtures of forest plots and pastureland may also be included in this category.

10. **Streams and Waterways**. All major streams in this region are included in this category.

11. **Reservoirs**. Any areas of water greater than 40 acres in size are mapped in this category. This includes two large multi-use reservoirs and several smaller reservoirs built for municipal water supplies or recreation. Locally, some of these reservoirs may also be called lakes. The reservoirs were mapped from satellite photography of September 17, 1972, when the Red Rock Reservoir was at a level of 738 feet and Rathbun Reservoir at 906 feet.

12. **Water (Other)**. Basically this category includes any water features not classified elsewhere. On this map the category specifically includes the flood control pool acreage of the two large reservoirs. (However, at low reservoir level this acreage may be farmed and thus may also be considered agricultural land.)

LAND-USE MAP: The land use categories presented here were primarily mapped from ERTS-1 satellite imagery, although Agricultural Stabilization and Conservation Service photo indexes and photographs served as supplementary reference sources. Both visible and near-infrared satellite imagery was utilized for preparing this map. The imagery was collected between August 11, 1972 and February 8, 1973. Anyone interested in more details about the photographic imagery available or the analysis technique employed may contact the Iowa Geological Survey, located in Iowa City or consult the Eleven-County project's technical report.

This land-use map is very generalized having only twelve land-use categories plotted on a map scale of one inch represents about eight miles (1:250,000). However, it provides an overview of current information and has potential for multi-county regional planning activities. Currently agricultural land usage is the most widespread, followed by forest land, urban land and water. This current land-use information should be an important future reference to monitor land-use change. In recent years three changes have been noted based on the research involved in producing this atlas:

1. Clearing of forest land for agriculture.
2. Conversion of agricultural land to reservoir flood control.
3. Conversion of agricultural land to urban land.

Future land-use change can be anticipated. Increased tourism brought about by the Red Rock and Rathbun Reservoirs and an expansion of the present coal industry may reverse the trend of decreasing population which is currently prevalent throughout the area. This expansion may promote the conversion of more forest and agricultural land into residential, commercial, industrial, or extractive land-use categories.

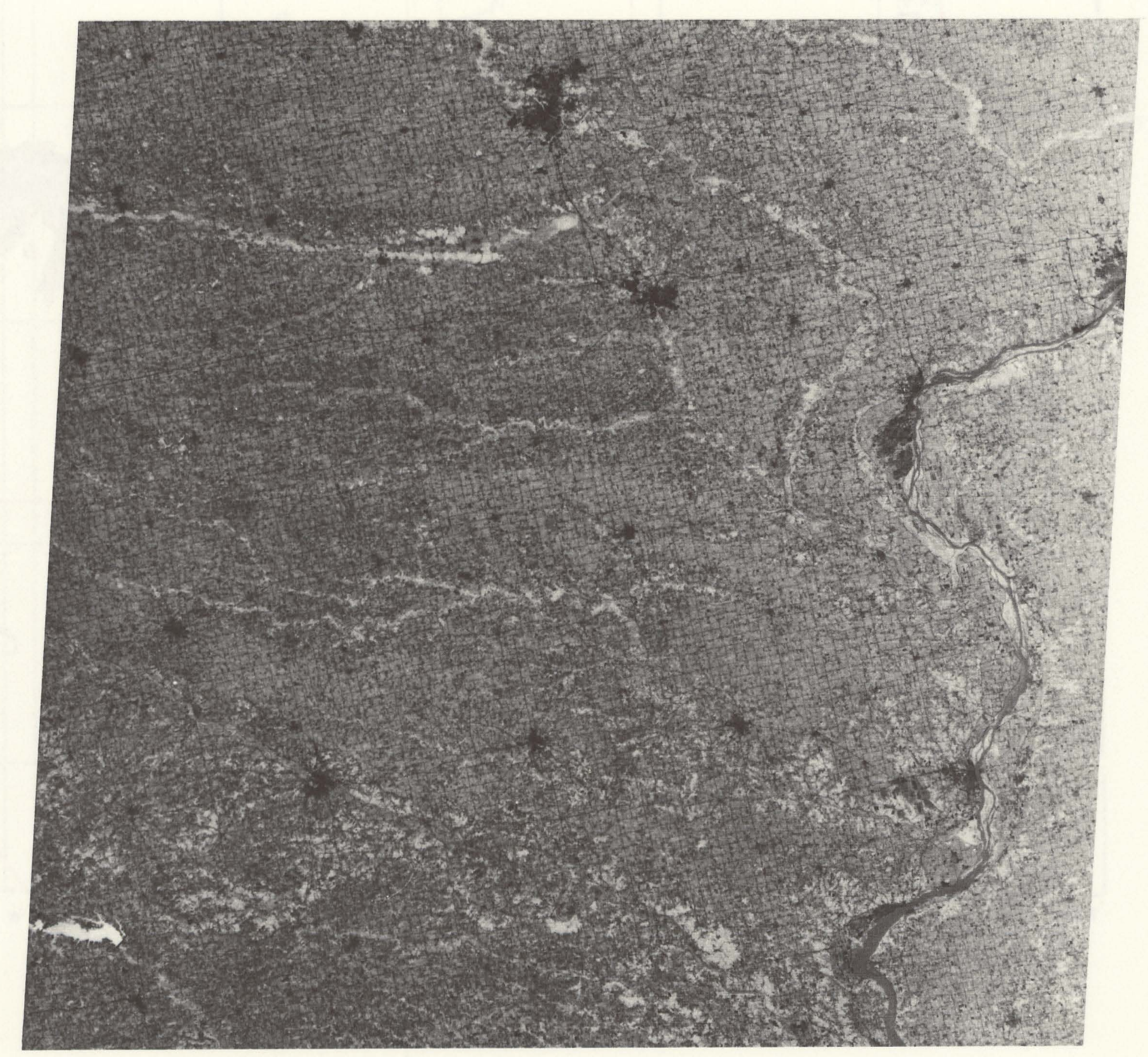
Agriculture is and will remain the single most important land-use in the Eleven-County region. A summary of recent statistics on crop acreage and productivity as well as livestock production is available on page two of this atlas.

REFERENCE

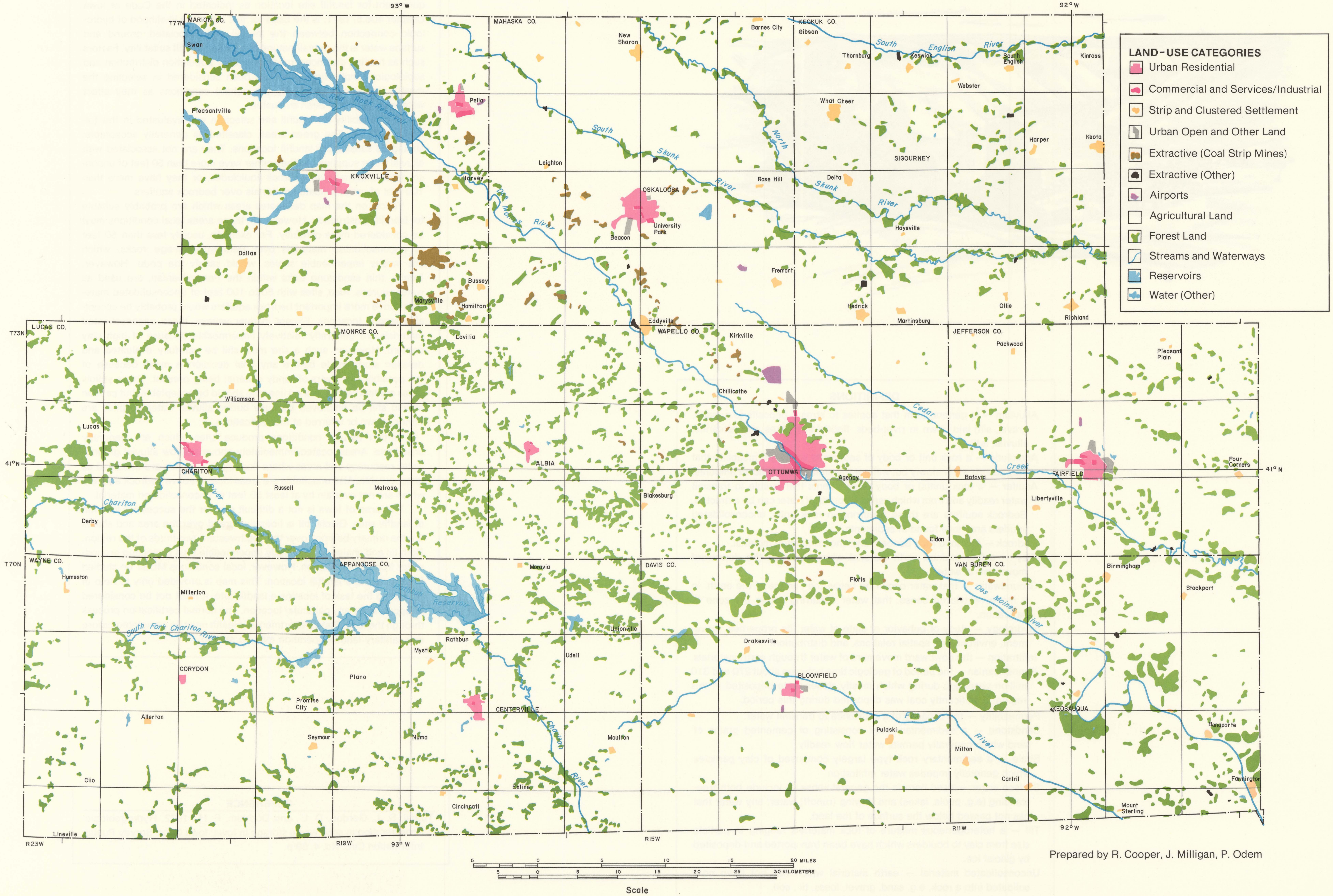
Anderson, J.R., Hardy, E.E., and Roach, J.T., 1972, A land-use classification system for use with remote-sensor data: U.S. Geol. Survey Cir. Ser. No. 671, 16 p.

ERTS

The land-use map was partially constructed from imagery obtained by the ERTS-1 satellite. An example of this imagery is presented here with about two thirds of the Eleven-County region shown in the lower left corner. This image was produced on August 29, 1972. Notice that the image includes a very wide area — approximately 110 miles on each side. Cedar Rapids — Iowa City are at the northern edge of the image; the Mississippi River is near the eastern edge; Rathbun Reservoir is in the extreme southwest corner. Full descriptions of imagery sources for the Eleven-County region are contained in a technical report available at the Iowa Geological Survey.



LAND-USE



Prepared by R. Cooper, J. Milligan, P. Odem

SUITABILITY FOR LANDFILL SITE LOCATION MAP: The legal requirement for landfill site location as indicated in the Code of Iowa Chapter 406.5, 1971, is the basis for this map. The likelihood of hydrologic connection between the landfill and associated ground and surface water is the overall natural criteria for landfill suitability. Factors such as hauling distances, road conditions, population distribution and sociological implications have not been considered in selecting the most suitable locations. Only the natural conditions as they affect water supplies have been evaluated.

The suitability for landfill site selection was evaluated in the following manner. The green areas, classifed as generally acceptable, should be satisfactory landfill locations. They are not associated with alluvial water supplies and they either have more than 50 feet of unconsolidated material over bedrock aquicludes, or they have more than 100 feet of unconsolidated materials over bedrock aquifers.

Yellow on the map delineates areas which are probably suitable for landfill construction. However, in these areas local conditions must be considered more carefully. For example, usually less than 50 feet of unconsolidated materials over Pennsylvanian-age rocks, which are mostly impermeable shales, would satisfy the code. However, locally, thin sandstone units within the Pennsylvanian, are used as water sources. Also, sites with 50 to 100 feet of unconsolidated materials above more important bedrock aquifers would probably be acceptable landfill locations. Except in river valleys, these unconsolidated materials are generally relatively impermeable because of high clay content. However, such a site must still be carefully evaluated and detailed study made before any final decision is made because of the possibility of layers of sandy material being present. Those yellow areas outlined with a dashed line also should be acceptable, but caution should still be employed because buried alluvial water supplies are either known or inferred at these locations.

Certain natural conditions produce sites which are generally unsuitable. Areas located immediately above shallow alluvial groundwater resources and areas where flooding is common are indicated as unacceptable. Also unsuitable are areas located above bedrock aquifers which are not overlain by at least 50 feet of unconsolidated material.

This area of Iowa is not a difficult one for the successful location of landfill sites. Glacial till is liberally spread over the area and shales are the primary bedrock over the southwestern two-thirds of the region. Both till and shales are generally impermeable thus protecting groundwater from contamination. However, local conditions MUST be studied for any possible landfill location. This map is provided only to help in beginning the task of locating a landfill site. It must not be considered as approval for any particular location. The normal certification process through the Iowa State Department of Health must be completed before any sanitary landfill operation may be started.

DEFINITIONS

Alluvium — a general term that applies to stream deposits (e.g. sand, gravel, silt) laid down in river-beds, floodplains, lakes and estuaries; alluvial, adj.

Aquiclude — a rock unit or body of sediments of low permeability that may absorb water slowly but will not transmit it in significant amounts.

Aquifer — a rock unit(s) or body of sediments that is able to transmit water readily and from which useful amounts of water can be extracted. Bedrock aquifers are those occurring in rock units; unconsolidated aquifers are those found in sediments.

Bedrock — the solid rock beneath any unconsolidated material.

Clay — a fine grained earth material which impedes the downward movement of water.

Groundwater — that water occurring below the surface of the earth. In a more restricted sense, that water occurring within the zone of saturation.

Hydrology — study of behavior or state of water, its properties, movement, environment, spatial relations, and distribution.

Infiltration — the downward movement of water through earth materials.

Pennsylvanian — the period of geologic time between about 270 and 310 million years ago during which mostly shales were deposited in this region. Significantly coal was deposited during this period.

Permeability — the capacity of a substance to transmit water.

Sandstone — a sedimentary rock consisting of cemented grains of sand which generally permits water flow readily.

Shale — a sedimentary rock type largely composed of clay particles which generally impedes water infiltration.

Surface water — used here in the general sense to include both free-standing (e.g. pools, lakes) and flowing (runoff) water; any water that has not passed below the surface of the land.

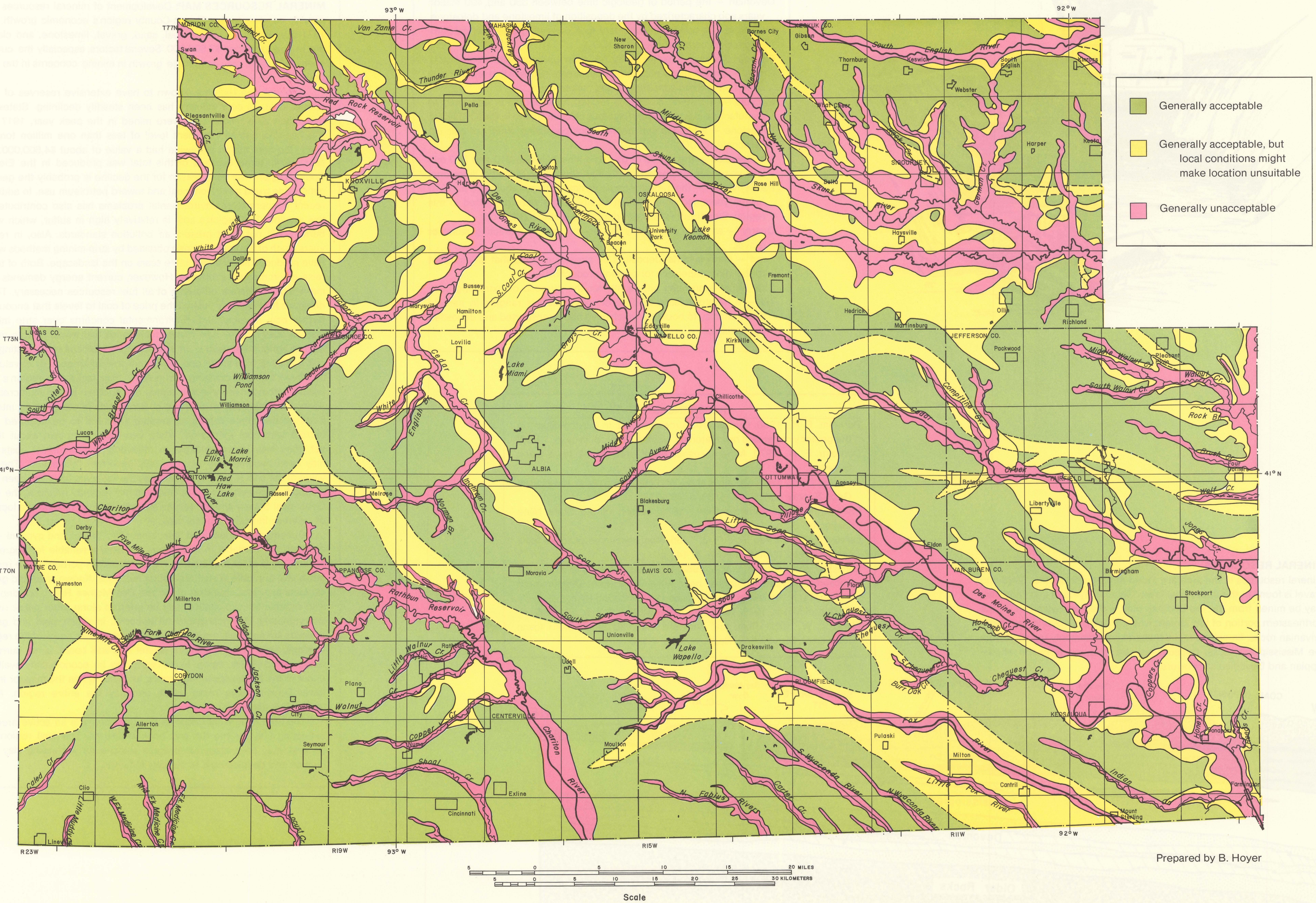
Till — a heterogeneous mixture of rock materials ranging in particle size from clay to boulders which have been transported and deposited by glacial ice.

Unconsolidated material — earth material which has not been consolidated into a rock, e.g. sand, gravel, loess, till, soil.

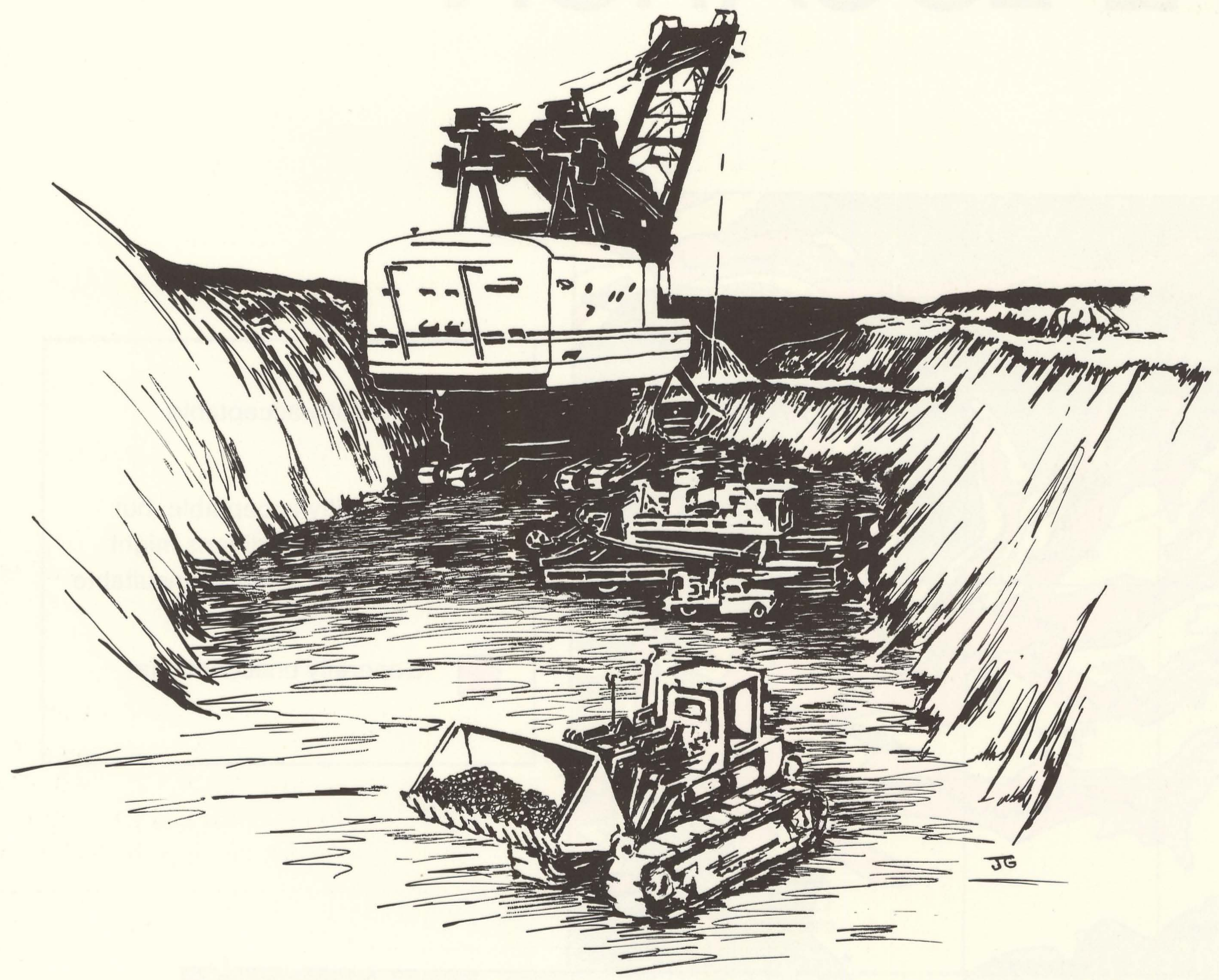
REFERENCE

Tuthill, S. J., Gordon, D. L., and Dorheim, F. H., 1972, Hydrogeologic consideration in solid waste storage in Iowa: Iowa Geol. Survey Public Information Circ. No. 4, 59 p.

SUITABILITY FOR LANDFILL SITE LOCATION



Prepared by B. Hoyer



DEFINITIONS

Anhydrite — a mineral commonly formed in proximity to gypsum but not economically important (anhydrous calcium sulfate — $CaSO_4$).

Bituminous Coal — naturally occurring form of coal found in Iowa which has properties intermediate between anthracite and lignite; soft coal; commonly black, somewhat shiny and blocky in appearance.

Clay — a fine grained earth material that is used in producing drain tile, brick, and ceramic products.

Devonian — the period of geologic time between 350 and 400 million years ago characterized by the deposition of limestone and dolostone.

Dolostone — a bedded sedimentary rock consisting chiefly of calcium-magnesium carbonate — $CaMg(CO_3)_2$.

Flue-gas cleaning — technique for reducing emissions after combustion.

Gravel — earth material excavated from stream deposits that is especially important for road construction and maintenance.

Gypsum — a mineral commonly formed by evaporation and used to manufacture plaster of Paris (Hydrous calcium sulfate — $CaSO_4(2H_2O)$).

Limestone — a bedded sedimentary rock consisting chiefly of calcium carbonate ($CaCO_3$).

Mississippian — the period of geologic time between 310 and 350 million years ago characterized by the deposition of much limestone.

Pennsylvanian — the period of geologic time between about 270 and 310 million years ago during which mostly shales were deposited in this region. Significantly, coal was deposited during this period.

Quarry — an open pit, usually for the purpose of extracting stone or gravel.

Sand — earth material deposited by streams or wind that is important for building, especially for cement production.

Strip Mine — an open pit, usually for the purpose of extracting coal.

Till — a heterogeneous mixture of rock materials ranging in particle size from clay to boulders which have been transported and deposited by glacial ice.

REFERENCES

Dorheim, F. H., 1966, Gypsum resources of Iowa, in a symposium on the geology of cement raw materials: Indiana Geol. Survey, p. 73-82.

Dorheim, F. H., 1970, Mineral resources of Iowa (Map): Iowa Geol. Survey.

Gwynne, C. S., 1941, Ceramic shale and clay deposits in Iowa: Iowa Geol. Survey Ann. Rept., v. 38, p. 263-377.

Iowa Mines and Minerals Dept., 1970, Report of the State Mine Inspector, 32 p.

Landis, E. R. and Van Eck, O. J, 1965, Coal resources of Iowa: Iowa Geol. Survey Tech. Paper No. 4, 141 p.

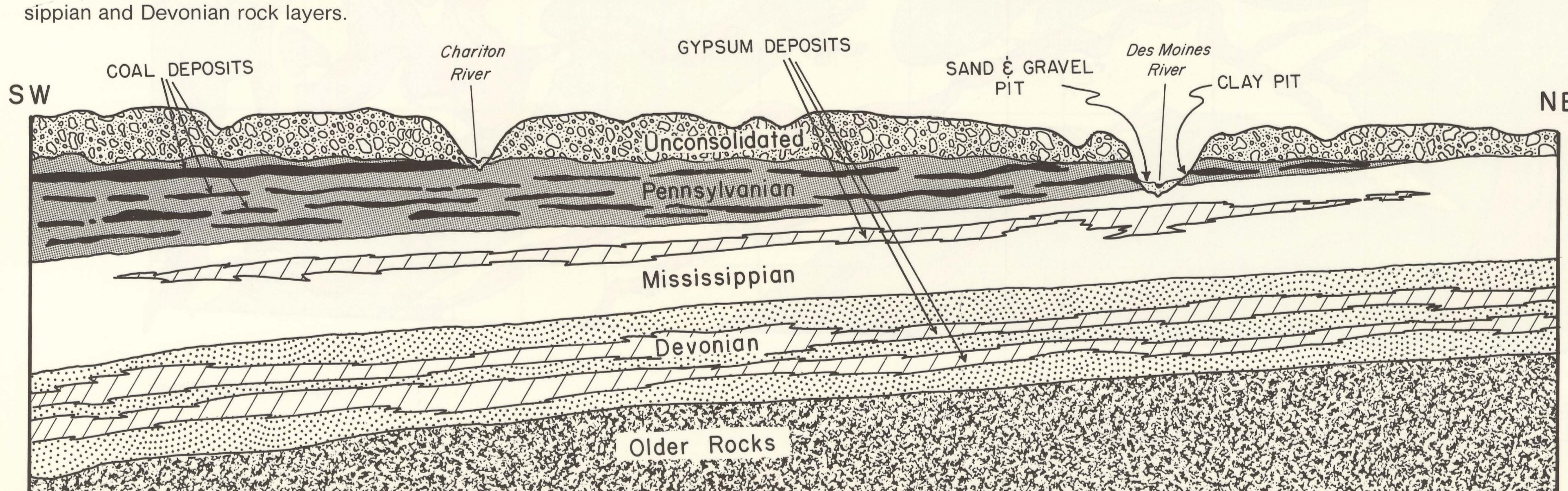
Lemish, J. and Lendlein, L. V.A., 1968, Exploration drilling to determine subsurface gypsum potential near Albia, Iowa: Eco. Development Admin. Tech. Assist. Proj., U. S. Dept. of Commerce, 87 p.

U.S. Bur. of Mines, 1973, 1971 Minerals yearbook, v. II, p. 291-306.

Wood, L. W., 1933, Road and concrete materials of southern Iowa: Iowa Geol. Survey Ann. Rept., v. 36, p. 7-310.

MINERAL RESOURCES

Mineral resources in the area are found at different depths. Sand and gravel is found in the uppermost layer. Several layers of coal, and clay may be mined from the top bedrock unit — the Pennsylvanian. In the northeastern portion of the region, where there is no overlaying Pennsylvanian rocks, limestone and dolostone are commonly quarried from the Mississippian rocks. Gypsum may be obtained from the Mississippian and Devonian rock layers.



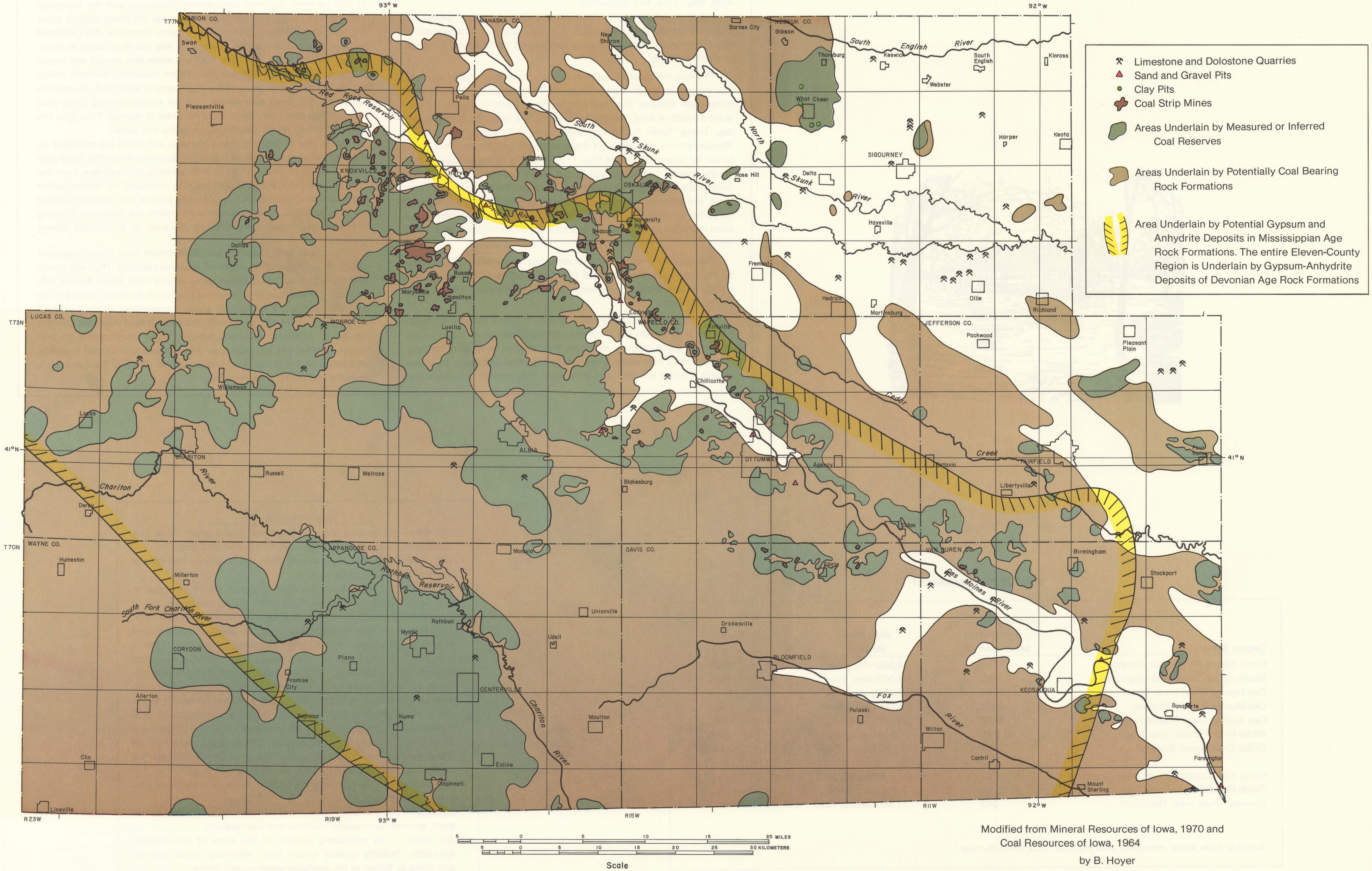
MINERAL RESOURCES MAP: Development of mineral resources may provide one key to the Eleven-County region's economic growth. The 1971 total value for mining coal, sand, gravel, limestone, and clay in the region exceeded $7,500,000. Several factors, especially the current energy situation, may encourage growth in mining concerns in the near future.

Although the region is known to have extensive reserves of bituminous coal, its coal industry has been steadily declining. Statewide, more than nine million tons were mined in the peak year, 1917, but this has declined to a present level of less than one million tons. In 1971, the coal mined statewide had a value of about $4,600,000. Approximately three quarters of this total was produced in the Eleven-County region. The main reason for the decline is probably the general nationwide trend away from coal and toward petroleum use. In addition, recent concern over environmental problems has also contributed to this decline. The region's coal is relatively high in sulfur, which when burned, will not meet present air pollution standards. Also, in recent years much of the coal has been obtained by strip mining methods which have produced many undesirable scars on the landscape. Both of these raise environmental problems. However, current energy demands may make more complete utilization of all fuel resources necessary. These demands have already pushed the price of coal to levels that encourage further coal development. Environmental concerns over strip mining may be alleviated by new mining techniques that would restore mined land to agricultural usage. In addition, new methods of extracting the sulfur, mixing high sulfur coal with other low sulfur coal, or developing improved flue-gas cleaning technology, may make this region's coal usable within environmental standards. Another factor in increasing economic development of these coal reserves is the growing interest in associated trace metals as another resource to be acquired concurrent with coal extraction. While very little is known about these yet, they may prove valuable in offsetting environmental costs and may even become very economically important themselves. The real value of the coal is not known because the reserves have not been fully mapped. Research into these reserves has recently begun at the Iowa Geological Survey and the results may significantly change the location of reserves indicated on this map.

Building industries need limestone, sand, gravel, and gypsum — all of which are available in this region. Limestone suitable for aggregate or fertilizer is most prevalent in the northeastern portion of the region, but is also available at scattered other locations. Known sand and gravel deposits are most abundant along the Des Moines River, but deposits also suitable for exploitation may be inferred along other major rivers. Unfortunately, clay-rich glacial till deposits, in which sand and gravel deposits are not usually abundant, are prevalent over much of the region. Gypsum, used in the making of plaster and wall board, is not currently being mined in the region. However, it may be economically available either in the Mississippian-age rocks, as indicated on the map, or in the lower Devonian-age rocks which underlay the entire region. More research is necessary.

The area near What Cheer in Keokuk County is an active area for extracting clay for the tile and brick industries. The coal regions, in general, may have many other areas suitable for increasing clay production and developing a larger clay industry.

MINERAL RESOURCES



Modified from Mineral Resources of Iowa, 1970 and Coal Resources of Iowa, 1964

by B. Hoyer

FLOOD HAZARDS MAP: The Eleven-County region is blessed with several major rivers. But along with these river resources comes the intermittant problem of floods. Flooding is most prevalent in the spring and, less frequently, in the late summer-fall. Most flooding occurs in April, May, June, and September.

Flood inundation areas have been divided into four categories based on the duration of flooding. A flood's duration and associated other properties should be well understood to facilitate informed land-use planning.

Perhaps the most frequent floods occur on the smaller streams. The map indicates as brown the areas which could be flooded along these small streams. Overland flooding here tends to endure for very short periods of time, varying from only a few hours to, perhaps, one day. These "flash" floods commonly occur with spring and summer thunder storms. Flooding on these uncontrolled larger rivers tends to last for longer periods of time — usually one to seven days — than on the smaller rivers because of the larger basins. Floods on these uncontrolled rivers can be very serious because the rivers are relatively large, the volumes of water great, and the inundation may continue for rather extended periods of time. The most important river in this class is the Skunk River which has recently experienced severe flooding.

Flooding in the remaining two categories has been greatly modified by the construction of the Red Rock and Rathbun Reservoirs. Previously these streams experienced moderate duration flooding like the Skunk River.

The regulation of these dams greatly reduces the risk of major flooding downstream but it cannot entirely eliminate all flood threat. These two dams produce the areas indicated as controlled flooding. The reservoirs hold water when spring high flow conditions exist and release it under conditions of lower flow. This storage process allows the sediment which the water picks up in abundance during these high flow periods to settle-out in the reservoir. Water released during the summer months remains relatively low in sediment load. This has two effects downstream. First, the reduced sediment load allows the river to pick up more sediment downstream. Combined with the increased average flow during regional low flow periods the rivers tend to scour the river channel causing increased erosion. Secondly, the increased summer flow means that the water table may not drop much in downstream lowland areas. Thus low cropland areas may remain wet longer in the spring and into the summer. When reservoirs become nearly full, as has happened twice in the four years of Red Rock Reservoir's existence, flow rates may remain high for especially long times after uncontrolled flow rates would have returned to normal. Thus very low lying areas may remain flooded even below the dams.

Areas may be flooded above the dam and these are indicated on the map as areas affected by prolonged flooding. When the flood pool level is reached, the inundated area extends far upstream from the normal reservoir level. This area may be inundated for weeks before the flow out of the reservoir can greatly reduce the reservoir's water level. In addition, if the reservoir were nearly full, overbank flooding upstream may subside more slowly because of a reduced stream gradient.

Conditions both upstream and downstream from these reservoirs should be understood for informed land use planning. Thus any development above or below these dams should take these factors into account. For example, the change of previously forested lowland areas into crop land is not necessarily sound management. While the threat of flooding may inhibit crop growth, the cleared land may then become subject to additional erosion. Likewise, urban development on previously flood-prone property may prove disastrous without a careful evaluation of the drainage properties of the site and the need for a possible protective levee system.

STREAM FLOW SUMMARY

Gaging Station	Average Discharge in cubic feet per second (cfs)	High Flow cfs/date	Low Flow cfs/date
North Skunk River (near Oskaloosa)	770	14,500/May, 1944	.1/Oct., 1956
South Skunk River (near Sigourney)	396	37,000/May, 1944	1.8/Oct., 1956
Des Moines River (near Tracy)	4334	155,000/June, 1947	40/Jan., 1940
Des Moines River (Ottumwa)	4688	135,000/June, 1947	30/Jan., 1940
Des Moines River (Keosauqua)	5227	146,000/June, 1903	40/Jan., 1940
White Breast Creek (near Dallas)	145	12,000/June, 1962	.07/Sept., 1968
Cedar Creek (near Bussey)	177	31,500/June, 1946	0/Sept., 1955 and Oct., 1956
North Fork Chariton River (near Chariton)	71	15,000(est)/March, 1960	.1/Sept., Oct., Nov., 1966
South Fork Chariton River (near Promise City)	69	7,660/Aug., 1970	.1/July, 1970
Chariton River (near Rathburn)	268	21,800/March, 1960	.01/Oct., 1957 and 1966

Adapted from Water resources data for Iowa: U.S. Geol. Survey

DEFINITIONS

Discharge — the amount of water that flows past a given point in a unit of time, usually recorded as cubic feet per second (cfs).

Flood — any relatively high stream flow that overtops the natural banks of a stream at some location.

Flood plain — the area adjoining a river or stream, which has been or may be hereafter covered by flood water. Flood plains are nearly flat and are made up of sediments (alluvium) deposited by the river.

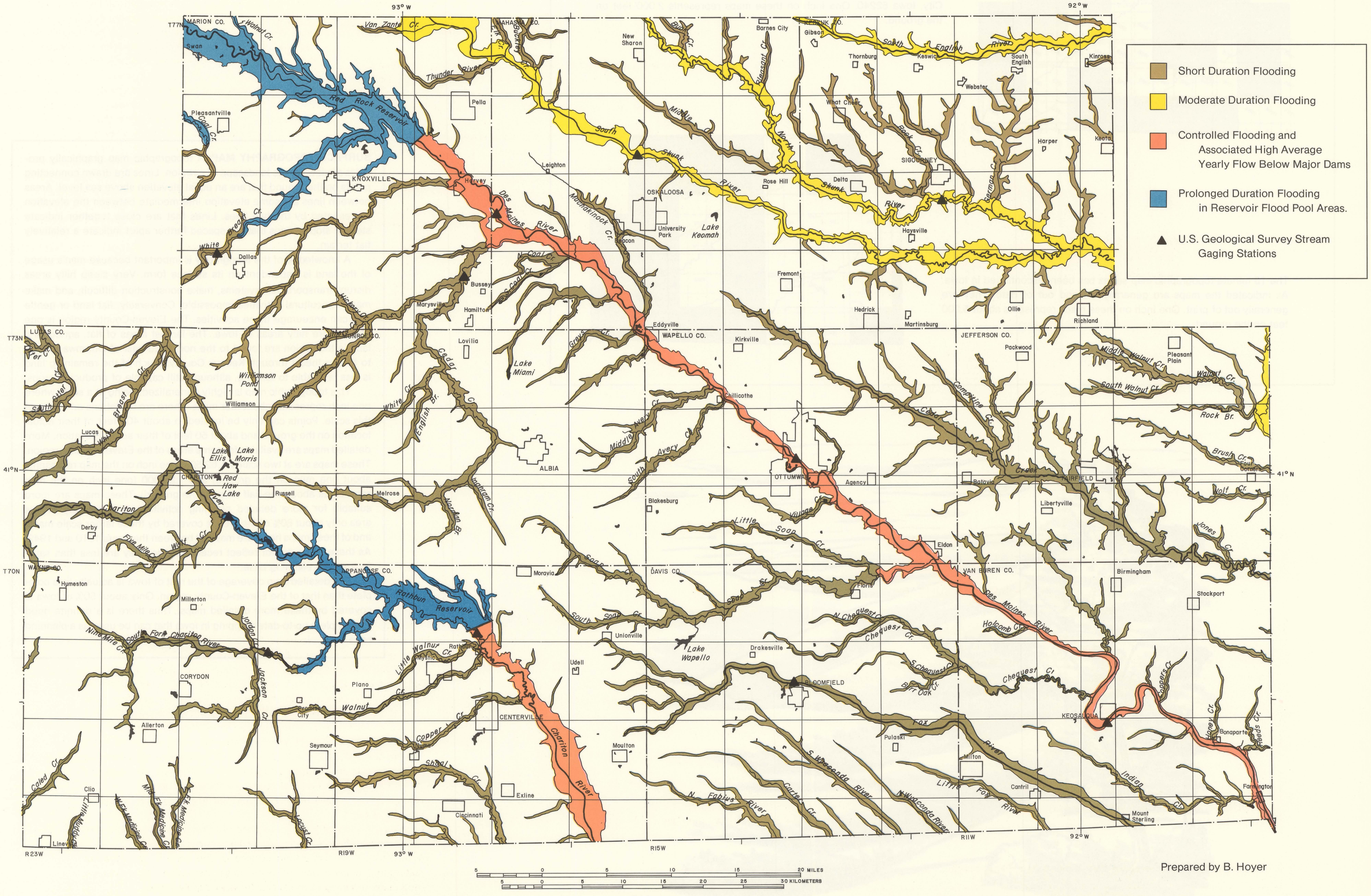
Flood frequency — a statistical probability figure based on the recorded flow record of a stream that a certain magnitude flood may occur in any given year. The length of time a stream is monitored and physical changes like deforestation and urbanization that occur constantly within a river basin are complicating variables in the statistical base that the calculation is based. The larger numbers represent larger floods which are less likely to occur. Thus, the calculated 20 year flood has a 5% chance of occurring whereas a 100 year flood has a 1% chance of occurring in a given year. The numbers should not be interpreted to mean "that since the 100 year flood occurred last year, a flood like that will not occur for another 100 years."

Gaging stations — instruments established to monitor the level and flow of streams.

Hydrology — study of behavior or state of water, its properties, movement, environment, spatial relations and distributions.

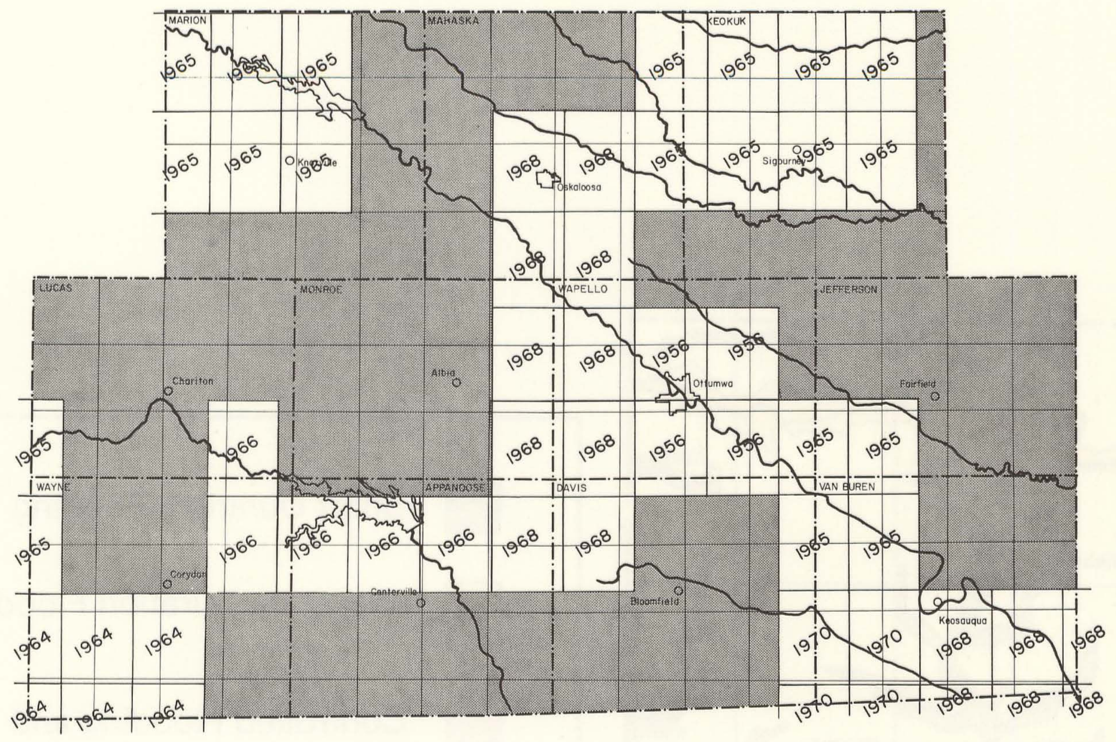
Water table — the undulating surface of the zone of groundwater saturation, bulging upward under hills, flattening under valleys, and rising or falling as the available water supply varies.

FLOOD HAZARDS

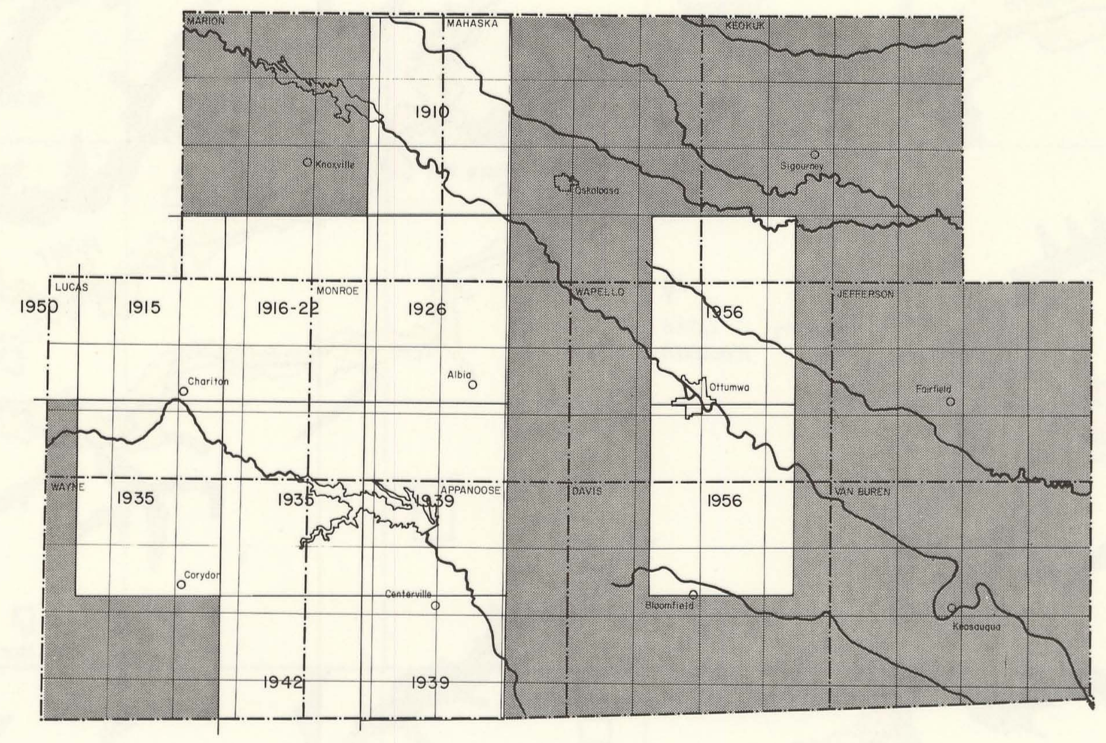


Prepared by B. Hoyer

DETAILED TOPOGRAPHIC MAPS



The U.S. Geological Survey 7-1/2 minute topographic map series coverage of the Eleven-County region is indicated on this map. The year of final publication is given within the map borders. Maps are available at the Iowa Geological Survey, 16 W. Jefferson St., Iowa City, Iowa 52240. One inch on these maps represents 2,000 feet on the ground.



The 15 minute topographic map series has been discontinued in Iowa. As indicated the maps are generally old and out of date. They are generally out of print. One inch on these maps represents about 5,200 feet on the ground.

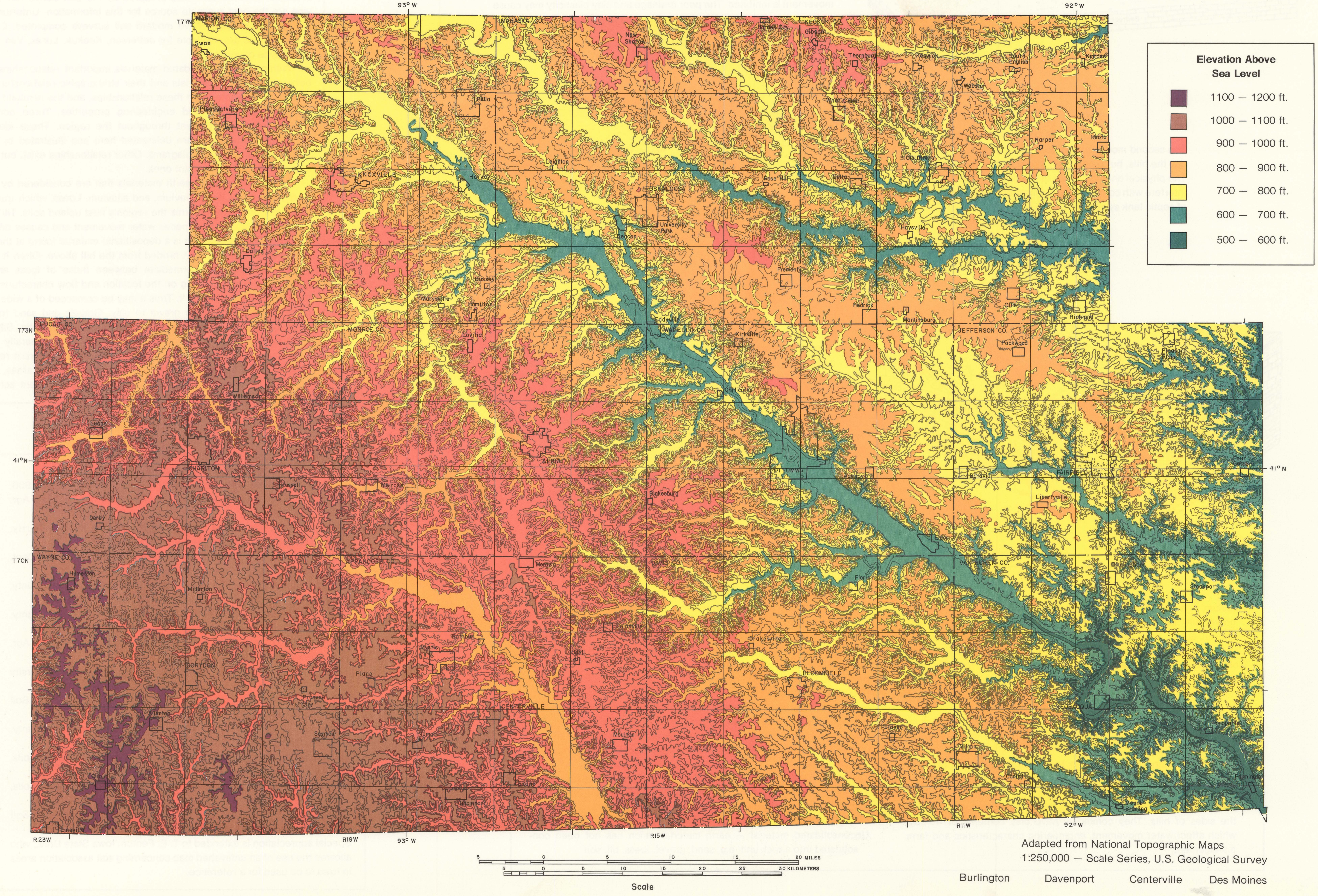
SURFACE TOPOGRAPHY MAP: A topographic map graphically provides a "view" of the landscape of a region. Lines are drawn connecting points on the ground that are an equal elevation above sea level. Areas between lines are some elevation intermediate between the elevation represented by the two lines. Lines that are close together indicate steeper slopes; lines that are spaced further apart indicate a relatively flat terrain.

A knowledge of the topography is important because man's usage of the land is dependent on its surface form. Very steep hilly areas disrupt transportation systems, make construction difficult, and make many agricultural activities impossible. Conversely, flat land or gentle hills can encourage these activities. The Eleven-County region is one of the more hilly areas of Iowa. The largest areas of flat, agricultural land in the region are found to the north and east of Ottumwa and on to the northeast through Keokuk County. Much of the remaining land is less favorable to farming, although still capable of producing crops.

This topographic map is highly generalized, being at a scale where one inch represents about four miles. There are limitations on a map of this scale. Points can only be located to about 400 feet of their actual location on the ground and about 50 feet of their actual elevation. More detailed maps are available for some areas of the Eleven-County region. These maps are at two scales: 1:62,500 (one inch on the map represents about one mile on the ground) and 1:24,000 (one inch on the map represents about one-half mile on the ground). These maps are more suitable for more detailed planning activities. Unfortunately in this area only about 80% of the area is covered by these larger scale maps, and of these maps half were mapped between the years 1910 and 1942. As these maps do not reflect recent change, they are less than satisfactory as a planning base.

The detailed map coverage of the rest of Iowa is actually less complete than that of the Eleven-County region. Only about 50% of Iowa is covered by these more detailed maps. Thus there is a definite need for complete up-to-date mapping in Iowa that can be used as a planning base.

SURFACE TOPOGRAPHY



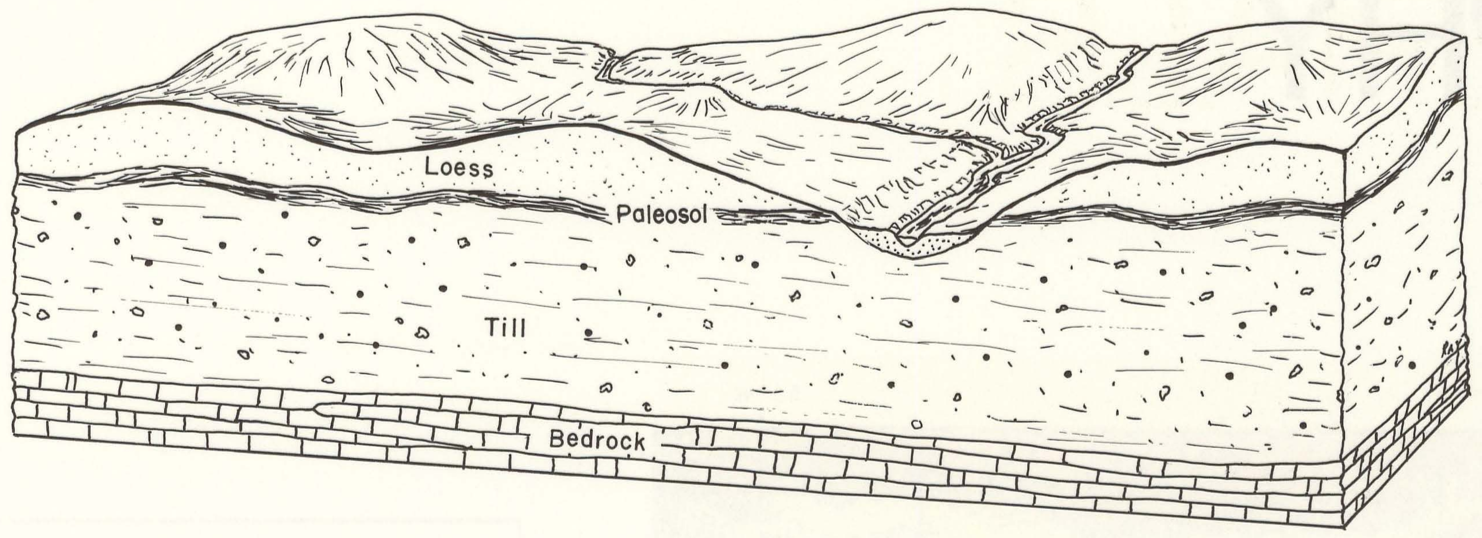
Adapted from National Topographic Maps
1:250,000 — Scale Series, U.S. Geological Survey

Burlington Davenport Centerville Des Moines

UNCONSOLIDATED MATERIALS MAP: Though any land-use study obviously depends on knowledge of surface topography, an understanding of the unconsolidated materials which lie beneath the surface is also necessary. Such information may help solve problems relating to septic systems, general construction, soil erosion, farm management, and road upkeep. Unfortunately, the information about the unconsolidated materials necessary to solve most of these problems must be very specific and detailed, and could not be conveyed satisfactorily on this scale map. In addition, much of this information is not presently available. Detailed soil maps prepared by the Soil Conservation Service are the best available source for this information. Unfortunately, not all Iowa counties have modern soil surveys completed. Current detailed maps are available for Jefferson, Keokuk, Lucas, Van Buren and Wayne counties.

Within the unconsolidated materials important relationships exist between the earth materials and their stratigraphic relationships, the landforms associated with these relationships, and the resultant effect on water movement and engineering properties. Three dominant relationships are prevalent throughout the region. These idealized landscape model areas are delineated here and illustrated by these three dimensional block diagrams. Other relationships exist, but these models reflect the dominant ones.

The unconsolidated earth materials that are considered by these models are loess, till, colluvium, and alluvium. Loess, which transmits water moderately well, forms the region's best upland soils. Till's high clay content generally impedes water movement and causes difficulty in construction. Colluvium is a depositional material found at the base of slopes, which has been eroded from the hill above. Often it would have characteristics intermediate between those of loess and till. Alluvium varies depending on the location and flow characteristics of the stream that deposited it. Thus it may be composed of a wide range of materials varying from gravel to clay. Gravels and sand transmit water readily but cannot be compacted or become plastic. Silts and clays readily become plastic, shrink and swell, and generally inhibit water movement. The three idealized models have different relationships of these four basic earth materials. Thus, certain areas, based on these materials, are more or less suitable for different activities.

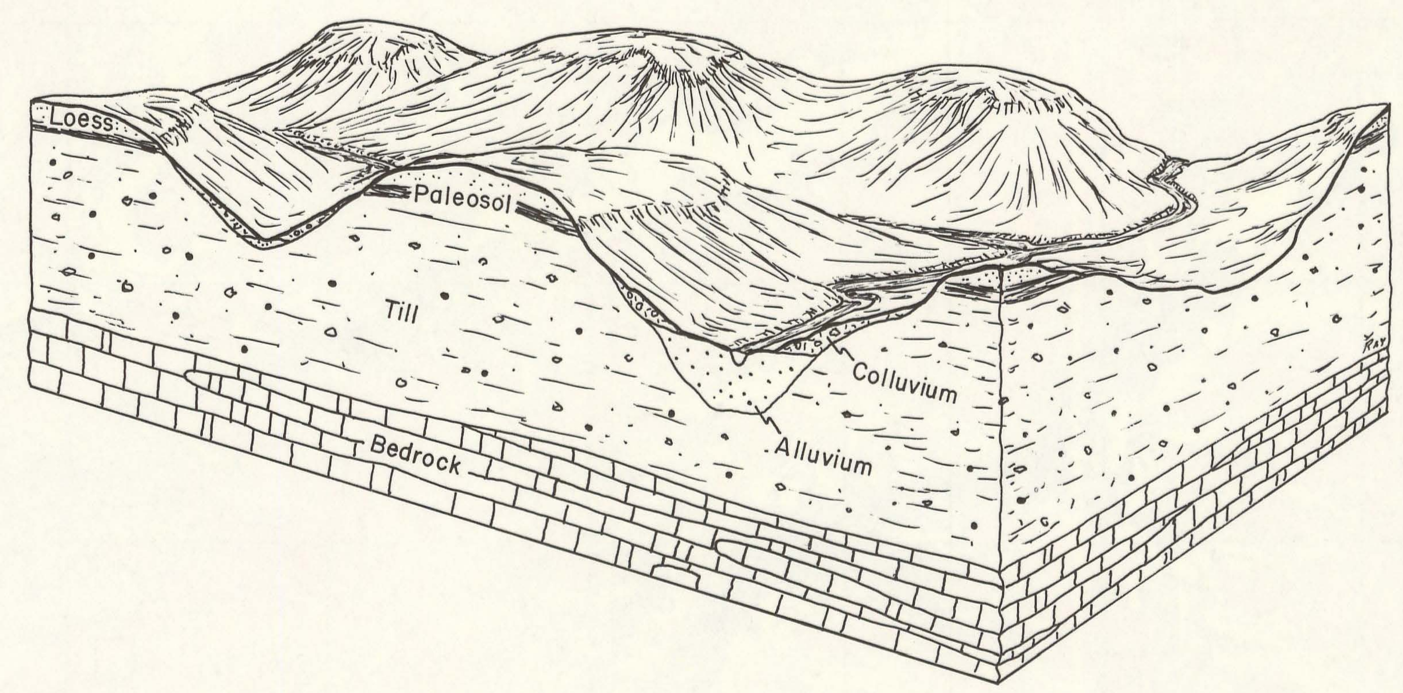


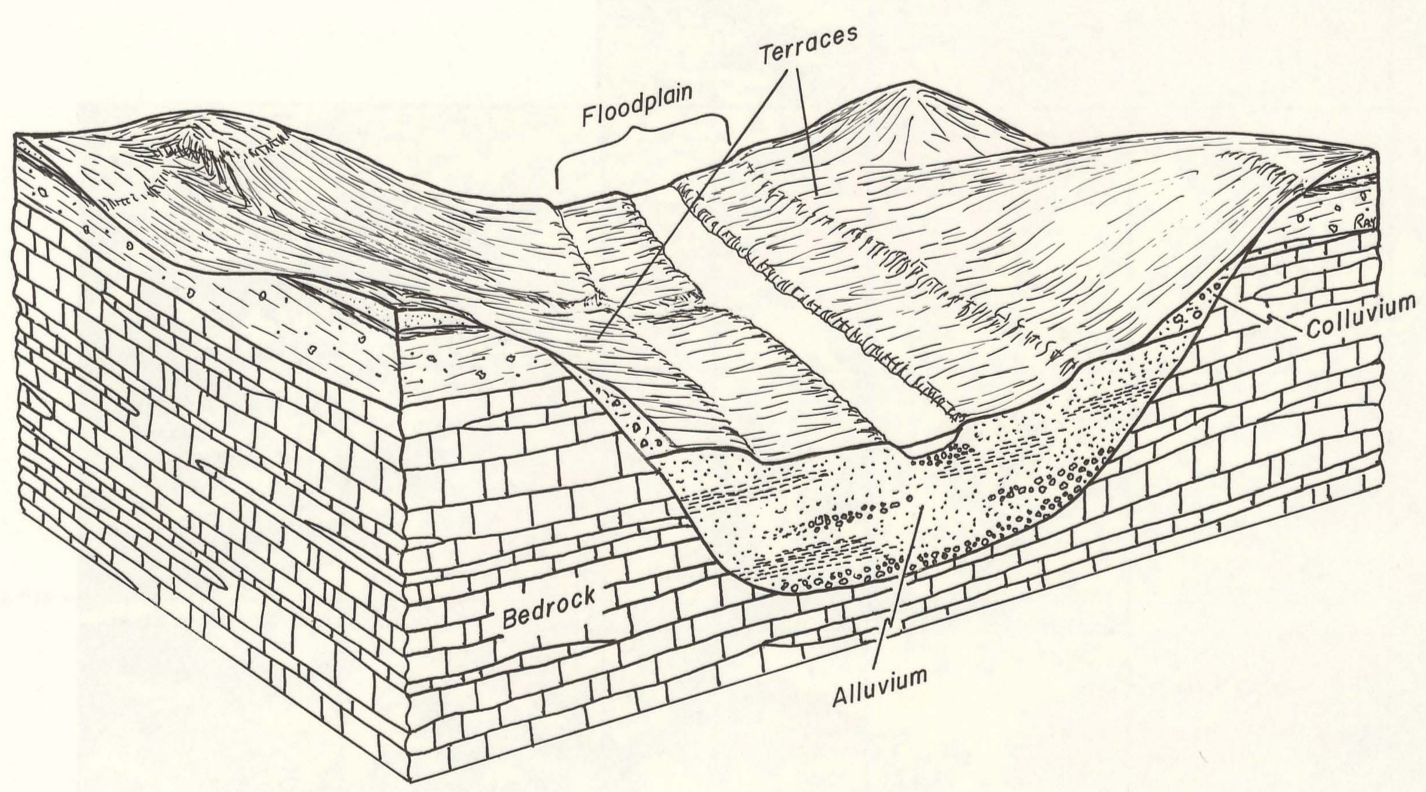
LOESS UPLANDS

The first model area is dominated by loess. This area is generally located along the high and generally flat stream divides. The most extensive example is located to the north or east of Ottumwa. Generally it is very good agricultural land although it may be somewhat poorly drained. The loess thickness varies to a maximum of about ten feet. Below the loess, a buried soil lies on top of glacial till. The flat terrain and the glacial till combine to create some drainage problems, as downward water movement is inhibited. The poor drainage and clay plasticity may cause construction some problems in these areas but generally the problems would be less than in some other areas.

HILLS OF GLACIAL TILL

The second model area is dominated by hills of glacial till. Loess may cap the hills, but paleosols and glacial till are exposed on the hillsides. The physical characteristics of the till make farm management difficult, interfere with construction and interfere with the satisfactory operations of septic tank systems.





VALLEY COMPLEX

The third landscape model includes the valley areas. These are very complex with colluvial deposits on the edges of the valley and an alluvial complex of deposits on the flood plain. Thus, the earth materials here are composed of all textures of material from clays to sands and gravels. Since different materials have unlike physical properties, large construction projects need careful engineering design or unequal subsidence might occur. Surface texture is not the only consideration in this region. Frequently dissimilar textural materials are adjacent to one another. A sand, for example, could be underlain by a clay. In addition, water can cause problems in this area because of the possibility of flooding and the frequent high water table levels. Furthermore, this area is most subject to water pollution because anything which enters the ground could readily enter water supplies.

DEFINITIONS

Alluvium — a general term that applies to stream deposits (e.g. sand, gravel, silt) laid down in river-beds, floodplains, lakes, and estuaries; alluvial, adj.

Clay — unconsolidated material with particles smaller than .002mm.

Colluvium — a general term applied to deposits at the foot of slopes that accumulated by the combined work of gravity and water.

Gravel — accumulation of waterworn pebbles less than three inches in size.

Loess — a fine-grained, unconsolidated, sediment of wind-blown origin, composed predominantly of angular silt grains and minor amounts of clay minerals.

Outcrop — location where a bedrock formation or paleosol is exposed at the earth's surface, commonly found along rivers or construction projects such as railroads or highways.

Paleosol — a buried soil or part of a buried soil which may outcrop on the sides of hills. They commonly have clay contents of 40-50% which affect water movement, engineering characteristics and farm management.

Plasticity — ability to deform from pressure without breaking and to to retain the new shape after stress is released.

Sand — unconsolidated material with particles ranging in size between .05 and 2.0mm. The particles are largely quartz, but with many other minerals possibly present.

Silt — unconsolidated material with particles that range in size between .002 and .05mm.

Soil — a natural body of unconsolidated material that is produced as a function of climate, biotic factors, slope, and time. In Iowa, it is generally dark near the surface and more reddish at a depth of several feet. An increase in clay content is generally associated with the more reddish zone.

Texture — relative amounts of sand, silt, and clay-sized particles.

Till — a heterogeneous mixture of rock materials ranging in particle size from clay to boulders which have been transported and deposited by glacial ice.

Unconsolidated material — earth material which has not been consolidated into a rock unit, e.g. sand, gravel, loess, till, soil.

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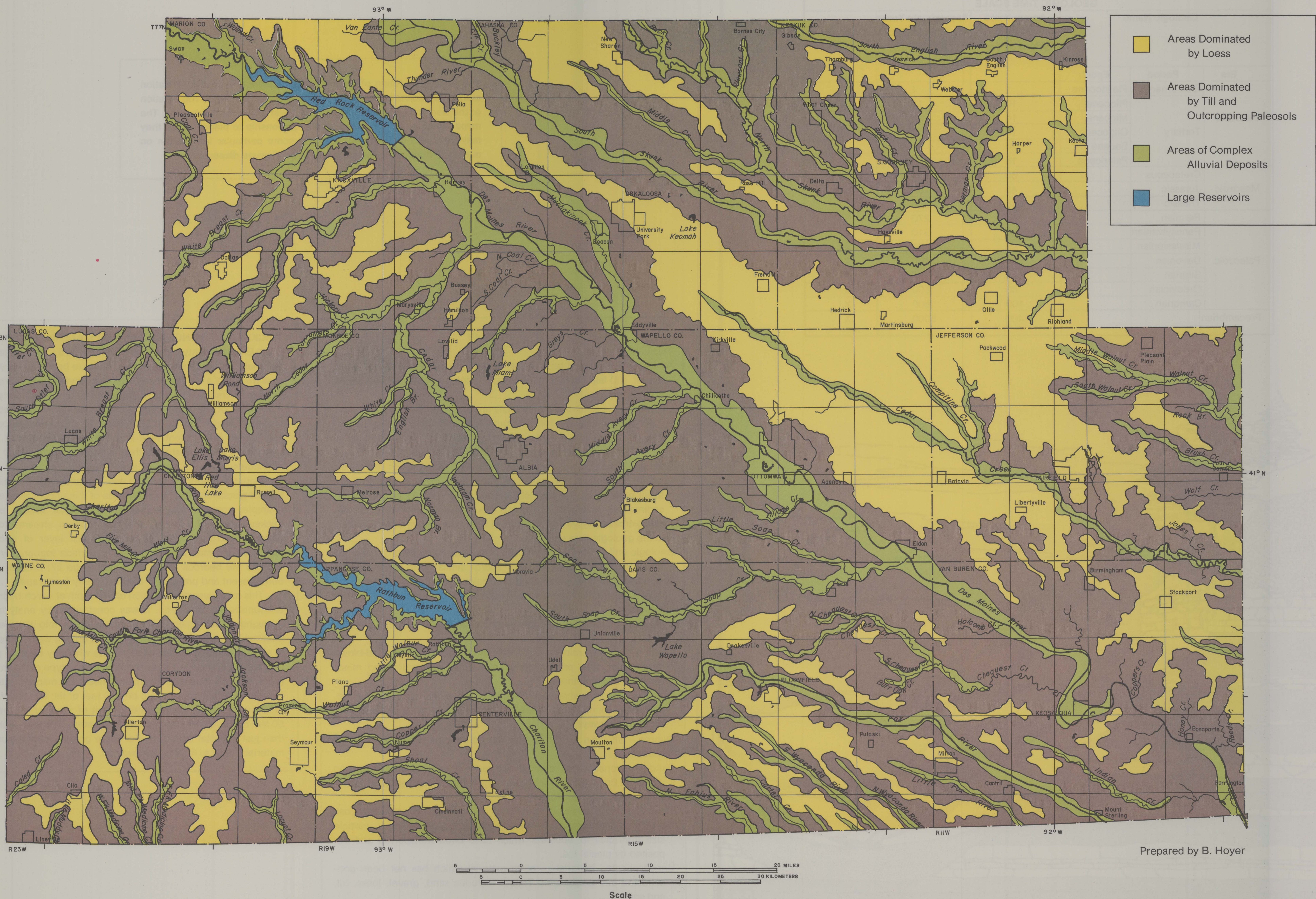
Special appreciation is extended to T. E. Fenton, Iowa State Univ., who allowed the use of an unfinished map concerning soil association areas in Iowa to be used for a reference.

UNCONSOLIDATED MATERIALS

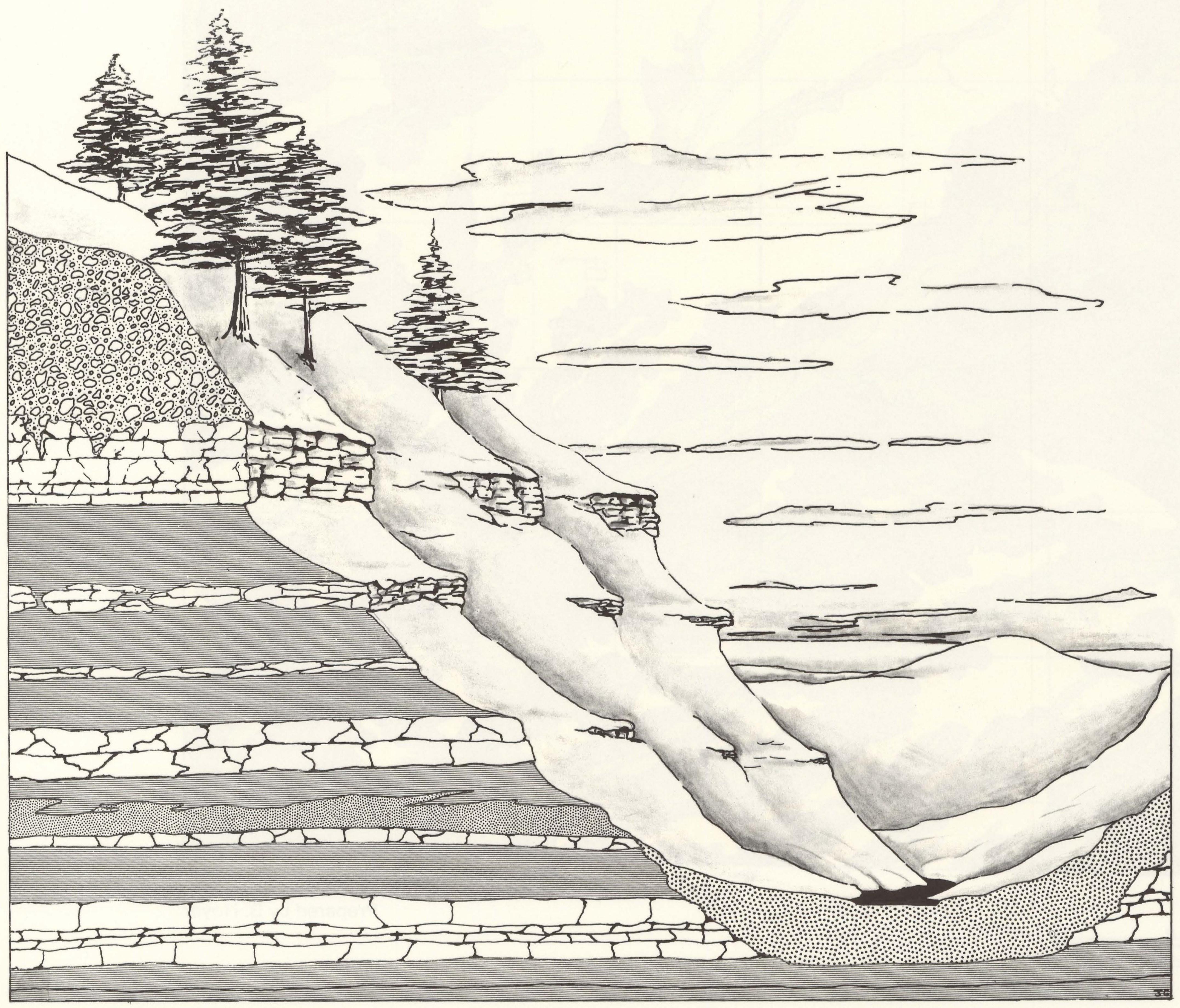


Prepared by B. Hoyer

SUBSURFACE GEOLOGY

GEOLOGIC TIME SCALE					
Geologic Name			Approximate Duration (Millions of Years)	Approximate Years To Beginning of Time Unit (Millions of Years)	Occurrence in Iowa
Era	Period	Epoch			
Cenozoic	Quaternary	Pleistocene	1	1	X
	Tertiary	Pliocene	10	11	
		Miocene	14	25	
		Oligocene	15	40	
		Eocene	20	60	
		Paleocene	10	70	
Mesozoic	Cretaceous		65	135	X
	Jurassic		45	180	X
	Triassic		45	225	
Paleozoic	Permian		45	270	
	Pennsylvanian		40	310	X
	Mississippian		40	350	X
	Devonian		50	400	X
	Silurian		40	440	X
	Ordovician		60	500	X
	Cambrian		100	600	X
Precambrian			4400	5000	X

The following section of three maps is designed to give information about the thickness of the uppermost layer of the earth, the location of the bedrock units, and the surface relief on the bedrock units. The maps probably do not have a direct relationship to planning, but they may be useful to specialists needing some particular information on mining, groundwater, development or solid waste disposal.



DEFINITIONS

Thickness

Alluvium — a general term that applies to stream deposits (e.g. sand, gravel, silt) laid down in river-beds, floodplains, lakes, and estuaries; alluvial, adj.

Bedrock — the solid rock beneath any unconsolidated material.

Buried valleys — valleys formed from streams which existed in the past but are now buried by other material and do not relate directly to active surface stream systems.

Geologic Time Scale — geologic time is divided into units of unequal length, as defined by the appearance and disappearance of the fossil remains of characteristic organisms preserved in the various sedimentary rock units. By means of a variety of scientific methods, approximate time values, in terms of solar years, have been assigned to the geologic time units.

Geologic unit — informal term used to denote a grouping of materials based on similar characteristics and/or similar time of deposition.

Groundwater — that water occurring below the surface of the earth. In a more restricted sense, that water occurring within the zone of saturation.

Gravel — accumulation of waterworn pebbles less than three inches in size.

Loess — a fine-grained, unconsolidated, sediment of wind-blown origin, composed predominantly of angular silt grains and minor amounts of clay minerals.

Outcrop — location where a formation is exposed at the earth's surface, commonly found along rivers or construction projects such as rail-roads or highways.

Quarry — an open pit, usually for the purpose of extracting stone or gravel.

Sand — unconsolidated material with particles ranging in size between .05 and 2.0mm. The particles are largely quartz, but with many other minerals possibly present.

Strip mine — an open pit, usually for the purpose of extracting coal.

Till — a heterogeneous mixture of rock materials ranging in particle size from clay to boulders which have been transported and de-posited by glacial ice.

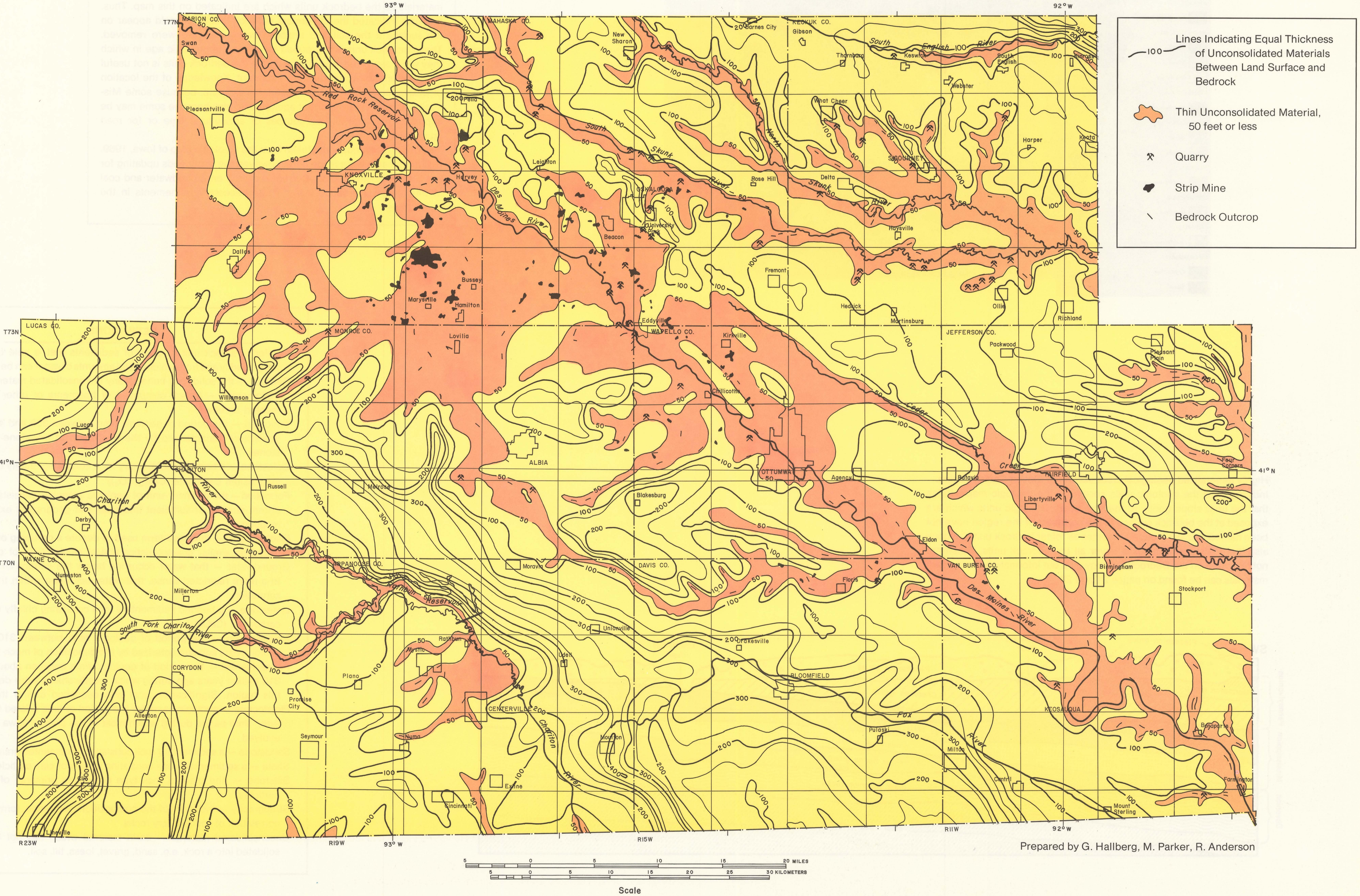
Unconsolidated material — earth material which has not been con-solidated into a rock unit. Thus it includes sand, gravel, loess, till, and soil.

THICKNESS OF UNCONSOLIDATED MATERIALS MAP: Most areas of the Eleven-County region are covered with a layer of unconsolidated materials. The unconsolidated layers overlie bedrock and vary in thick-ness from only a few feet to perhaps four hundred feet. Normal geologic processes transported these materials and subsequently deposited them. Most of the unconsolidated materials were deposited by melting glaciers. These deposits include glacial till and various deposits of sand and gravel. Subsequent time and the erosional work of water upon these materials have shaped the landscape and produced the modern drainage system and its associated alluvium.

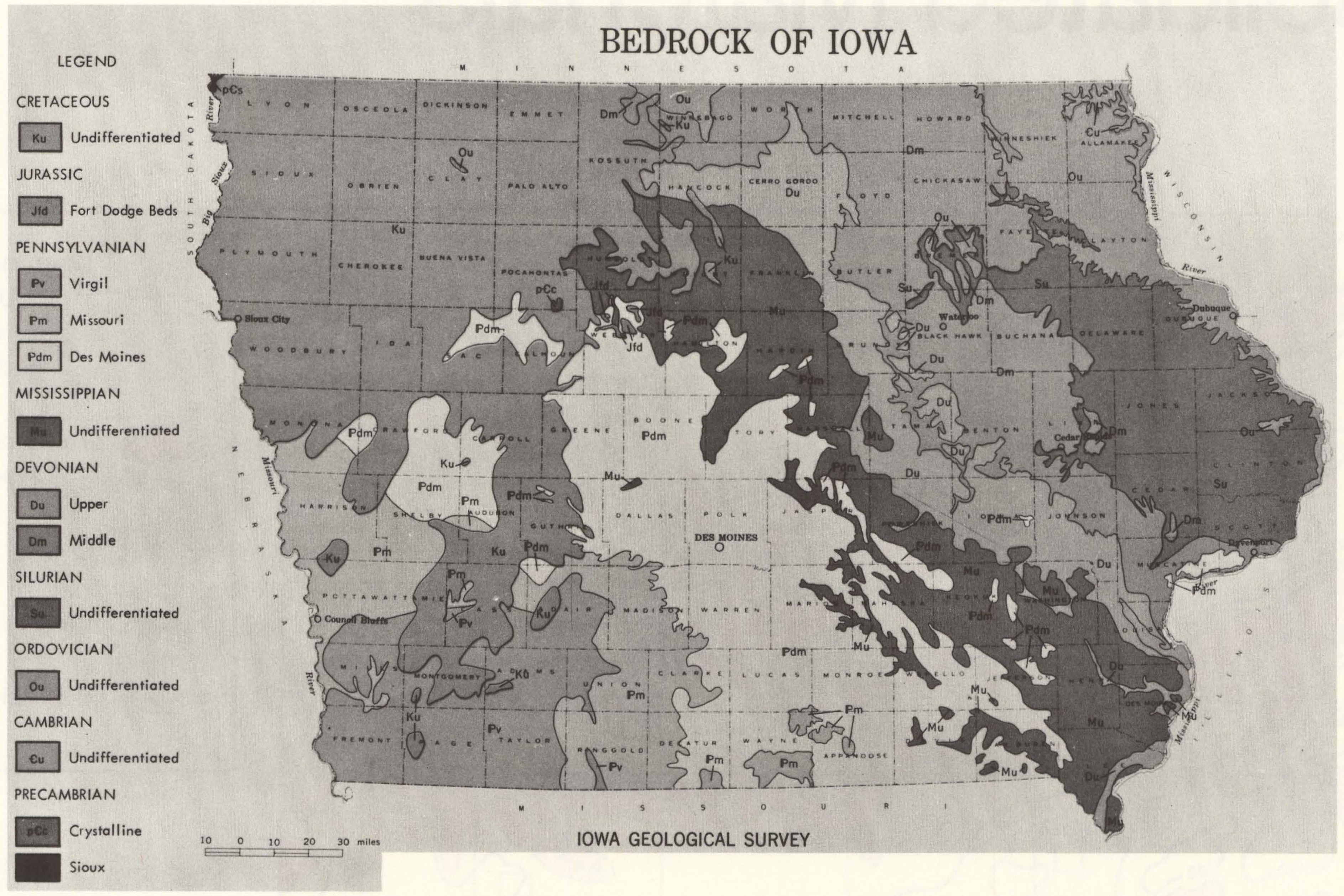
Both the modern landscape and the landscape that existed at the time of glaciation affect the thickness of this unconsolidated layer. For example, present hills located over bedrock valleys produce the thickest areas of material, whereas modern streams located over bedrock hills have generally the thinnest layer of unconsolidated material. This map together with the surface topography map (page 19) and the bedrock topography map (page 27) present a picture of both present and pre-glacial Eleven-County landscape.

This map gives an indication of the depth at which bedrock may be encountered in any area. It was constructed by analyzing all wells throughout the region that penetrate down into the bedrock. This information may prove useful to anyone drilling wells, people involved in sanitary waste disposal, or engineers who may need to put footings into bedrock. This map does not indicate the type of materials that are there, but only their total thickness. Thus if the map indicates 100 feet, for example, that figure could be 100 feet of till; 50 feet of till, 10 feet of loess, 20 feet of gravel, and 20 feet of sand; or 50 feet of till and 50 feet of gravel. For many needs, the materials may be more important than just the total thickness. For more general information about the materials, refer to the map on page 21.

Thickness of Unconsolidated Materials



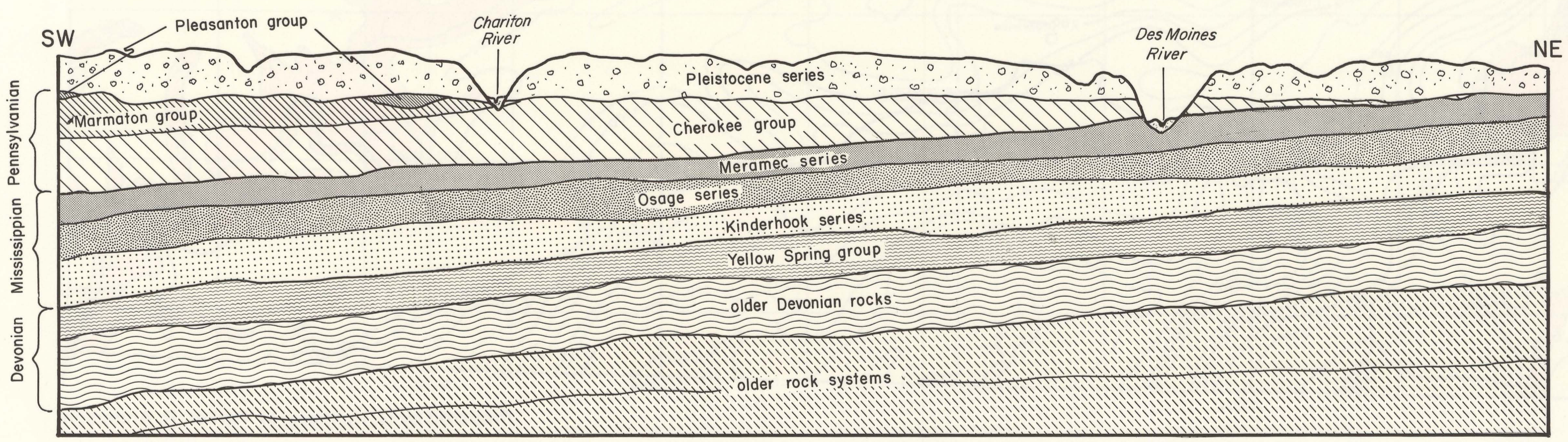
Prepared by G. Hallberg, M. Parker, R. Anderson



BEDROCK GEOLOGY MAP: Generally, in the Eleven-County region, the bedrock is covered by unconsolidated materials. Beneath these materials lie the bedrock units which are indicated on this map. Thus, this map indicated the uppermost bedrock unit that would appear on the surface if the soil and unconsolidated materials were removed. These bedrock units are grouped based on the geologic age in which they were deposited. Though the age of the bedrock units is not useful to planners, their properties are important. Knowledge of the location of Mississippian age rocks is useful, for example, because some Mississippian rocks are important aquifers and also because some may be important economically as sources of agricultural lime or for road aggregate.

The map reproduced is taken from the Geologic Map of Iowa, 1969. No refinements were made here; however, the map needs updating for the Eleven-County region. Current research on groundwater and coal in this area will produce many of the necessary refinements in the near future.

Highly generalized geological cross section of Eleven-County region. Indicated are the geologic units shown on the geologic map. Notice that the units slope gently to the southwest. Geologic units which are exposed at the bedrock surface to the northeast of the region have not been named, but are grouped together as "older bedrock units." Notice also that Pleistocene deposits cover all the bedrock units. These are not indicated on the Bedrock Geology map but information about these materials can be found on pages 21 and 23.



DEFINITIONS

Aquifer — a rock unit or body of sediments that is able to transmit water readily and from which useful amounts of water can be extracted.

Bedrock — the solid rock beneath any unconsolidated material.

Conglomerate — a rock composed of fragments of other rocks cemented together.

Devonian — the period of geologic time between 350 and 400 million years ago characterized by the deposition of limestone and dolostones.

Dolostone — a bedded sedimentary rock consisting chiefly of calcium-magnesium carbonate. $CaMg(CO_3)_2$

Formation — the ordinary unit of geologic mapping consists of a persistent stratum of sufficient thickness and geographic extent to be mapped.

Geologic unit — informed term used to denote a grouping of materials based on similar characteristics and/or similar time of deposition.

Groundwater — that water occurring below the surface of the earth. In a more restricted sense, that water occurring within the zone of saturation.

Limestone — a bedded sedimentary rock consisting chiefly of calcium carbonate. $(CaCO_3)$.

Mississippian — the period of geologic time between 310 and 350 million years ago characterized by the deposition of much limestone.

Pennsylvanian — the period of geologic time between about 270 and 310 million years ago during which mostly shales were deposited in this region. Significantly, coal was deposited during this period.

Pleistocene — geologic name for the period of time related to the "Ice Age;" time period during which most of the present Iowa landscape evolved.

Sandstone — a sedimentary rock consisting of cemented grains of sand.

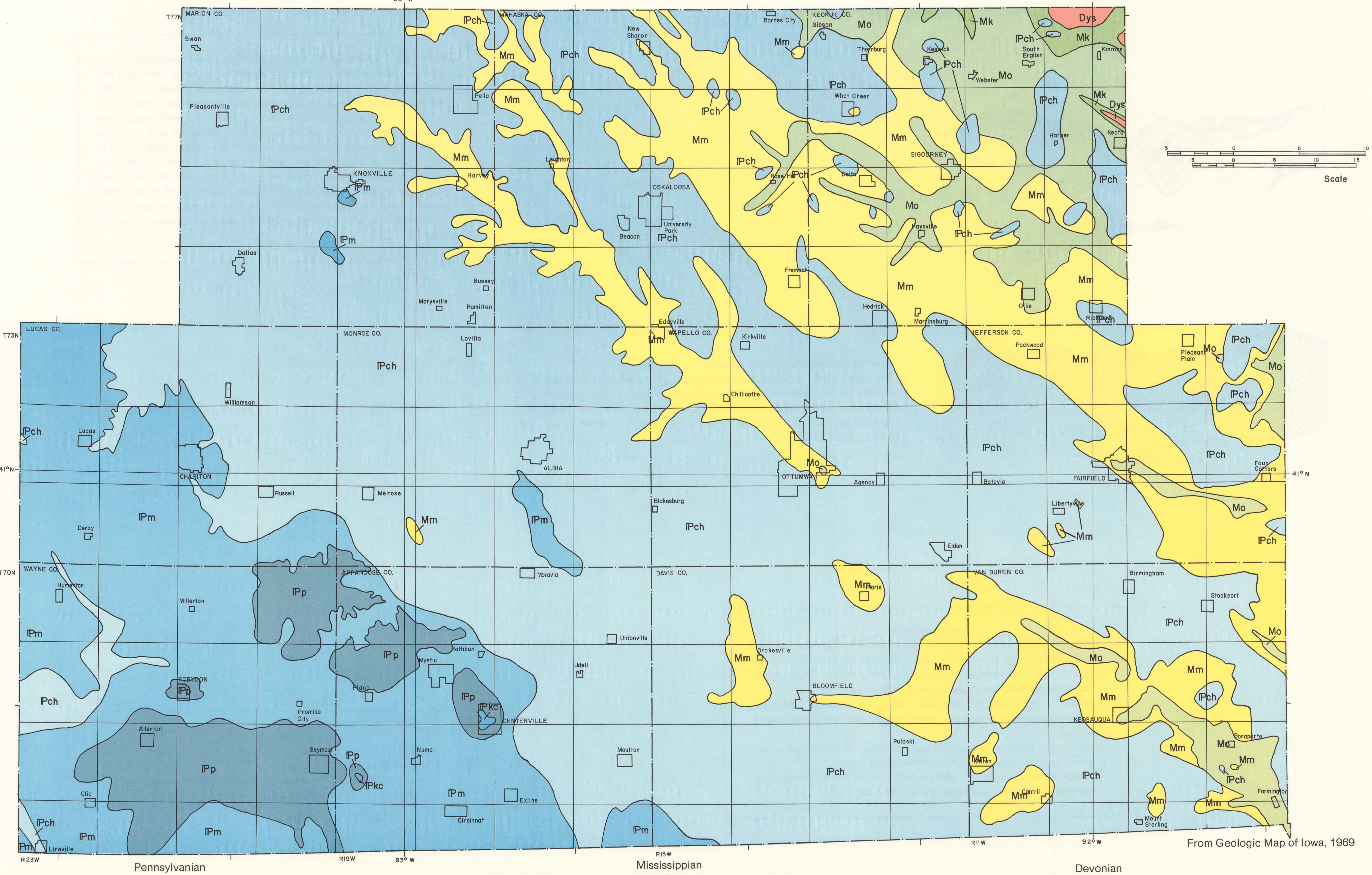
Shale — a sedimentary rock consisting largely of clay particles.

Siltstone — fine grained rock type composed primarily of silt sized particles.

Stratigraphy — the study of the composition, sequence, formation, and correlation of sedimentary rocks.

Unconsolidated material — earth material which has not been consolidated into a rock, e.g. sand, gravel, loess, till, soil.

Bedrock Geology



Pennsylvanian

IPkc

Kansas City Group

Cyclic deposits with prominent limestone beds, shale; Bonner Springs Shale at top and Hertha Limestone at base.

IPm

Marmaton Group

Alternating shale and limestone, with some sandstone and coal; Lenapah Formation at top and Fort Scott Formation at base.

IPp

Pleasanton Group

Shale with some sandstone, thin limestone beds and minor amounts of coal; Exline Limestone near top and Chariton Conglomerate at base.

IPch

Cherokee Group

Cyclic deposits with carbonaceous shale, clay, siltstone, sandstone, and thick coal beds; minor, but persistent limestone beds; may include parts of the Atoka or Morrow Series.

Mississippian

Mm

Meramec Series

Ste. Genevieve Limestone—fossiliferous limestone and red and green shale.
St. Louis Limestone—limestone and dolomite, sandstone locally predominant; locally contains chert.
Spergen Formation—sandy, micaceous dolomite.

Mo

Osage Series

Warsaw Formation—gray, dolomitic shale and argillaceous dolomite; chalcedonic chert. Locally contains many geodes.
Keokuk Limestone—fossiliferous, gray or brown limestone and dolomite; gray and brown chert with white spicules, locally predominant in lower portion; minor brown or gray shale.
Burlington Limestone—gray, fossiliferous limestone and darker gray dolomite; white and gray mottled fossiliferous chert, locally contains dolomite crystals; two widespread glauconite zones; basal sandstone locally in southeastern Iowa.

Mk

Kinderhook Series

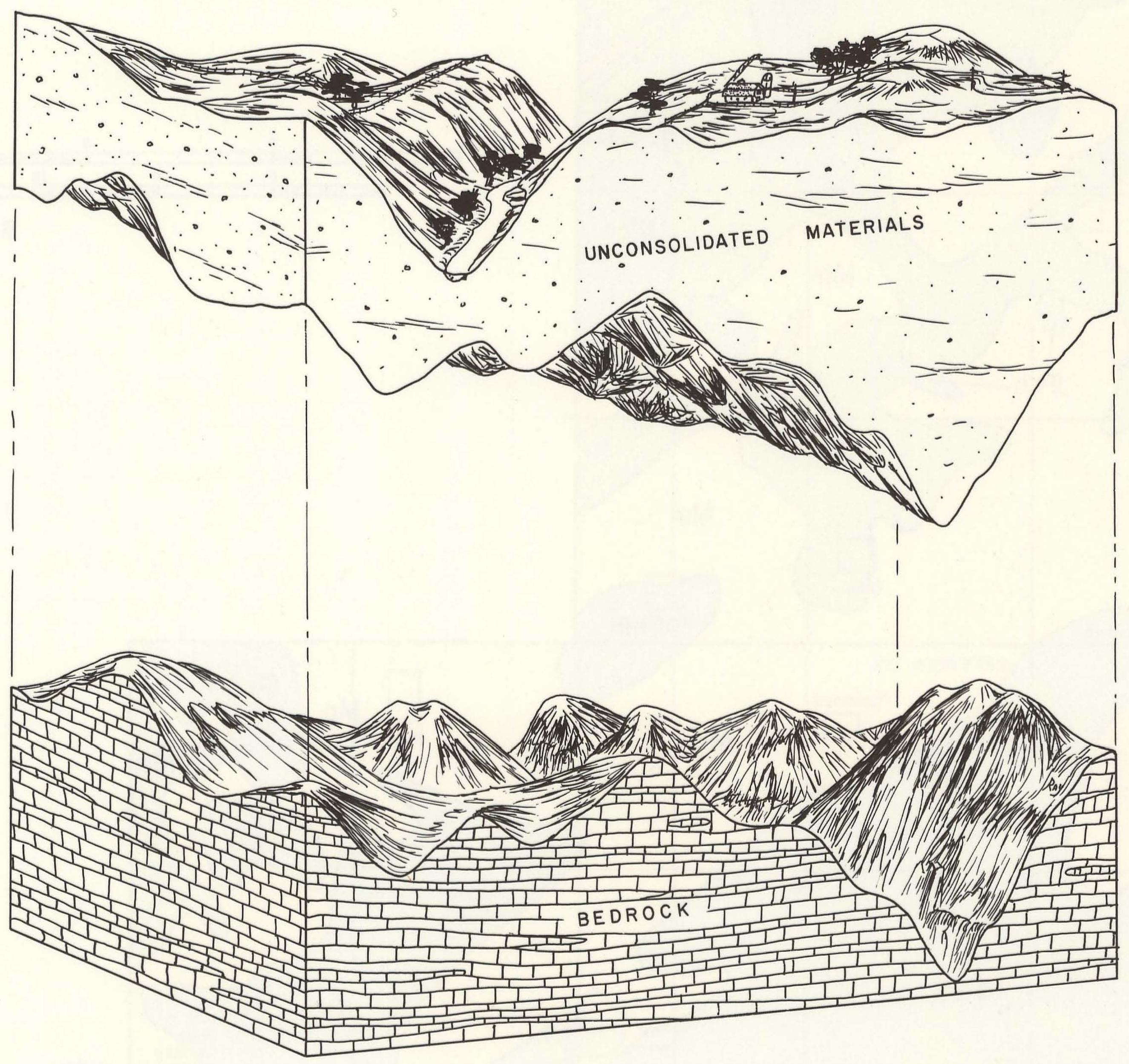
Gilmore City Limestone—light gray, fossiliferous limestone, commonly oolitic.
Hampton Formation—limestone and dolomite; fossiliferous gray chert in lower portion.
Starrs Cave Formation—bio-fragmental limestone; oolitic in part.
Prospect Hill Formation—greenish-gray siltstone.
McCraney Limestone—very pale-orange to pale yellowish-brown, sublithographic limestone and brown dolomite.

Devonian

Dys

Yellow Spring Group

English River Formation—gray siltstone; southeastern Iowa; locally in north-central Iowa.
Maple Mill Shale—greenish-gray shale, silty in upper part; contains spore carps; discoidal, concentrically laminated limonite pellets at top in the subsurface of central and southwestern Iowa.
Aplington Formation—argillaceous, silty dolomite and minor chert; quartz geodes.
Sheffield Formation—greenish-gray shale in central Iowa and in the subsurface of southwestern Iowa; in descending order, dusky yellowish-brown shale followed by greenish-gray shale, very light olive-gray shale, and dark olive-gray shale in the subsurface of southeastern Iowa.



Bedrock Topography — Block diagram
The relationship between the overlaying unconsolidated materials and the bedrock below is illustrated in this block diagram. The removal of the unconsolidated material reveals a preexisting landscape developed on bedrock. The elevation of the rock surface is provided on the map on the facing page.

BEDROCK TOPOGRAPHY MAP: If the layer of unconsolidated materials were stripped off, the bedrock would be exposed. However, the surface exposed would not be flat, but would exhibit land forms much like the present surface. There are bedrock valleys and ridges which can affect water movement within the overlying unconsolidated materials, thus this map may prove useful to hydrologists and scientists of related disciplines. For general usage, it is probably most useful to well drillers or engineers who must locate the top of the bedrock surface. In addition, well drillers may infer that some unconsolidated gravel aquifers lie in the bedrock valleys, but many of these gravel deposits have not been confirmed. Those that are known or are directly inferred to exist are indicated on the Unconsolidated Aquifer map on page 31.

DEFINITIONS

Aquifer — a rock unit(s) or body of sediments that is able to transmit water readily and from which useful amounts of water can be extracted. Bedrock aquifers are those occurring in rock units; unconsolidated aquifers are those found in sediments.

Bedrock — the solid rock beneath any unconsolidated materials.

Gravel — accumulation of water worn pebbles less than three inches in size.

Hydrology — study of behavior or state of water, its properties movement, environment, spatial relations, and distribution.

Unconsolidated materials — earth material which has not been consolidated into a rock, e.g. sand, gravel, loess, till, soil.

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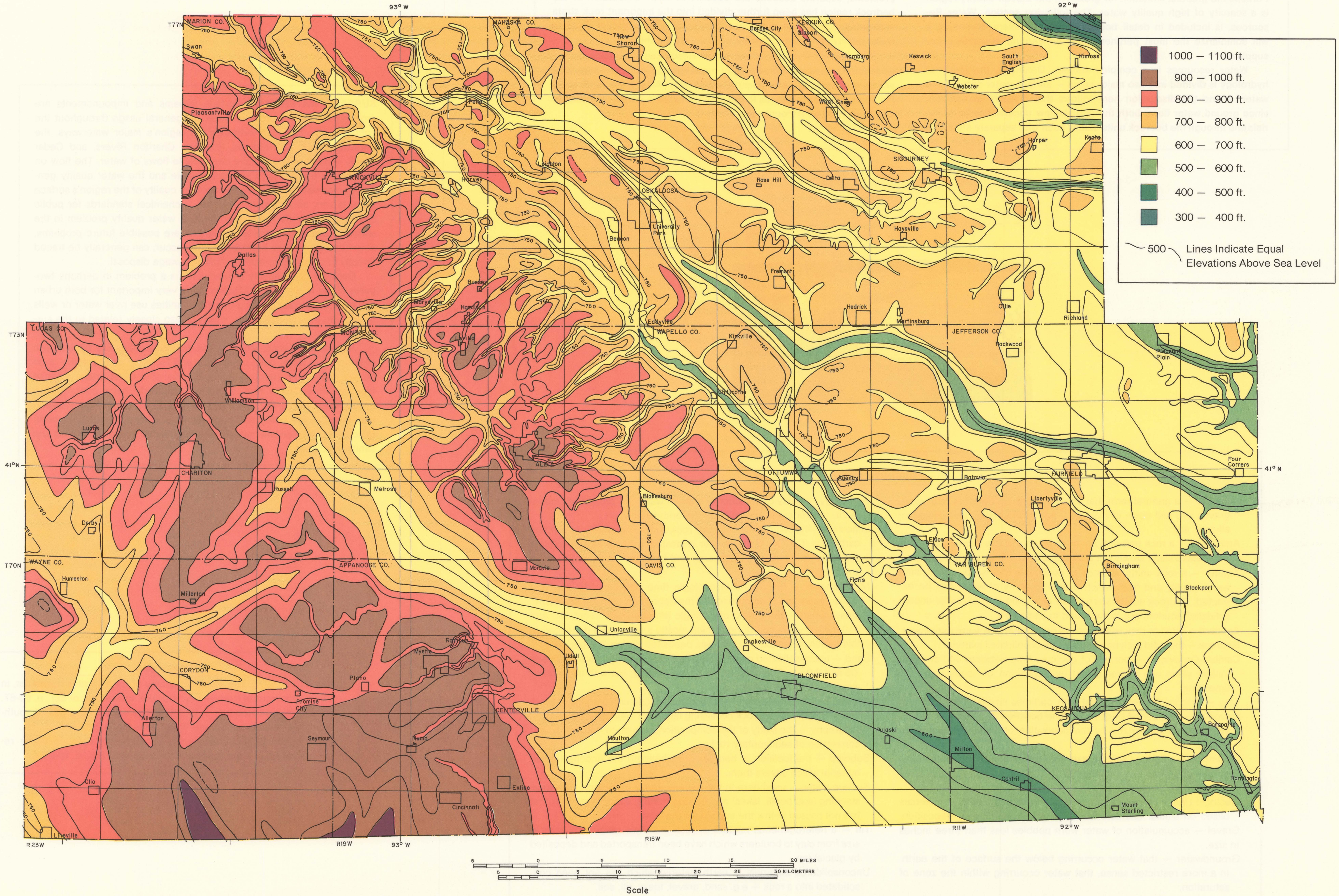
Hanson, R. E., 1973, Bedrock topography of southeast Iowa; U.S. Geol. Survey Misc. Geol. Inv. Map I — 808.

Bedrock Topography



WATER RESOURCES

Perhaps the greatest limitation for growth in the Eleven-County region is a scarcity of high quality water. The following section, Water Resources, is included in detail because of this problem. Hopefully it will summarize the most pertinent facts concerning available water supplies.

Water resources is a complex subject. Generally, the study of hydrology is divided into two major areas — surface water and ground water — and the discussion here follows that division. In addition, since ground water flows both through shallow unconsolidated materials and through the bedrock units below, each with separate attendant problems, separate sections are devoted to each. Discussion of the bedrock region has been further divided into the important rock strata containing usable water resources. This division is necessary because water quality varies from one geologic unit to another.

With the subdivisions of the Water Resources discussion, larger generalized maps as well as smaller more specific maps and diagrams are used to indicate water quantity and quality. Also, maps have been included with information as to the depth at which a particular geologic unit is likely to be encountered.

SURFACE WATER MAP: Surface streams and impoundments are probably the best sources of water for general usage throughout the entire region. The map indicates the region's major waterways, the English, Skunk, Des Moines, Fox, and Chariton Rivers, and Cedar Creek — most of which have dependable flows of water. The flow on the smaller tributaries is less dependable and the water quality generally somewhat worse. However, overall quality of the region's surface water is very good, usually meeting all chemical standards for public consumption. While there is no general water quality problem in the surface water, high nitrates or bacteria are possible future problems, at least locally. These problems, if they occur, can generally be traced directly to either agricultural runoff or sewage disposal.

Because good quality groundwater is a problem in perhaps two-thirds of the region, this surface water is very important for both urban and rural water uses. Many urban communities use river water or wells drilled into the river alluvium, which is also closely related to the surface streams.

Appanoose, Lucas, Monroe, and Wayne counties are beginning a regional rural water plan, using local and federal funds to make good quality water from Rathbun Reservoir available to all areas of these four counties. These four counties particularly have poor quality groundwater, hence the guarantee of good quality water from Rathbun may increase the cattle and hog raising industries by 100% or more. In addition, the plan will help provide good water for domestic uses and sanitary facilities.

DEFINITIONS

Alluvium — a general term that applies to stream deposits (e.g. sand, gravel, silt) laid down in river bed, floodplains, lakes and estuaries; alluvial, adj.

Aquiclude — a rock unit or body of sediments of low permeability that may absorb water slowly but will not transmit it in significant amounts.

Aquifer — a rock unit(s) or body of sediments that is able to transmit water readily and from which useful amounts of water can be extracted. Bedrock aquifers are those occurring in rock units; unconsolidated aquifers are those found in sediments.

Aquitard — a unit or rock which retards or restricts free water movement.

Bedrock — the solid rock beneath any unconsolidated material.

Cambro-Ordovician — periods of geologic time between 440 and 600 million years ago characterized by deposition of sandstones and limestone.

Clay — unconsolidated material with particles smaller than .002mm.

Devonian — the period of geologic time between 350 and 400 million years ago characterized by the deposition of limestone and dolostones.

Dolostone — a bedded sedimentary rock consisting chiefly of calcium-magnesium carbonate — $CaMg(CO_3)_2$. Water moves through fractures and solution channels.

Geologic Unit — informal term used to denote a grouping of materials based on similar characteristics and/or similar time of deposition.

Gravel — accumulation of water worn pebbles less than three inches in size.

Groundwater — that water occurring below the surface of the earth. In a more restricted sense, that water occurring within the zone of saturation.

Hydrology — study of behavior or state of water, its properties, movement, environment, spatial relations, and distribution.

Limestone — a bedded sedimentary rock consisting chiefly of calcium carbonate ($CaCO_3$). Groundwater is located in fractures and solution channels which may be quite large and facilitate movement of large amounts of water quickly.

Mississippian — the period of geologic time between 310 and 350 million years ago characterized by the deposition of much limestone.

Pennsylvanian — the period of geologic time between about 270 and 310 million years ago during which mostly shales were deposited in this region. Significantly, coal was deposited during this period.

Sand — unconsolidated material with particles ranging in size between .05 and 2.0mm. The particles are largely quartz, but with many other minerals possible present.

Sandstone — a sedimentary rock consisting of cemented grains of sand.

Shale — a sedimentary rock consisting largely of clay particles.

Stratigraphy — the study of the composition, sequence, formation, and correlation of sedimentary rocks.

Subcrop — the location of bedrock units beneath the unconsolidated material which covers them.

Surface water — used here in the general sense to include both free-standing (e.g. pools, lakes) and flowing (runoff) water; any water that has not passed below the surface of the land.

Till — a heterogeneous mixture of rock materials ranging in particle size from clay to boulders which have been transported and deposited by glacial ice.

Unconsolidated materials — earth material which has not been consolidated into a rock — e.g. sand, gravel, loess, till, soil.

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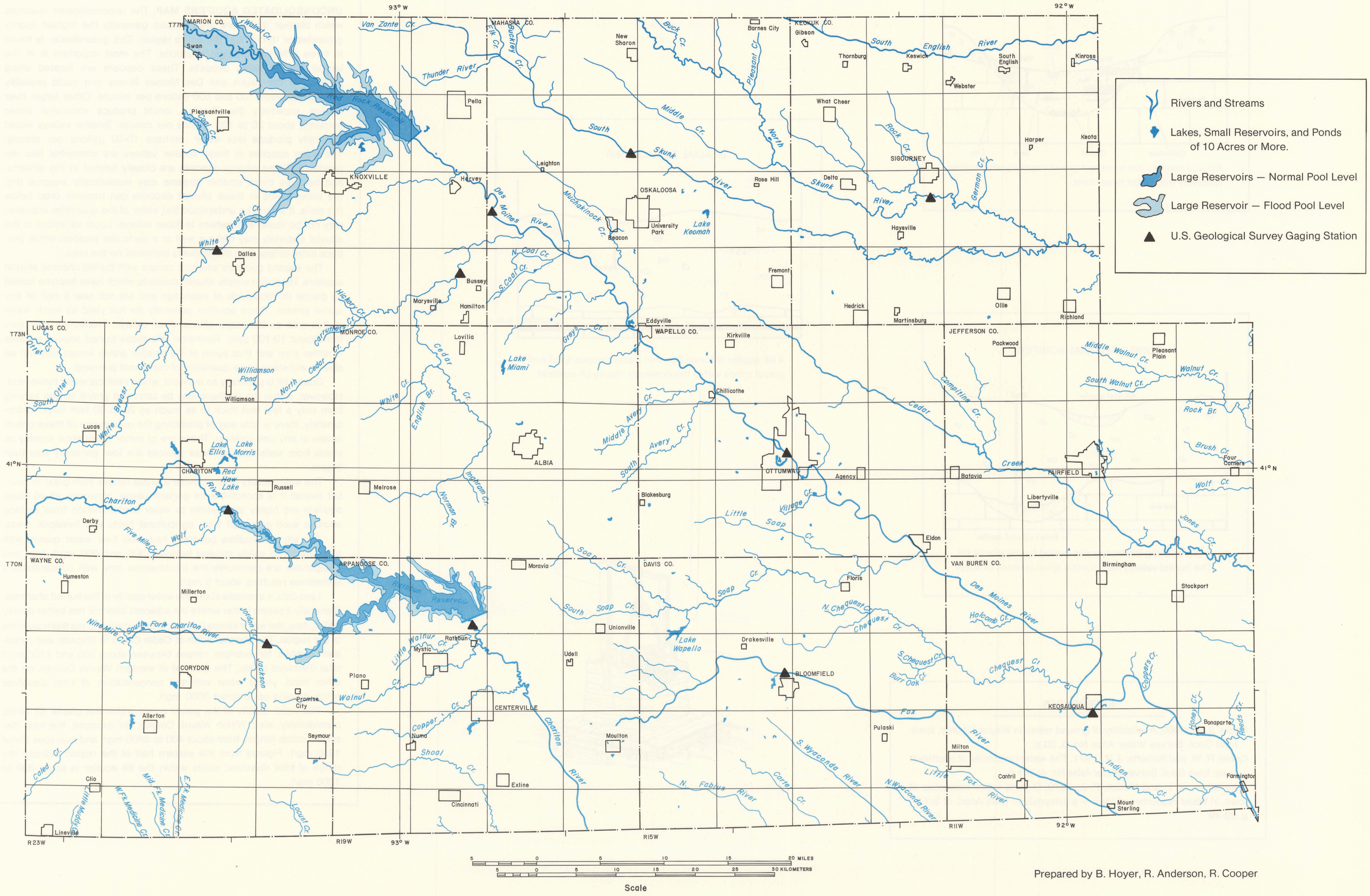
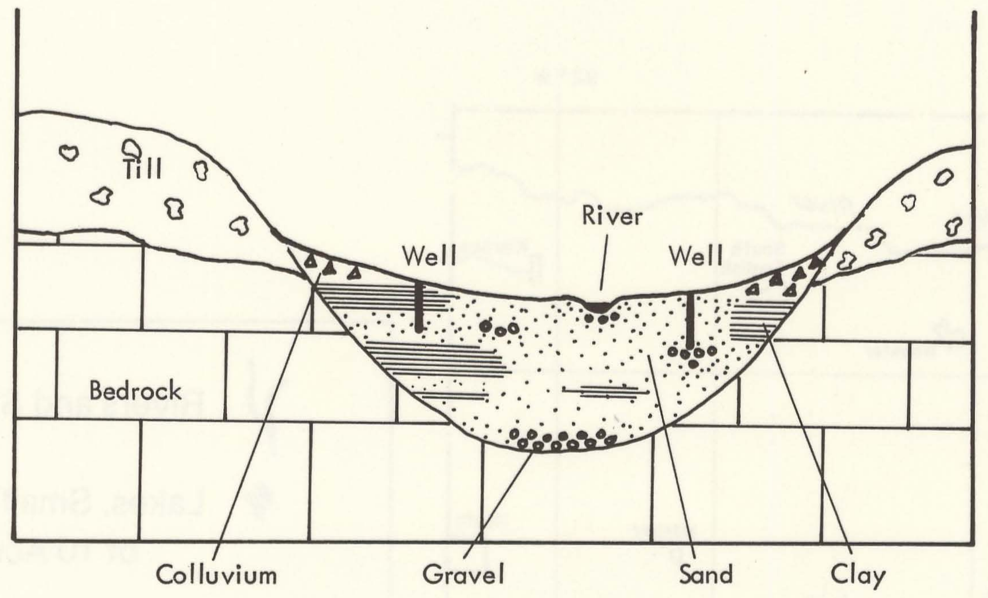
Surface Water



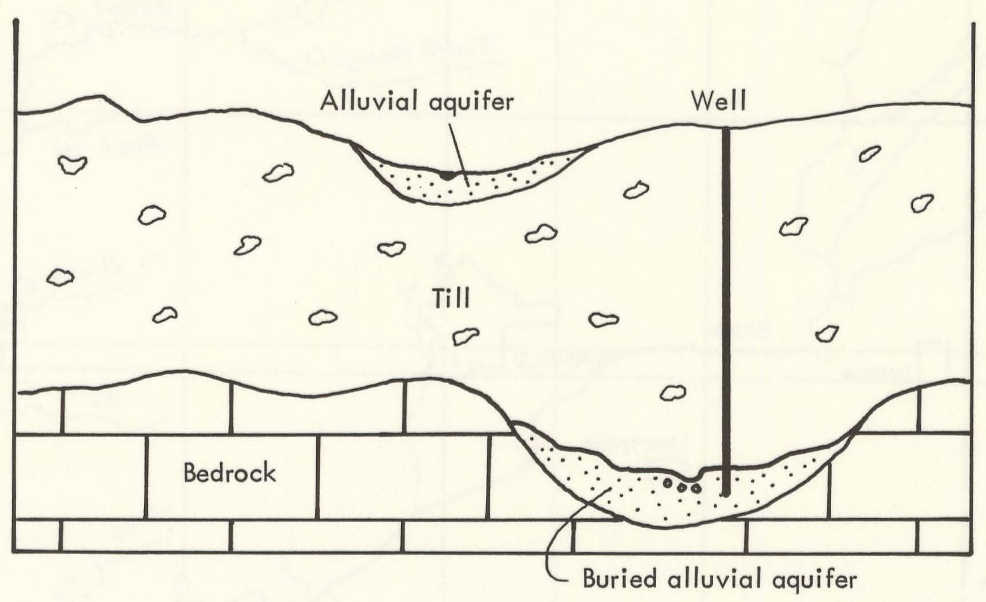
Prepared by B. Hoyer, R. Anderson, R. Cooper

ALLUVIAL AQUIFER



Alluvial aquifers are sand and gravel deposits which allow relatively free water movement.

BURIED ALLUVIAL AQUIFER



A pre-existing landscape was buried by the glacial till. The buried valleys may contain good sources of water.

REFERENCES

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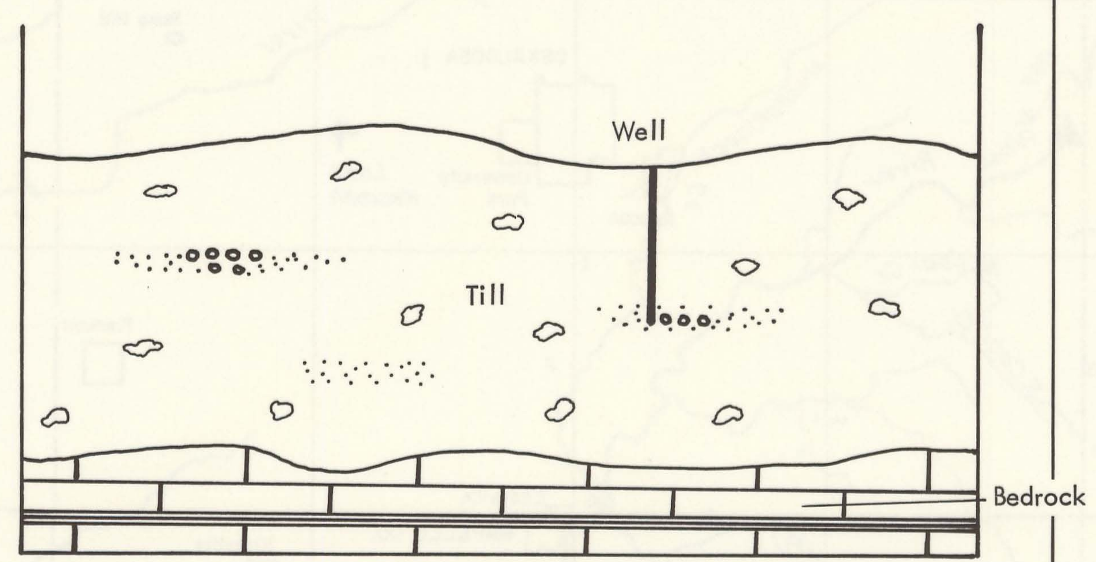
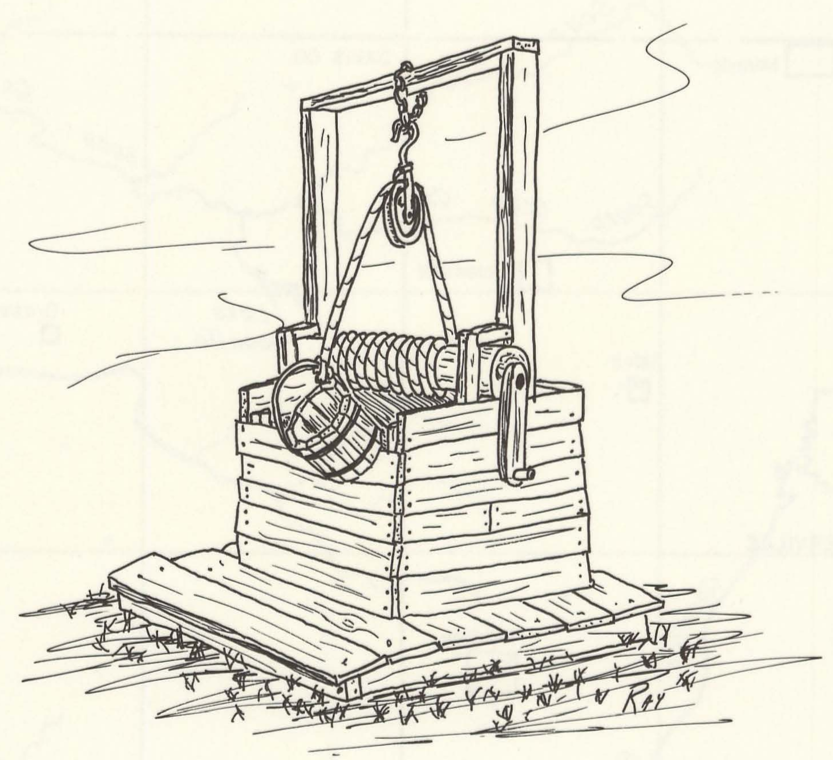
Coble, R. W. and Roberts, J. V., 1971, The water resources of southeast Iowa: Iowa Geol. Survey Water Atlas No. 4, 101 p.

Steinhilber, W. L. and Horick, P. J., 1970, Ground water resources of Iowa, in Water resources of Iowa — a symposium: Iowa Acad. of Sci., p. 28-49.

GLACIAL TILL AQUIFER



A till aquifer is formed by thin discontinuous sand and gravel zones within the dominant clayey till material.



UNCONSOLIDATED AQUIFERS MAP: The unconsolidated materials which blanket the entire area contain generally the highest quality groundwater throughout the entire region. This groundwater is found in three different geologic situations. The most important is in the largest alluvial valley deposits. These deposits are located along portions of the Skunk and Des Moines Rivers and could probably produce between 100 and 500 gallons per minute. Other larger river valleys, especially the Chariton, could produce somewhat lesser amounts, about 20 to 100 gallons per minute. Smaller valleys would generally produce less water, perhaps 10-50 gallons per minute. The water supplies in these smaller valleys are somewhat less dependable. These alluvial deposits are closely related to the streams, and because these smaller streams may occasionally become dry, the water levels in these alluvial deposits can possibly drop below the wells. It should be understood that water of the quantities indicated may not be found everywhere in these valleys. Local variations in the alluvial materials may make a well in a particular location either produce more or less than the amounts indicated on the map.

The second geologic situation occurs with buried channel alluvial aquifers. These are simply alluvial deposits which have become buried by glacial till thousands of years ago and are not now a part of any active stream. These aquifers generally do not yield as much water in this area as the major alluvial river valleys. Production may vary from about 10-100 gpm. Recharge into these buried alluvial aquifers is rather slow and thus some of the smaller gravel lenses may not be able to withstand large quantities of continued pumping.

Glacial till is generally an aquitard, which restricts water movement. However, within the till there may be sand and gravel lenses varying from only a few feet thick to as much as 20 to 30 feet thick. Unfortunately, there is little way of predicting the occurrence of these gravel lenses at any one location. These are of minor importance anyway as yields from wells tapping these sources are low, generally less than 5 gpm.

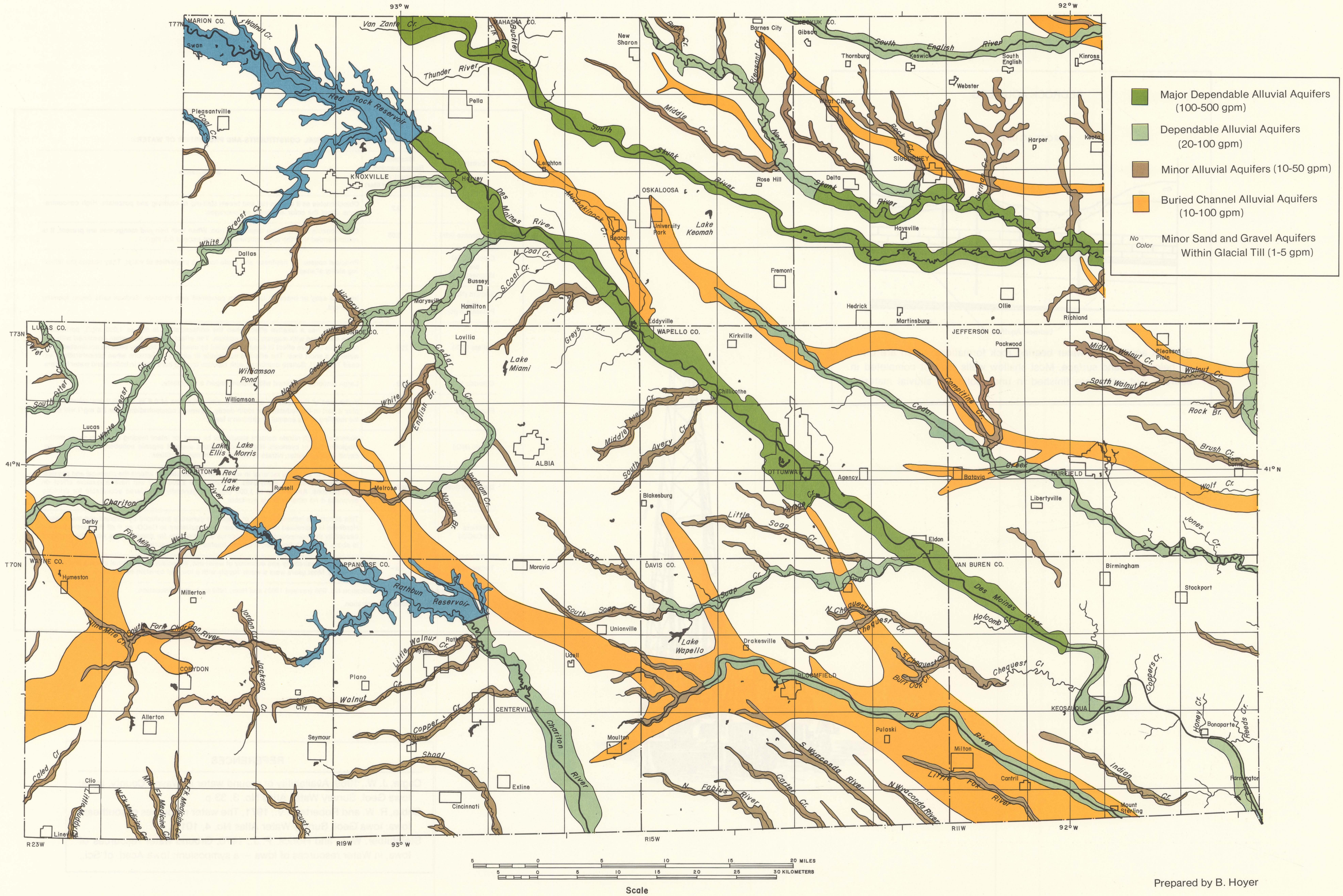
The water quality from all these sources ranges from good to poor, but overall it is acceptable for general usage. However, all of these aquifers are highly susceptible to water contamination from surface sources such as runoff from agricultural fields and livestock areas.

The alluvial aquifers generally have the best water quality with total dissolved solids ranging between 300 and 600 mg/l. Iron and manganese are commonly the troublesome ions with concentrations sometimes reaching about 5 mg/l.

Less data is available about the water quality of the buried channels. Generally it seems better where the adjacent bedrock has better quality water; thus, the water seems better in the eastern and northern portions of the region. The channel north of Cedar Creek in Wapello and Jefferson Counties, for example, ranges between about 300 and 1100 mg/l total dissolved solids. The channel in western Wayne County, on the other hand, yields water with the concentration of total dissolved solids ranging up to about 3000 mg/l.

The water quality of the gravel zones within the glacial till varies considerably, also. Within Wayne County, for example, the total dissolved solids ranges from about 400 to 3600 mg/l and averages about 1250 mg/l. Figures from the eastern half of the region indicate the range of total dissolved solids within the till aquifer is about 350 to 1000 mg/l.

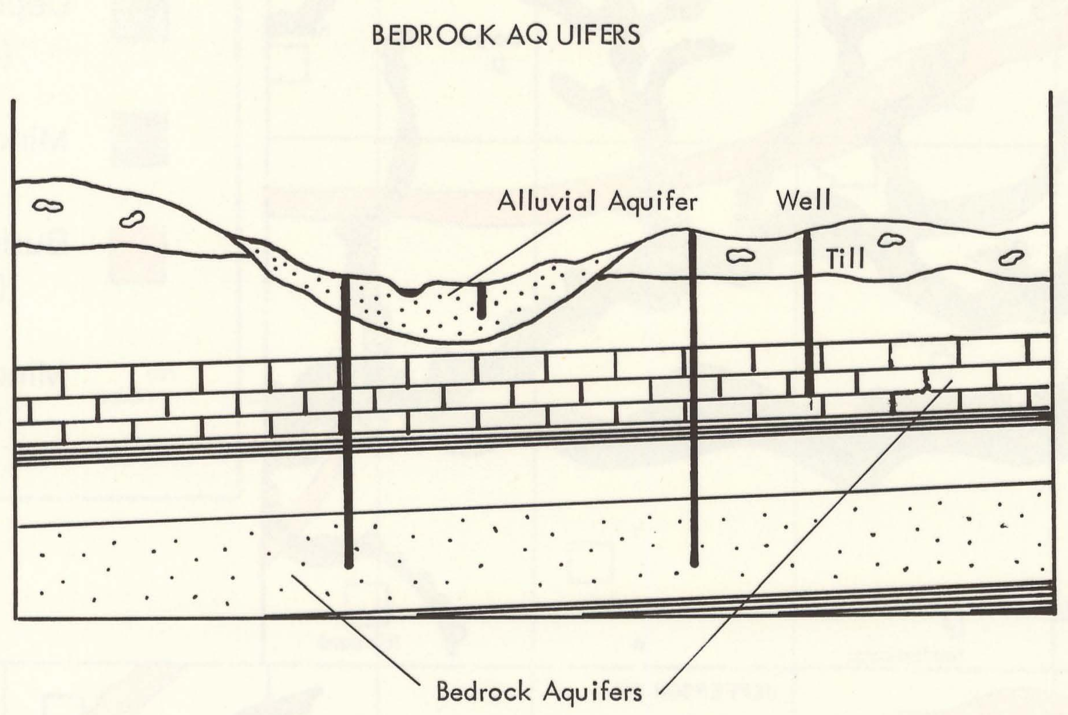
Ground Water: *Unconsolidated Aquifers*



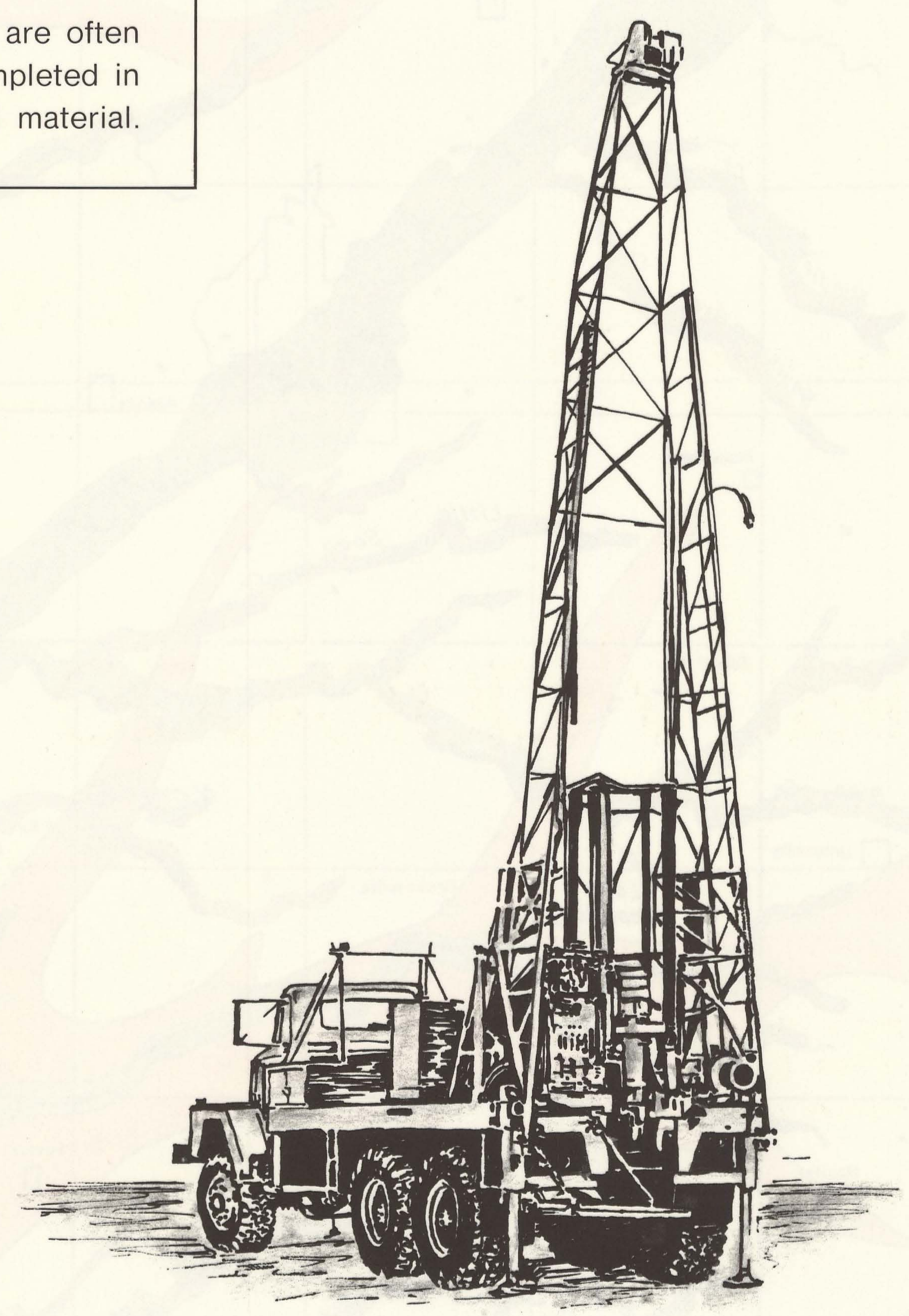
Prepared by B. Hoyer

Ground Water *Bedrock Aquifers*

BEDROCK AQUIFERS



Bedrock aquifers are water bearing rock formations which are often far below the land surface. Most shallow wells are not completed in bedrock, but rather are finished in unconsolidated alluvial material.



SIGNIFICANCE OF MINERAL CONSTITUENTS AND PROPERTIES OF WATER①

Constituent or Property	Maximum Recommended Concentration (Milligrams per liter)	Significance
Iron (Fe)	0.3	Objectionable as it causes red and brown staining of clothing and porcelain. High concentrations affect the color and taste of beverages.
Manganese (Mn)	0.05	Objectionable for the same reasons as iron. When both iron and manganese are present, it is recommended that the total concentration not exceed 0.3 mg/l.
Calcium (Ca) and Magnesium (Mg)	- a -	Principal causes for hardness and scale-forming properties of water. They reduce the lathering ability of soap.
Sodium (Na) and Potassium (K)	- a -	Impart a salty or brackish taste when combined with chloride. Sodium salts cause foaming in boilers.
Sulfate (SO_4)	250	Commonly has a laxative effect when the concentration is 600 to 1,000 mg/l, particularly when combined with magnesium or sodium. The effect is much less when combined with calcium. This laxative effect is commonly noted by newcomers, but they become acclimated to the water in a short time. The effect is noticeable in almost all persons when concentrations exceed 750 mg/l. Sulfate combined with calcium forms a hard scale in boilers and water heaters.
Chloride (Cl)	250	Large amounts combined with sodium impart a salty taste.
Fluoride (F)	2.0	In the area of the aquifer's occurrence, concentrations of 0.8 to 1.3 mg/l are considered to play a part in the reduction of tooth decay. However, concentrations over 2.0 mg/l will cause the mottling of the enamel of children's teeth.
Nitrate (NO_3)	45	Waters with high nitrate content should not be used for infant feeding as it may cause methemoglobinemia or cyanosis. High concentrations suggest organic pollution from sewage, decayed organic matter, nitrate in the soil, or chemical fertilizer.
Dissolved Solids	500	This refers to all of the material in water that is in solution. It affects the chemical and physical properties of water for many uses. Amounts over 2,000 mg/l will have a laxative effect on most persons. Amounts up to 1,000 mg/l are generally considered acceptable for drinking purposes if no other water is available.
Hardness (as $CaCO_3$)	- a -	This affects the lathering ability of soap. It is generally produced by calcium and magnesium. Hardness is expressed in milligrams per liter equivalent to $CaCO_3$ as if all the hardness were caused by this compound. Water becomes objectionable for domestic use when the hardness is above 100 mg/l; however, it can be treated readily by softening.
Temperature	- a -	Affects the desirability and economy of water use, especially for industrial cooling and air conditioning. Most users want a water supply with a low and constant temperature.

① See U.S. Public Health Service Publication No. 956 (revised 1962) and Hem, 1959 for further discussion.

a. No maximum recommended concentration.

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Cagle, J. W., 1969, Availability of ground water in Wayne County, Iowa: Iowa Geol. Survey Water Atlas No. 3, 33 p.

Coble, R. W. and Roberts, J. V., 1971, The water resources of southeast Iowa: Iowa Geol. Survey Water Atlas No. 4, 101 p.

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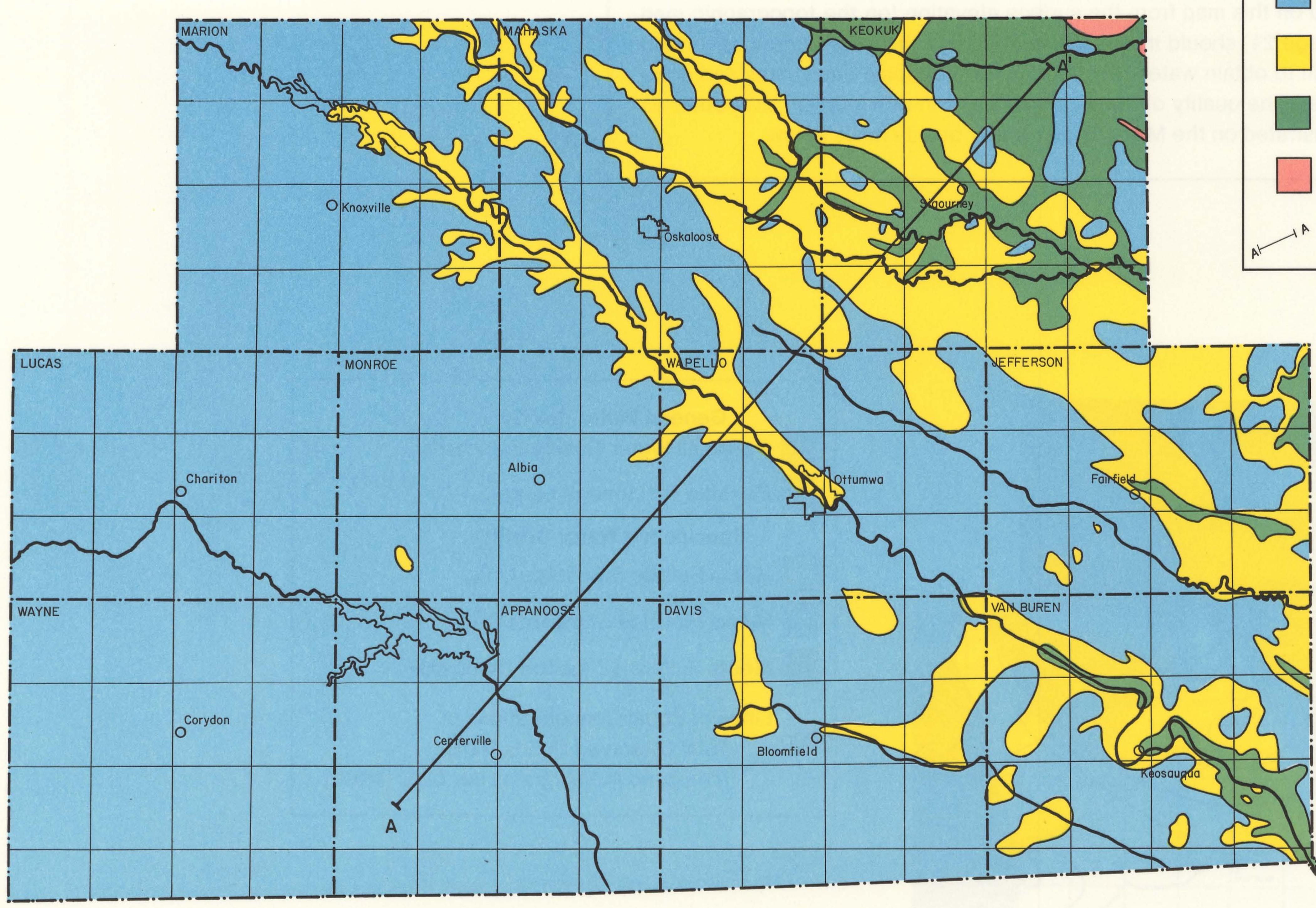
Hydrogeologic Units



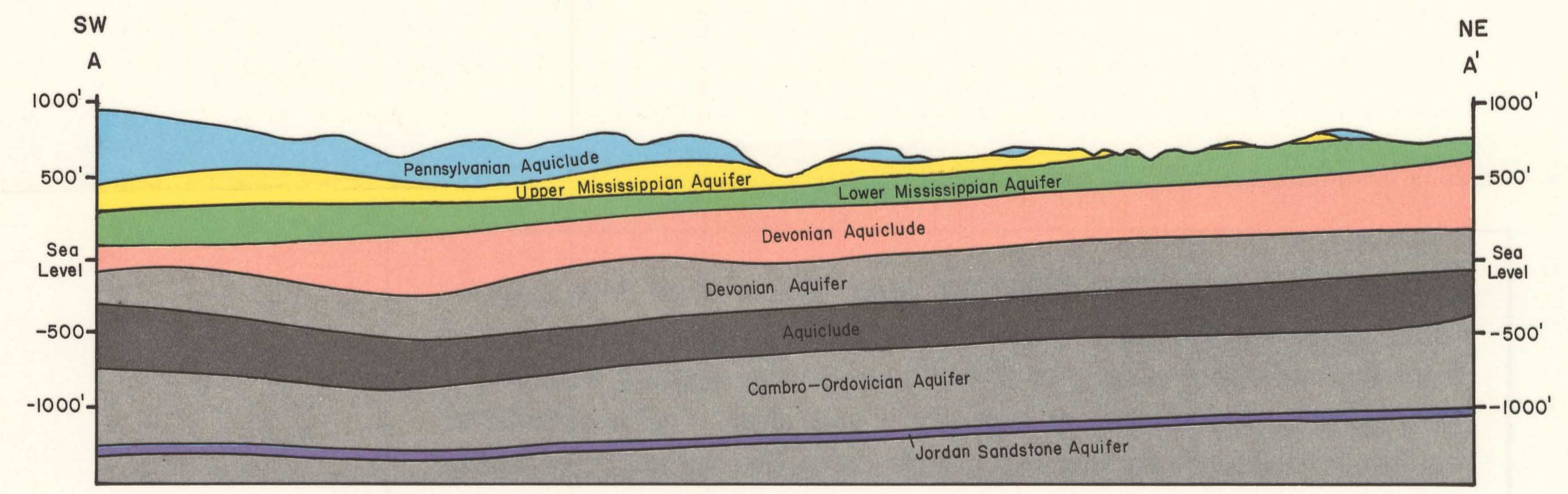
PENNSYLVANIAN AQUICLUDE (Mostly Shale with Minor Sandstone Aquifers)
UPPER MISSISSIPPIAN AQUIFER (Limestones and Sandstones) — Good to Poor Quality Water (500-2500 TDS)
LOWER MISSISSIPPIAN AQUIFER (Limestones, Dolostones, and Shales) — Fair to Poor Quality Water
DEVONIAN AQUICLUDE (Impermeable Siltstones and Limestones)
LINE OF CROSS SECTION

Prepared by B. Hoyer, modified from R. W. Coble

HYDROGEOLOGIC UNITS MAP: The geologic bedrock units are grouped here according to their general water-bearing characteristics. Those units designated as aquicludes do not contain appreciable supplies of available water; those designated as aquifers generally contain sufficient available water. All of the geologic units dip gently to the southwest. Their placement on this map indicates where they would be exposed at the earth's surface if there were not a mantle of unconsolidated materials overlying them.

The area indicated as the Pennsylvanian aquiclude is generally "water deficient," and obtaining high quality water is difficult there except from surface water sources. However, in this area near surface alluvial aquifers may be utilized, or underlying aquifers may be penetrated by drilling through the Pennsylvanian. There are two distinct Mississippian aquifers with dissimilar water quality. Generally the Upper Mississippian rocks contain the better water. However, where the Lower Mississippian rocks are not covered by other bedrock units, it, too, has high quality water.

Other aquifers not shown on this map can be tapped in the Eleven-County region. These are buried entirely in this area and become exposed in northeast Iowa. These buried units are illustrated in the schematic cross section of the area. All bedrock water is generally more available and of higher quality in the eastern and northern portions of the Eleven-County region. The maps on the following pages should give a more complete picture of the groundwater available in this region.



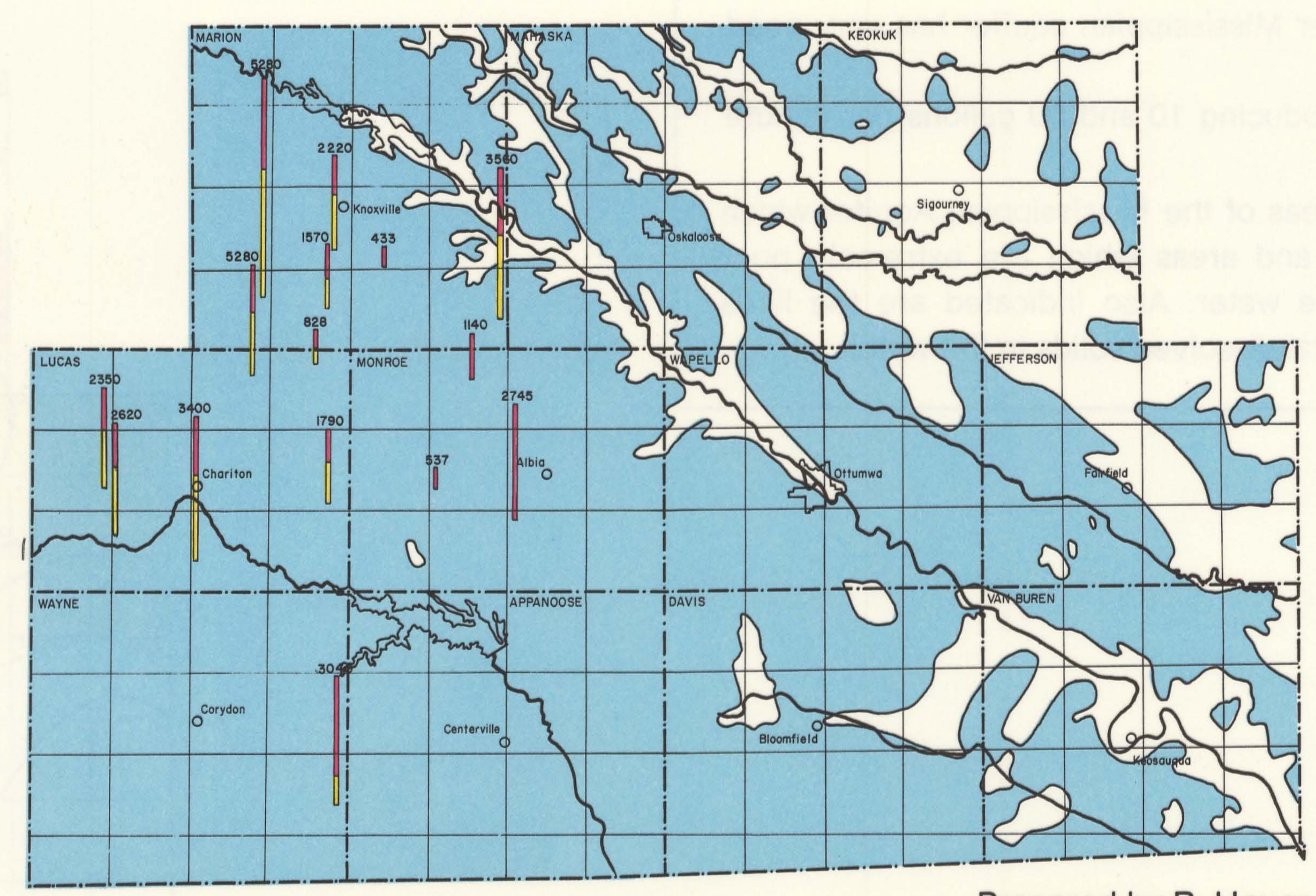
Pennsylvanian Aquiclude

PENNSYLVANIAN AQUICLUDE: In the southwestern portions of the Eleven-County region, the scarcity of other good quality water which can be obtained economically forces many land owners to obtain water from the Pennsylvanian rocks.

Taken as a single bedrock unit, the Pennsylvanian age rocks are not important as a water source since they are primarily composed of shale which impedes water movement by not allowing sufficient pore space. However, several sandstone units are included within the Pennsylvanian rocks. These sandstone units, which are poorly mapped and may be discontinuous, do contain water.

Pennsylvanian water generally does not meet water quality standards. Sulfate ion concentrations as high as 7000 mg/l are especially troublesome. Iron is also a troublesome ion from Pennsylvanian water sources. However, the water quality varies considerably and some individual wells do contain relatively good quality water. The examples indicated on the map are water quality analyses made from wells producing water predominantly from these sandstone units within the Pennsylvanian aquiclude.

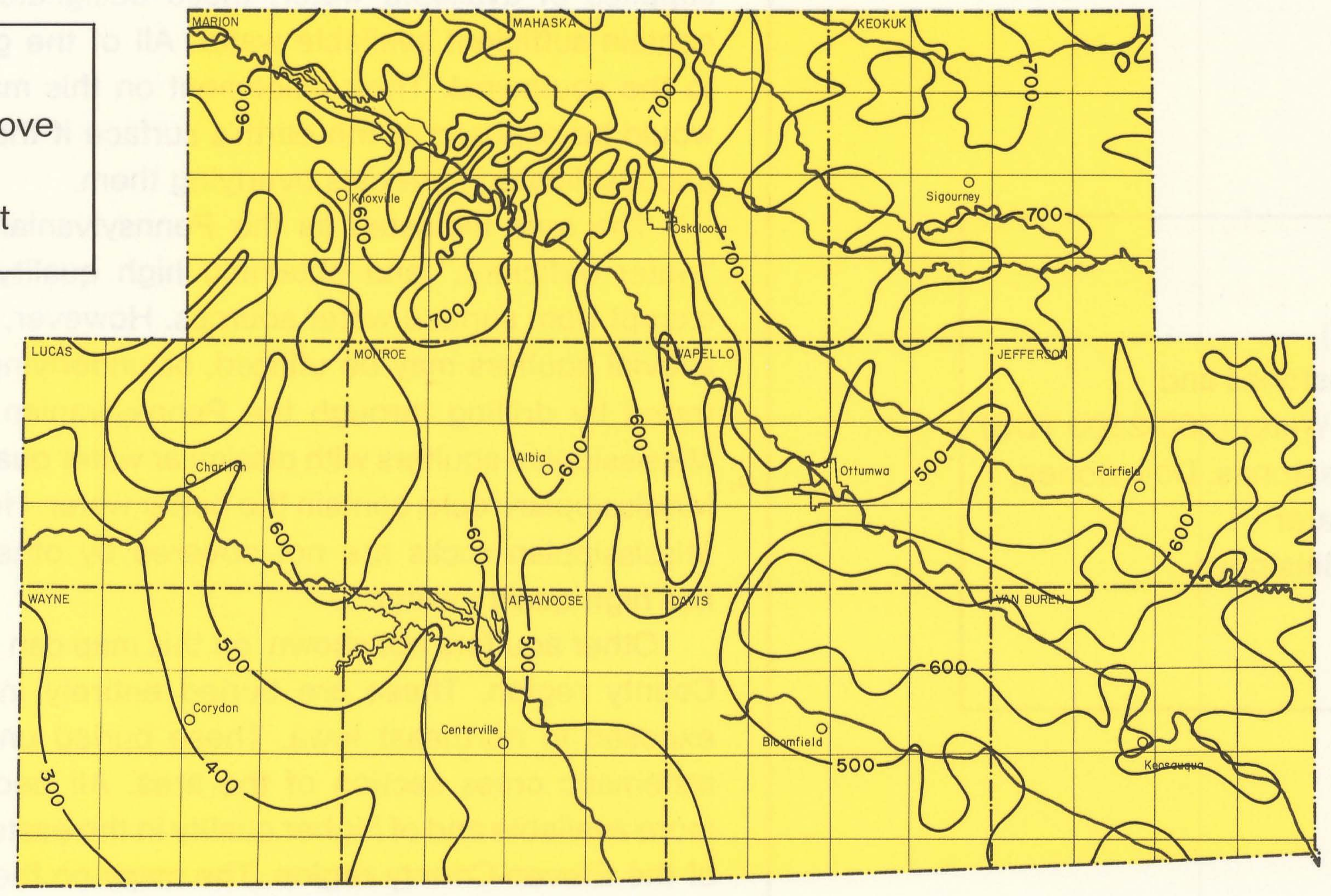
Area of Pennsylvanian Aged Rocks
3400 Concentration of Total Dissolved Solids (milligrams per liter)
Sulfate Portion of Total Dissolved Solids Indicated as Yellow



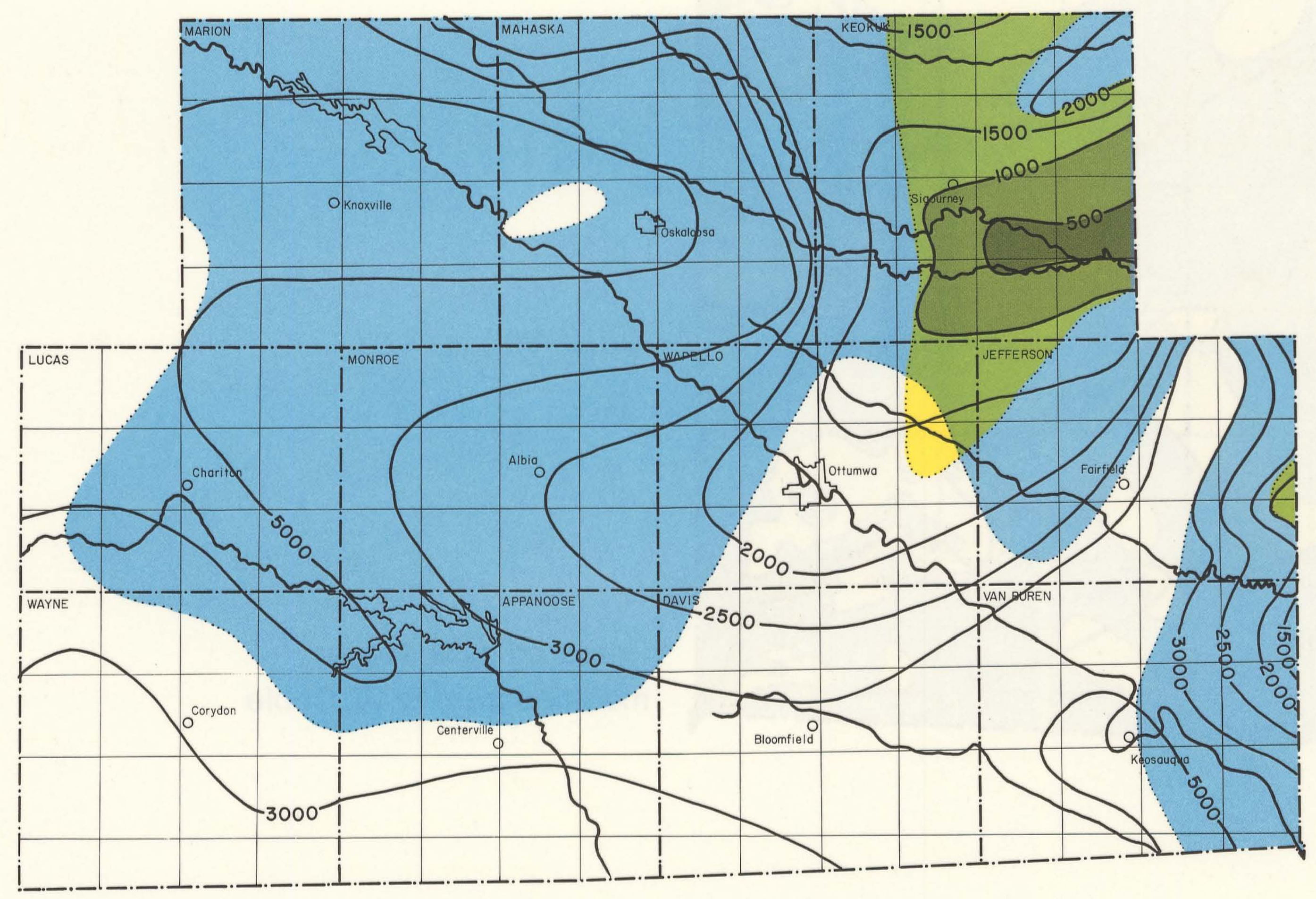
Prepared by B. Hoyer

Mississippian Aquifer

600 Line of Equal Elevation Above Sea Level
Contour Interval 100 Feet



CONTOUR MAP OF MISSISSIPPIAN AQUIFER: This map gives the expected elevation at which one drilling into the earth could expect to strike a Mississippian aquifer. Thus, subtracting the elevation indicated on this map from the surface elevation (on the topographic map on page 21) should indicate approximately the depth one would need to drill to obtain water contained in Mississippian limestones and dolostones. The quality of the water varies from one location to another as is illustrated on the Mississippian water quality maps below.



General Water Quality
Meets all Water Quality Standards
Suitable for General Usage

Specific Ion Water Quality
Meets Sulfate Standards Only
Meets Flouride Standards Only
Meets Sulfate & Fluoride Standards

1000 Lines of Equal Concentrations of Total Dissolved Solids (TDS) Measured in Milligrams per Liter (Mg/L)

MISSISSIPPIAN WATER QUALITY MAP: Water from Mississippian rocks varies considerably in quality. Its quality in general deteriorates from the northeast corner of the Eleven-County region, where it is very good, to the southwest, where it is very poor. The Mississippian aquifer is divided into two main units, with the Warsaw Formation, which is a thin shale unit, restricting water movement between the two aquifers. The Upper Mississippian contains the better quality water. Wells drilled into the Mississippian rocks where both the upper and lower parts are present, should generally stop in the St. Louis Formation, a unit in the Upper Mississippian, before the Warsaw shale is pierced. When this Warsaw Formation is pierced, the more highly mineralized water from below becomes incorporated with the water from above and adversely affects the water quality of the well. However, in the northeast corner of the region where the Upper Mississippian is not present, the Lower Mississippian aquifer has very good quality water.

The aquifer is capable of producing 10 and 50 gallons per minute for each foot of drawdown.

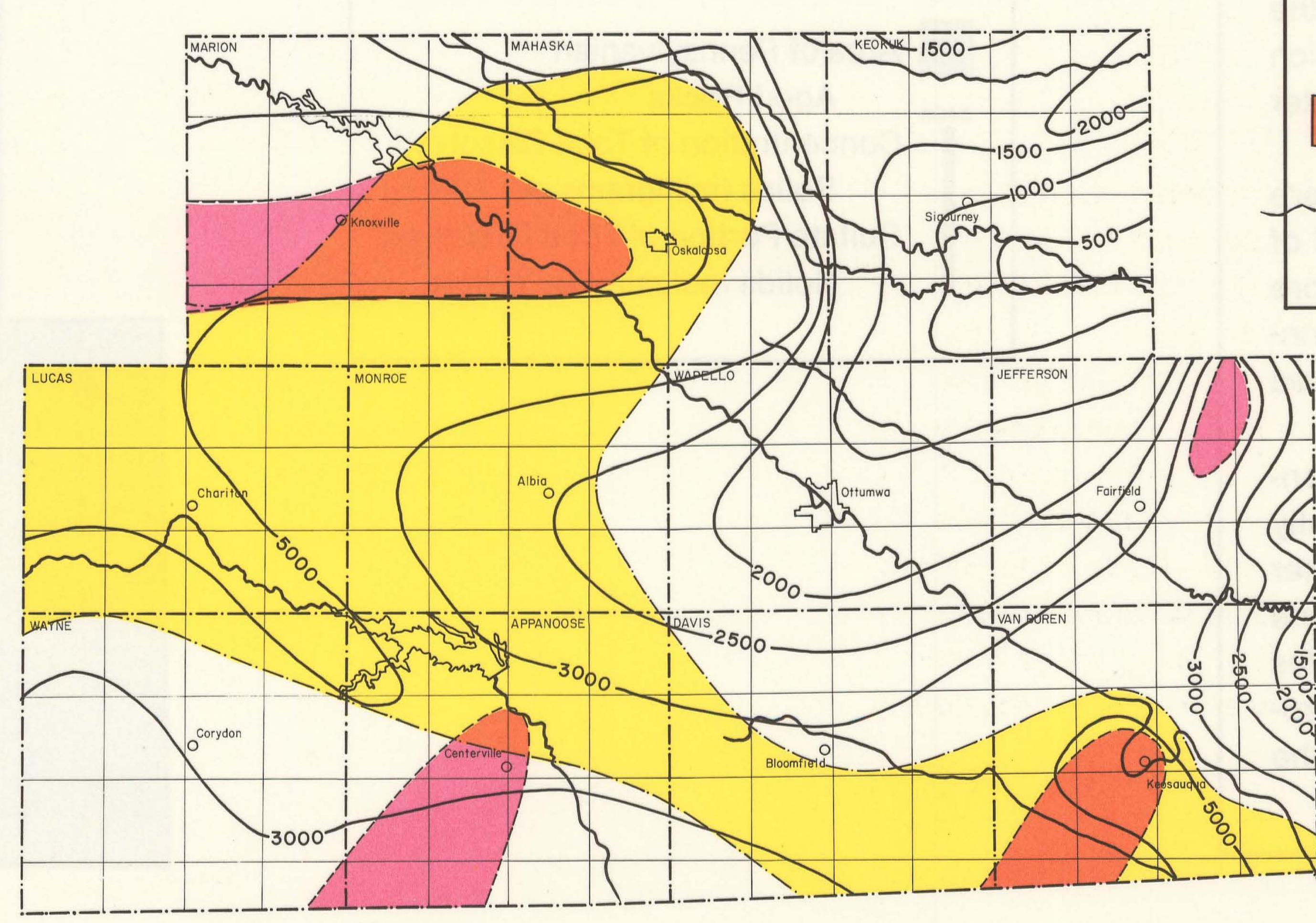
These maps pinpoint the areas of the Mississippian Aquifer which meet public health standards, and areas which are extremely poor for certain selected ions in the water. Also indicated are the lines showing the concentration of total dissolved solids in the water.

High Sulfate Concentrations (exceeding 2000 mg/L)
These concentrations may have a strong laxative effect.

High Sodium & Potassium Concentrations (exceeding 1000 mg/L)
These high concentrations may be hazardous to people with certain heart conditions.

High Sulfate, Sodium, & Potassium Concentrations

1000 Lines of Equal Concentrations of Total Dissolved Solids (TDS) Measured in Milligrams per Liter (mg/L)



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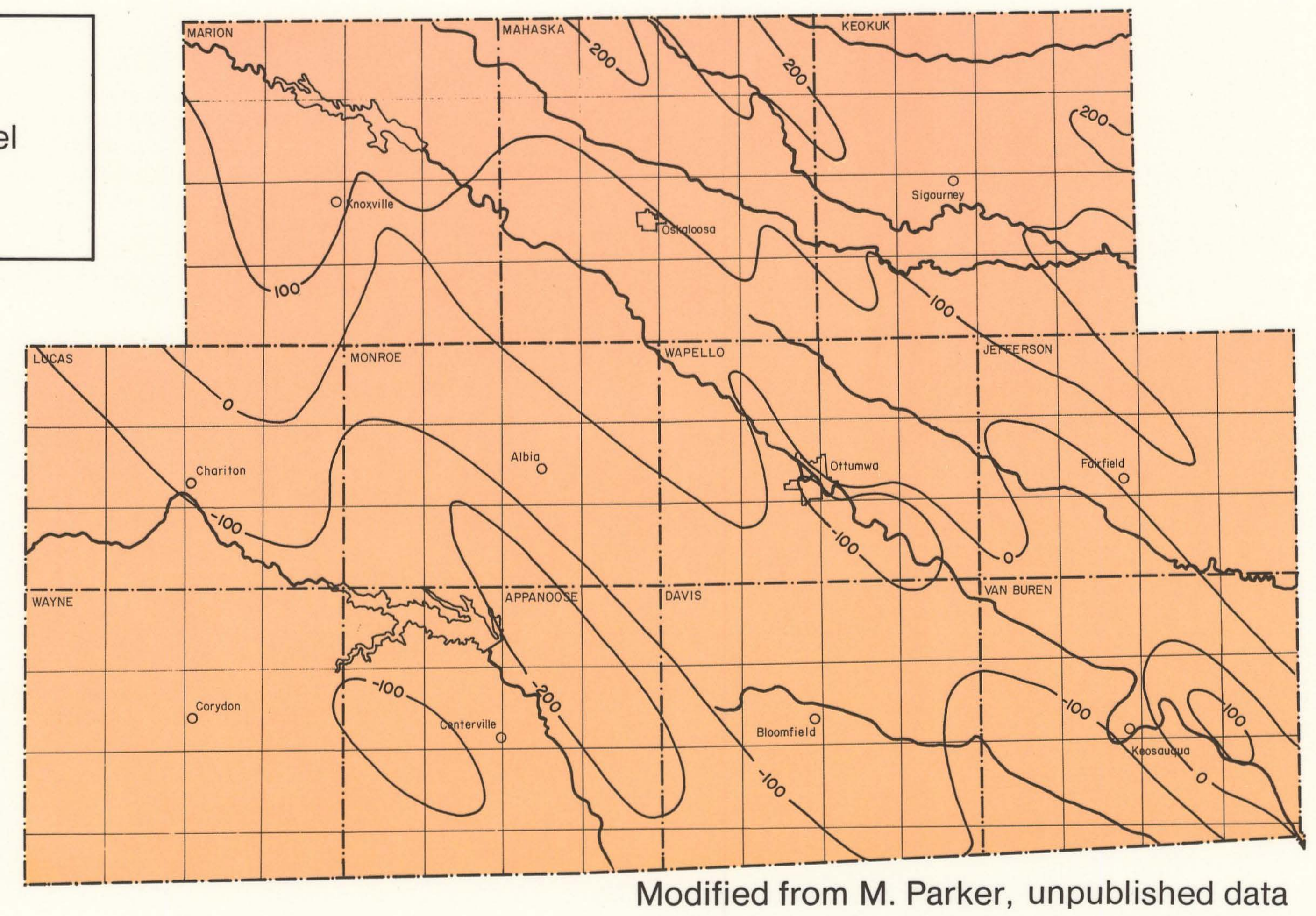
Devonian Aquifer



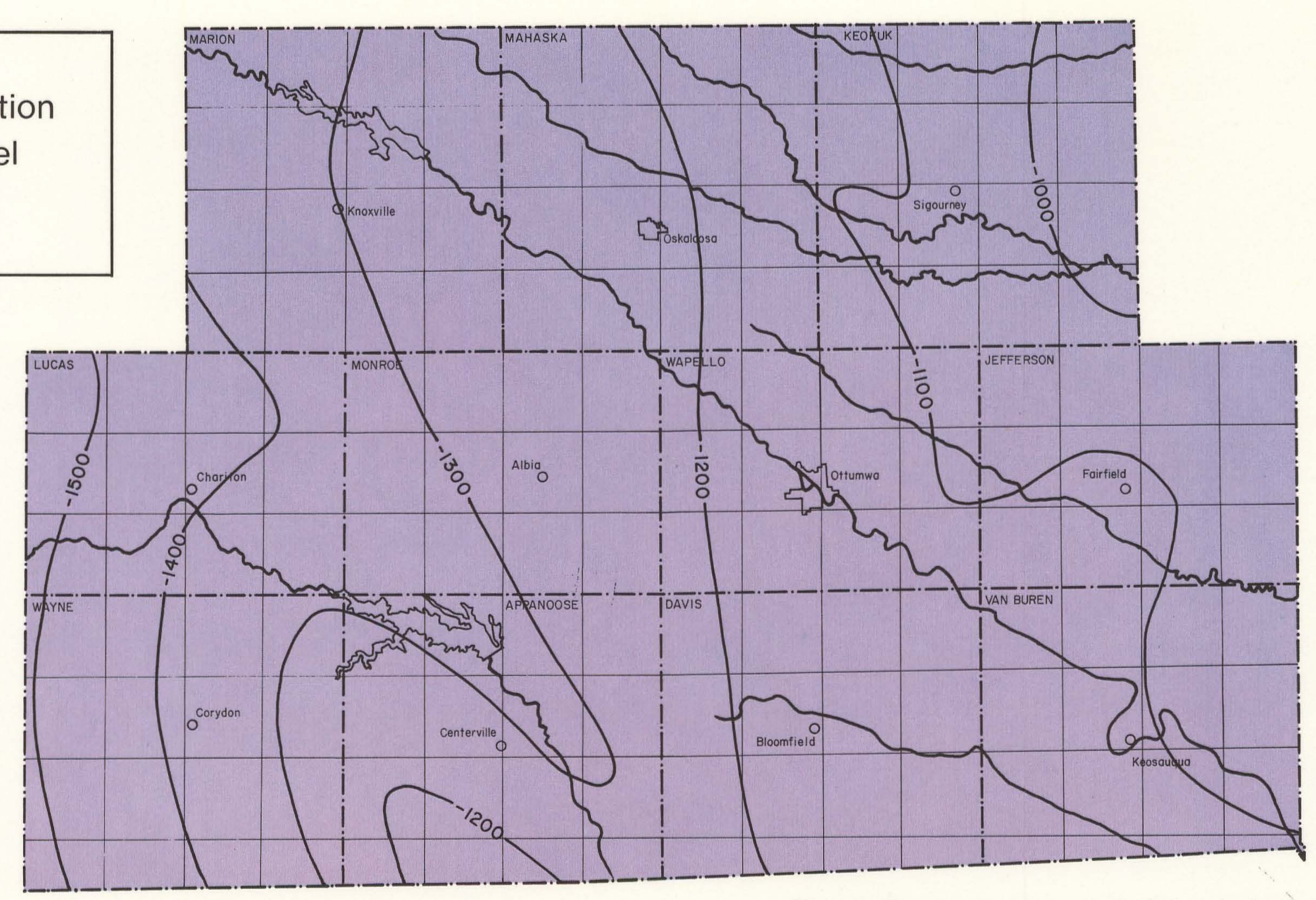
100 Line of Equal Elevation
Above/Below Sea Level
Contour Interval 100 Feet

Modified from M. Parker, unpublished data

WATER QUALITY AND CONTOUR MAP OF DEVONIAN AQUIFER: This map indicates the elevation at which Devonian limestones and dolostones may be expected. The water from Devonian rocks in this region is very high in total dissolved solids. Thus it is generally unacceptable for most uses and not now used in this region. However, the large quantities of water that are available might be used for cooling or could become important if desalinization techniques were to become economically practical.

Cambro-Ordovician Aquifer-Jordan Formation

-1200 Line of Equal Elevation
Below Sea Level
Contour Interval 100 Feet



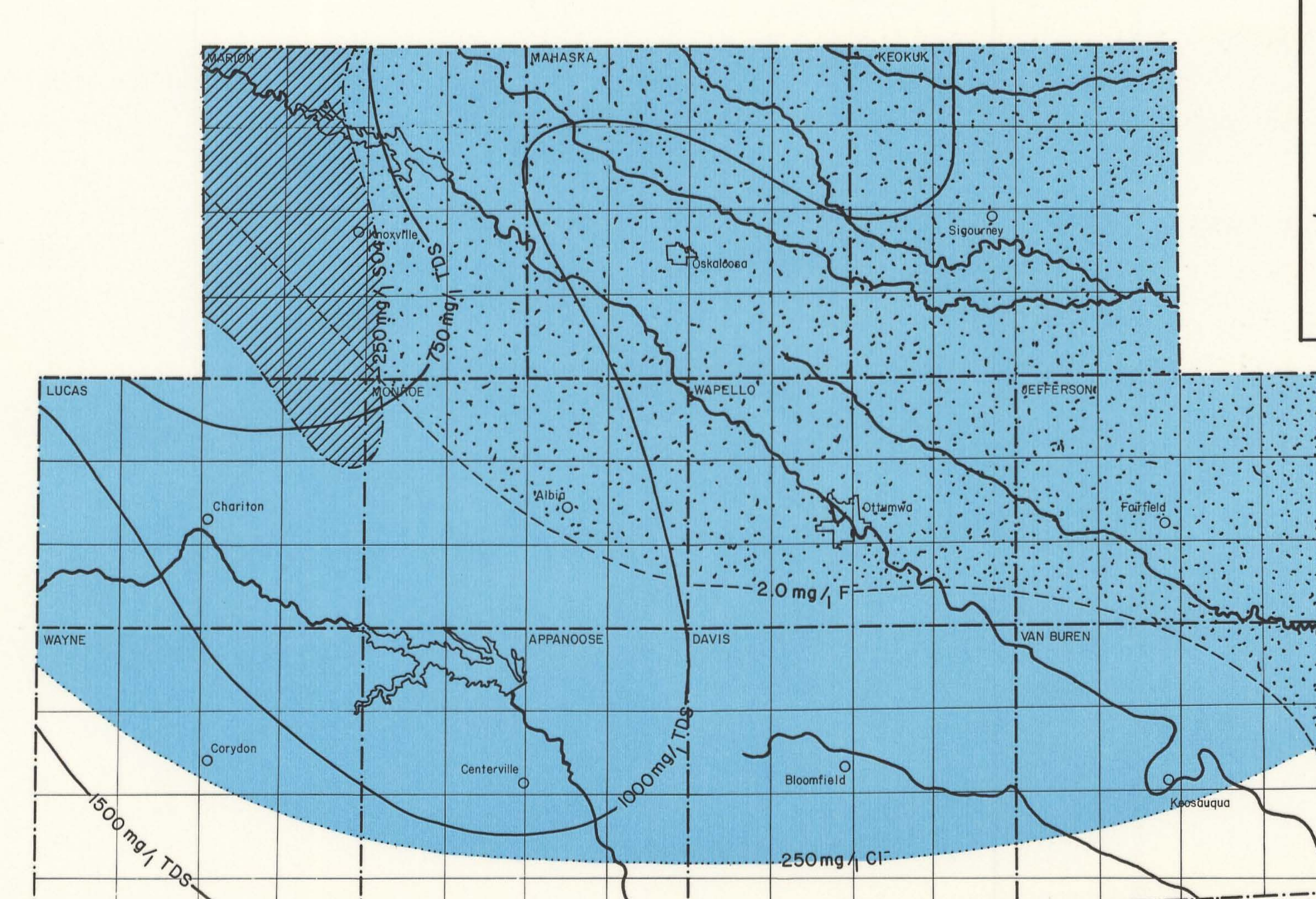
From P. Horick, unpublished data

CONTOUR MAP OF TOP OF JORDAN SANDSTONE: The Jordan sandstone is one of the most important aquifers in Iowa. Statewide, the water contained in this unit is both abundant and of the highest quality. It is currently being used as a municipal water supply in only a few places in this region. This is because the Jordan sandstone occurs at great depth in this region and thus is expensive to utilize. In addition, the quality of the water deteriorates somewhat in the Eleven-County region.

This map indicates the elevation below sea level that the Jordan sandstone may be found. The top of the Cambro-Ordovician aged aquifer, of which the Jordan sandstone is an important part, can be expected about 600 feet above the Jordan sandstone.

JORDAN SANDSTONE WATER QUALITY MAP: Efficient well fields, of two or three wells, drilled into the Jordan can be expected to yield about 1.5 million gallons per day. However, in the extreme southwestern corner of the region, the yield decreases to about half of that amount. Although the Jordan sandstone presently has only limited use as a water source, its use by municipalities in the Eleven-County region could be expanded. Thus, knowledge of its water quality is very important. Throughout the region the total dissolved solids ranges from about 750 to 1500 milligrams in each liter of water. Concentrations of flourides, sulfates, and chlorides all exceed allowed federal water standards in some portions of the region. However, mixing water from the Jordan sandstone with surface or alluvial water could provide water acceptable for most general purposes.

Sulfate Concentrations Meet Recommended Standards
Flouride Concentrations Meet Recommended Standards
Chloride Concentrations Meet Recommended Standards
750 Lines of Equal Concentrations of Total Dissolved Solids



From P. Horick, unpublished data