EXECUTIVE SUMMARY

The objective of this study is to describe and analyze the hydrologic, institutional, legal, and economic issues involved in assessing and interpreting estimates of water availability for synfuels development in four major river basins: (1) Upper Mississippi, (2) Ohio/Tennessee, (3) Upper Missouri, and (4) Upper Colorado. In addition, the study evaluates the adequacy of currently used estimates of water availability as a basis for energy planning in these four basins.

To meet the objectives of this study, assessments of water availability for the four basins were reviewed and analyzed. In addition, case studies of water availability for synfuel development in the Upper Colorado and Upper Missouri River Basins were completed. The general conclusions resulting from these analyses and case studies are detailed in the Discussions and Conclusions section herein.

Estimating water availability for synfuel development is a difficult and complex task involving incomplete and inadequate data, unforeseen and unpredictable future judicial decisions and legislation, imperfect demand forecasting methods, and political constraints on the entity responsible for assessing water availability. As a result, considerable variation exists in quality, detail, and scope of water availability assessments.

It is suggested that the primary use of these assessments will be to evaluate the availability of water for initial development of synfuel industries in the respective river basins. "Initial development" refers to that period of approximately 10-12 years in the future during which those synfuel plants which are presently in some stage of planning will be constructed. The considerable uncertainty that exists concerning almost all aspects of forecasting future water availability for synfuel development in, for example, 2000, severely limits the dependability of these forecasts and, consequently, their usefulness.

Therefore, it is suggested that rather than focus on predicting, the objective of water availability assessments should be to acknowledge this uncertainty and play out the consequences of some of the ways that unpredictable political, judicial, and administrative decisions may affect water availability.

WATER AVAILABILITY FOR SYNFUEL DEVELOPMENT

Upper Mississippi River Basin

From a regional perspective water supplies for synfuel development in the Upper Mississippi River Basin are adequate. Localized problems, however, may result depending on the specific site for a synfuel plant. Water supply Y shortages and negative impacts on water resources are most likely to occur for synfuel sites on tributaries. These shortages and negative impacts cal be eliminated or reduced by construction of reservoir storage on tributaries, conjunctive use of ground and surface water or other measures to reduce diversions from unregulated streams during low flow periods.

Ohio/Tennessee River Basin

The water availability situation for synfuel development in the Ohio and Tennessee Basins is comparable to that in the Upper Mississippi. From a regional perspective sufficient water is available for projected present and future synfuel development but localized problems or deficiencies may occur for synfuel plants sited on tributaries. The extent and nature of these deficiencies can only be predicted with site specific studies.

Upper Colorado River Basin

Water is available, and can be made available, in the Upper Colorado River Basin to meet presently proposed and future oil shale development. The question is not whether water is available, but rather what the impacts on agriculture and other sectors will be from allocating this water from its present and potential use to synfuel development. For, example, approximately 150,000 acre-feet of water storage presently exists in two Federal reservoirs on the western slope of Colorado which in part could be made available for synfuel production. Assuming the consumptive use requirements of a 50,000 bbl/d oil shale plant is approximately 5,700 acre-feet per year, the available stored water in these two Federal reservoirs alone could supply a number of unit-sized synfuel plants, more than the number of synfuel plants presently in some state of planning within Colorado. This available stored water could be more efficiently used and stretched further as a source of synfuel water supply when combined with the existing junior water rights of energy companies. If, however, the projected plants were to rely on water transferred from agricultural use rather than on existing available water in Federal reservoirs, the impact on the agricultural sector would be much more severe.

The case study of the Upper Colorado River Basin in Colorado herein goes into detail concerning the economic, political, institutional, and legal uncertainties which make it difficult to predict the level of future synfuel development in the Upper Colorado River Basin, and the source and amount of water supplied for this projected level of development.

Upper Missouri River Basin

To provide necessary water for projected synfuel energy development in this basin, major new water storage projects will be required because of the significant inter- and intra-year variation of streamflows for all rivers in the basin. Furthermore, the legal, institutional, political and economic issues are of such magnitude in this river basin that they do not allow unqualified conclusion as to availability of water for synfuel development. In the Yellowstone River Basin and the adjacent coal areas, it is not a matter, as in the Upper Colorado River Basin, of merely what the effects of transferring existing water for synfuel development will be, but rather whether this water will be available at all. Major state reservations of water on the mainstem Yellowstone River, Indian reserved rights, and the Yellowstone River Compact all present major uncertainties as to the availability of necessary water for synfuel development in this area. Section V, herein, details the nature and effects of these legal and economic, institutional and political uncertainties.

PHYSICAL AVAILABILITY

Estimates of water availability for synfuel development are based on streamflow measurements, groundwater data, and other hydrologic data.

Of the many data and information bases required for assessing water availability (e.g., future municipal demand projections, future cooling water requirements for coal fired electric generating stations, etc.), recorded historic streamflows are probably the most accurate and dependable. In the eastern basins, this recorded data base is used more or less directly to assess water availability based on 7-day, 10-year minimum low flows. The use of 7-day, 10-year low flow data for this purpose is desirable since this flow parameter: (1) coincides with many water quality regulations, (2) provides indication of low flow conditions for navigation, and (3) provides a useful estimate of flow in rivers with limited storage. Generally, the 7-day, 10-year minimum low flow estimate is based on original historic data. As flow depletions increase in the future, however, the frequency of the 7-day, 10-year minimum low flow estimate based on historic data will increase; i.e. the low flow associated with the 7-day, 10-year frequency will actually occur more often in the future than the expected 7-day, 10-year frequency would indicate. This bias in the 7-day, 10-year minimum low flow parameter must be understood by decision-makers when considering water availability for synfuel development based on 7-day, 10-year minimum low flow estimates.

In the western basins water availability assessments are based on virgin flow estimates since western state water laws and interstate compacts are generally predicated on this concept. Virgin flow estimates are based on recorded streamflow data and estimates of depletions. Significant effort is often made to estimate virgin flows, but the resulting data set may be inaccurate because of poor records of diversions, irrigated acreages, inaccuracies in estimating irrigation consumptive use, lack of records concerning return flows, etc. Therefore, the principal parameter in western basins on which water availability estimates for synfuel is based, mean annual virgin flow, incorporates considerable uncertainty. Furthermore, studies assessing water availability in western basins for synfuel development tend to treat mean annual virgin flow estimates as deterministic rather than stochastic variables. These studies do not clearly assess the uncertainty and risk (in the statistical sense) that exist in mean annual virgin flow estimates, thereby giving an unwarranted degree of certainty to the data set.

The use of mean annual or mean monthly flow flow estimates for assessing water availability is acceptable for rivers and tributaries where adequate storage exists to control the river. However, where little or no storage exists, or will exist in the near future, some estimate of low flows is needed. This could be weekly, monthly, or 7-day, 10-year minimum low flow data depending on local hydrologic conditions and data availability. Without this low flow data, decision-makers will have little idea how proposed synfuel water demands will affect instream uses: fish and wildlife habitats run-of-the-river hydropower generation, recreation, and water quality. Low flow data is especially important to assess the cumulative effect of all present and proposed depletions.

Groundwater quantity and quality are inadequate in all of the basin analyses and assessments reviewed. Some reports more or less ignore this potential water supply source for energy development because of insufficient quantitative data. Individual energy companies may have adequate groundwater data to assist in a specific siting decision, but this data may be unobtainable or do not exist on a regional scale for governmental decision-makers or entities concerned with state or regional water resources management. Use of groundwater for supplying synfuel development could, in some instances, reduce streamflow depletions, especially during low flow periods. Planned conjunctive use of ground and surface waters could result in more efficient use of surface water resources; i.e., more synfuel plants could be. sited within the basin with less impact on the water resource if conjunctive use is employed. However, because adequate groundwater data are not generally available to regional or state decision-makers, this opportunity may be lost.

ECONOMIC FACTORS

Within limits, cost data may not be very important to energy companies for selecting water supplies for synfuel development since cost of water is generally minor with respect to total capital and operating costs for a proposed synfuel development. Cost of water, however, is one determiner of the nature and extent of trade-offs that will occur as a result of water for synfuel development and, therefore, may be a very important parameter to governmental decision-makers or entities concerned with state and regional water resources management.

The cost data presented in most assessments of water availability for synfuel development are generally inadequate. There are several reasons for this inadequacy. First, dependable cost data are difficult to collect. No central collection of, for example, reservoir construction cost data exists and it must be collected from a number of individual sources. Second, cost data are site or project specific and generalization is often risky and inaccurate. Third, developing or obtaining comparable cost data may be impossible. For example, obtaining data on selling prices of irrigation water rights often results in a set of individual prices for widely different commodities. One selling price may be for a senior irrigation right or another may be for a junior right requiring construction of storage. Several examples of the variation are presented in the Upper Colorado River Basin section herein.

LEGAL. INSTITUTIONAL. AND POLITICAL FACTORS

Perhaps the most difficult requirement in assessing water availability for synfuel development is estimating the effects of legal, institutional, and political factors on future water availability. Future judicial decisions, compact interpretations, implementation of certain compact provisions, administrative decisions on marketing Federal reservoir storage, resolution of Federal and Indian reserved rights, reservation of water by states, and uncertainties in riparian law can all have a profound effect on water availability for future synfuel development. Estimating the quantitative effects of these possibilities in a water availability assessment and communicating these effects to decision-makers is a large task. This task is complicated by the fact that not only must the possible effects be indicated and analyzed but also some effort must be made to indicate the likelihood of occurrence.

In general, the reports and assessments reviewed herein contain highly variable analyses of the quantitative effects of future legal, institutional, and political constraints. These analyses are discussed further in Sections II through V herein.

Political, legal, and institutional factors affecting water availability are generally less numerous and less complex in the eastern basins than in the western basins. Complex local situations may exist but, in general, the political, legal, and institutional factors affecting water availability for synfuel development are less involved in eastern basins. The probable reasons for this are: (1) less competition for water in the eastern basins, (2) the relative simplicity of riparian water law for surface water, and (3) the general lack of, or relatively simple, groundwater regulatory law in the eastern states. As a result, forecasts of future water availability for synfuel development in the eastern United States may be somewhat less involved because of the reduced complexity of political, legal, and institutional factors.

The relative simplicity of riparian water law and riparian based groundwater law can, however, result in significant uncertainty concerning future water availability because of lack of protection given users against upstream diversions or pumping adjacent to their lands. In contrast, however, water law in western states can be a barrier to implementation of water supply alternatives. For example, western state water law is an obstacle to implementation of measures to increase irrigation efficiency since the Appropriation Doctrine does not generally allow users to retain a right to salvaged water.

Uncertainty resulting from legal, institutional, judicial, and political factors causes energy companies to be conservative in their water supply planning and require redundant supplies in order to be assured of adequate future water supply. The delays and uncertainties inherent in acquiring water rights, obtaining reservoir storage or otherwise initially securing water supplies also tend to cause energy companies to obtain redundant water supplies. This redundancy may extend until a firm supply is assured, or the additional water rights might be retained for future development.

WATER SUPPLY ALTERNATIVES

For all basins studied, the principal source of water supply considered in water availability analyses for synfuel development were: (1) direct diversion from rivers, (2) reservoir storage, or (3) acquisition of agricultural water rights. However, numerous other potential sources exist including: (1) development of groundwater, (2) conjunctive use of ground and surface water, (3) weather modification, (4) improvements in efficiency in agricultural and municipal use, (and subsequent use of water “saved” by synfuel industry), (4) change to more water efficient processes in synfuel production, and (5) watershed management to increase discharge. But in actual practice, significant legal, political, and economic forces oppose the implementation of these alternatives. In general, alternatives for synfuel water supply, other than the usual reservoir storage and direct diversion, are detailed in synfuel water assessment studies and reports with some limited discussion, without analysis of the legal, political, economic and institutional constraints which limit their consideration and practical implementation. Specific alternatives and problems with their implementation are discussed in Sections IV and V herein.

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The objective of this study has been to: (1) describe and analyze the hydrologic, institutional, economic, and legal issues involved in forecasting water availability for synfuel development and (2) evaluate the adequacy of currently used estimates of water availability for synfuel development. Based on this analysis and investigation, it is important to develop some possible recommendations for improving the future assessments of water availability for synfuel and energy development.

Because of the significant uncertainty which exists for forecasting future water availability beyond a 10-12 year period in the future, it is suggested that the primary use of synfuel water availability assessments should be to evaluate the availability of water for expected development of a synfuel industry in the next 10-12 years. Furthermore, it is suggested that rather than focusing on predicting water availability, the objective of the synfuel water availability assessment should be to acknowledge the significant uncertainties that exist and play out the consequences of some of the ways that generally unpredictable political, judicial, and administrative decisions may affect water availability.

It is likely that the present controversy and uncertainty concerning water availability for synfuel development will continue in the future. Doing additional studies in order to get “better” or more refined estimates of water availability for synfuel development will probably not significantly reduce the controversy surrounding water availability. The reason for this is that many assumptions must be made in aggregating data into forms useful to decision-makers and in forecasting future demand and supply. These assumptions cannot all be explicitly detailed, communicated to decision-makers and properly used by decision-makers in their own analyses. As a result of the general uncertainties surrounding these assumptions, there will always be potential for controversy over water availability.

This is not to say that ‘improved” analyses of water availability cannot be made: they can and should be completed. Improved water availability assessments for synfuel “development as well as other sectors (municipal, industrial, and agricultural), can probably not be done by devoting increased resources to improving the studies themselves. Rather, improvement of these assessments is contingent on improving water resources planning in general in the United States. The results of the inadequate water resources planning system existing in most areas of the United States today is continuously evident in the water availability forecasts analyzed herein. Without general improvement in the existing water resources planning system, data discontinuities at state boundaries will continue, incremental studies will ignore cumulative effects of depletions, local or site specific studies will ignore downstream or basin impacts, and analyses of water availability for synfuel development (or many other purposes) will continue to be a one-time effort with no one responsible for a continuous update or modification. These deficiencies cannot be cured by concentrating additional resources on the reports or assessments -- the system itself must be improved.

SECTION I
INTRODUCTION

AUTHORITY FOR STUDY

Wright Water Engineers has performed this study for the Office of Technology Assessment under Contract 133-2060.0.

GENERAL PURPOSE AND OBJECTIVES

Development of a major synfuel industry in the United States in order to reduce our dependence on imported oil is now a national goal. Achievement of this goal is dependent in part on water availability. Water availability for energy development has been the subject of a number of recent studies with conflicting conclusions and forecasts.

" In order to resolve some aspects of these conflicting studies, the Office of Technology Assessment commissioned the study herein to: (1) describe and analyze the hydrologic, institutional, legal and economic issues involved in assessing and interpreting estimates of water availability for synfuels development, and (2) evaluate the adequacy of currently used estimates of water availability as a basis for energy planning.

THE STUDY METHOD

Four major river basins were selected by OTA for this study: Upper Mississippi, Ohio/Tennessee, Upper Missouri, and the Upper Colorado= Major portions of the Nation's oil shale and coal reserves exist within these river basins, and conflicts over water availability for synfuel development can be expected to occur.

These five river basins are extensive, cover a major portion of the United States, and contain many complex water resources problems. Because of the extensive nature of these basins and their water resources problems, and the limited resources of this study, it was necessary to select priority areas within the basins for in-depth analysis and assessment. As a result, the analysis and assessment herein generally focus on those subareas in each basin which: (1) are in proximity to major energy resources that could be used for synfuel development and (2) may experience increased competition for limited water resources.

Reports and other documents concerning water availability for synfuel development in each of the four basins were reviewed and analyzed with respect to their adequacy for decision-making purposes. In general, two types of reports were reviewed: (1) a site specific report concerning the adequacy of water resources at a specific location for development of a particular synfuel plant, and (2) a much more general report concerned with the adequacy of a region's or river basin’s water resources for development of an extensive synfuel industry in the future.

The second category of reports is the major concern of the analyses herein. These reports and studies are intended to be of use for making policy and programmatic decisions concerning the synfuels industry by: (1) governors, their staffs, and state legislators; (2) Congress; (3) the White House and Federal agency officials; and (4) energy companies. Therefore, our review and analysis concentrates on the usefulness and effectiveness of the reports for programmatic and policy decisions by these categories of decision-makers.

Substantial differences in water availability exist among the four river basins studied. In addition, there is considerable disparity in the complexity of legal, institutional, political, and economic constraints among the basins. The volume of water available for synfuel development is much smaller in the Upper Colorado and Upper Missouri Basins than in the Upper . Mississippi and Ohio/Tennessee Basins. In addition, there are more legal, institutional, political, and economic constraints affecting water availability in the Upper Colorado and Upper Missouri than in the eastern basins. Therefore, in addition to reviewing the major reports concerning water availability for synfuel development in the Upper Missouri and Upper Colorado basins, case studies of these two basins have been completed. The purpose of these two case studies is to analyze and illustrate more thoroughly the ramifications of the legal, institutional, political, and economic constraints on water availability for synfuel development in these two western basins.

BACKGROUND

A major effort of the analyses herein is to assess the soundness of the data and forecasts concerning water availability for synfuel. Various areas of expertise are required for analyzing these data and forecasts: hydrology, water law, water resources planning, etc. Some familiarity with terms and concepts associated with these disciplines is necessary to understand the analyses and discussion presented herein. Brief discussions of water law and hydrology necessary for understanding water availability for synfuel development are presented elsewhere and will not be repeated herein. For example, the Office of Technology Assessment Report, "An Assessment of Oil Shale Technologies," presents an excellent discussion in Chapter 9 of the doctrine of prior appropriation, federal reserve rights, interstate compacts on the Colorado River, etc. The General Accounting Office report, "Water Supply Should Not be an Obstacle to Meeting Energy Development Goals" also presents a glossary of terms concerning water supply for synfuel development. Because of the availability of this general material elsewhere, an effort will not be made herein to include a complete introduction to terms and concepts necessary for understanding analyses of water supply availability for synfuel development. A few terms and concepts, however, are presented in order to provide a reader who may be unfamiliar with water resources and water law terms and concepts with a basic introduction necessary for understanding the analyses herein:

Annual Flows - The quantity of water (generally measured in acre-feet) to flow past a specific point in a river or stream during a period of one year. Annual flows are used frequently in assessing water availability for synfuel development but do not provide any indication of the variation in flow throughout the year, especially low flows.

Appropriation - The taking and applying of a specific amount of water for a specific use. Under the prior appropriation doctrine a state entity establishes dates for seniority rights for water use.

Consumption - That part of water diverted which is no longer available because it has been either evaporated, transpired, incorporated into products and crops, or otherwise removed from water the environment.

Depletion - Basically the same as consumption, i.e., that part of water diverted which is no longer available because it has been either evaporated, transpired, incorporated into products and crops, or otherwise removed from the water environment.

Diversion - A withdrawal of water from a natural source by artificial means. Irrigation, mining, municipal, and manufacturing needs for water all require diversions.

Mean Monthly Flows - The average amount of water to flow past a specific point in a stream or river during a particular month (generally measured in acre-feet). Mean monthly flows provide some indication of the variation that exists in flows throughout a year. Mean monthly flows do not, however, give an indication of minimum flows during critical periods--for example, the flow that could be expected to occur during the driest seven-day period in ten years.

Minimum Low Flow - Numerous statistical parameters are used to describe minimum low flows, e.g. the seven-day, ten-year low flow; the monthly flow which has an 80 percent chance of exceedance in any one year; etc. All of these-parameters are an effort to provide some indication of minimum low flows during critical dry periods.

Operational Hydrology - A statistical procedure to generate long stream flow records (e.g. 10,OOO years of monthly flows) which will preserve important statistical parameters of the historic record while providing a number of different sequences of flow not present in the historic record. Operational hydrology is used to evaluate proposed management, development, and projects in water resource systems.

Synthetic Fuel Plant Water Demand - This refers to the estimated consumptive use requirement of a synfuel plant. This requirement is estimated based on thermodynamic and production properties of a proposed plant. The demand is generally expressed in acre-feet per year and will be relatively constant throughout the year.

Transfer - A transfer of water rights involves the sale of those rights and a change of use (for example, irrigation to manufacturing), location of the use, or point of diversion.

Water Right - Legally established right to divert and use a given quantity of water.

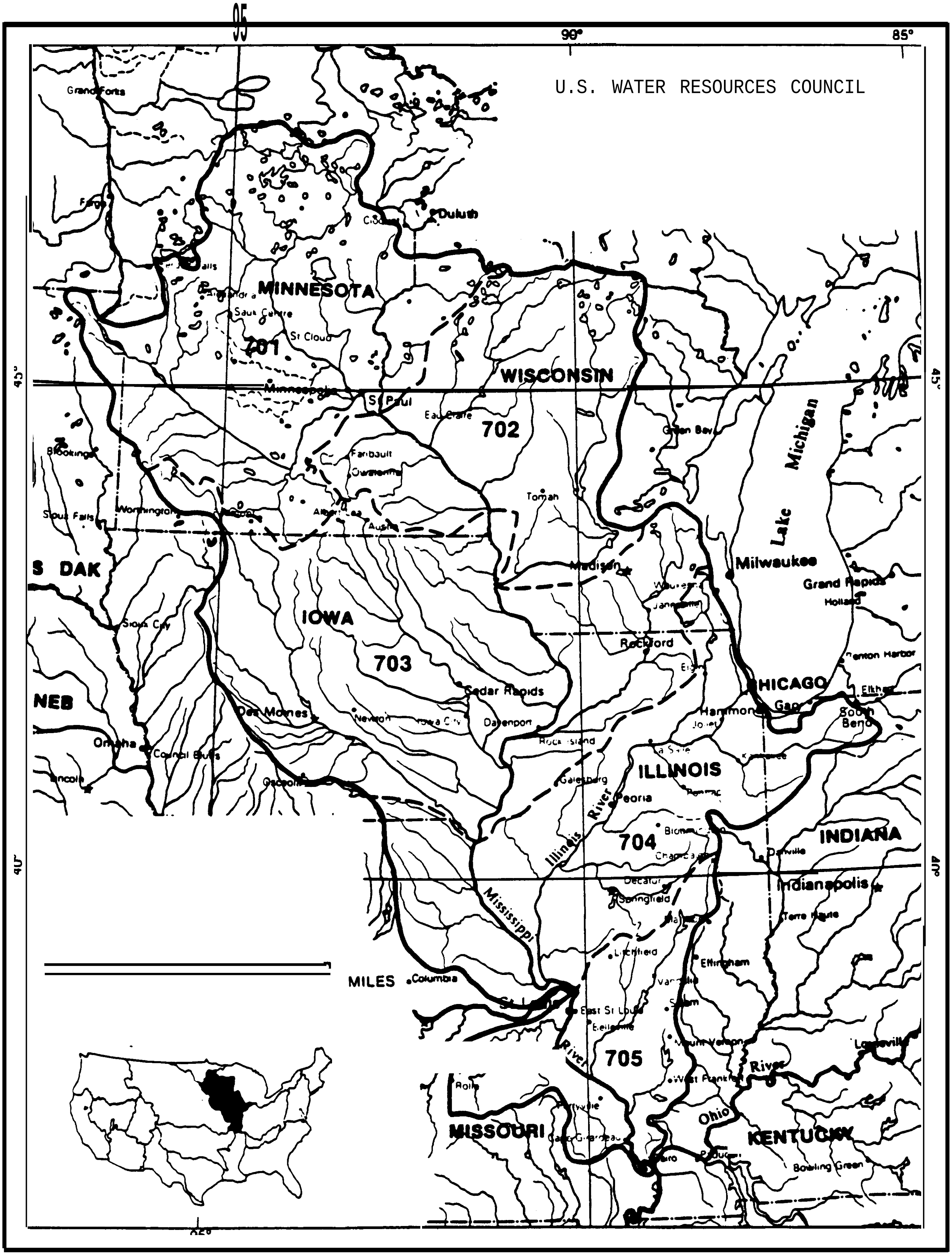
SECTION II
UPPER MISSISSIPPI RIVER BASIN

BACKGROUND

The Upper Mississippi River Basin is that portion of the Mississippi River upstream from the confluence of the Ohio and Mississippi Rivers at Cairo, Illinois and encompasses more than 115 million acres. The Upper Mississippi River Basin includes portions of the states of Minnesota, Wisconsin, Iowa, Illinois and Missouri. (See Figure 1.) Many rivers flow through the region in a generally north-south direction, and the Mississippi River bisects the area. The Upper Mississippi is a key element in the nation's inland waterway system. Large amounts of groundwater are stored within much of the region and the regional gross water supply is excellent (U.S. Water Resources Council, "The Nation's Water Resources," Volume 2, p. V-43). For a summary of hydrology in the Upper Mississippi Basin, see: U.S. Water Resources Council, "The Nation's Water Resources," Volume 2, Part V and Vol. 3, Appendix II.

Illinois is the only state in the Upper Mississippi River Basin with significant coal reserves: Illinois has 15.1 percent by tonnage of total demonstrated coal reserves in the United States or 16.6 percent of demonstrated coal reserves in the United States on the basis of heat value. Montana is the only state exceeding the reserves in Illinois. In comparison, no other state in the Upper Mississippi River Basin has more than 1 to 2 percent of demonstrated coal reserves in the United States.

Because of the concentration of coal reserves in Illinois, competition for water for synfuel development is expected to be significantly greater in Illinois than in other areas of the Upper Mississippi River Basin. Consequently, the assessment herein concentrates on availability of water for synfuel development in Illinois. This assessment is structured around review and analysis of available reports and information on water availability in Illinois. The discussion and conclusions resulting from this review and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analysis, however, extend beyond the reports reviewed and are generally applicable to those areas in the entire basin where demand for synfuel water supply exists, or will exist. Conclusions concerning deficiencies in analysis and forecasting procedures, deficiencies in quality and quantity of data, obstacles resulting from riparian water law, lack of economic and cost data, and statistical bias in streamflow data can be extrapolated to other states and areas in the Upper Mississippi River Basin outside of Illinois.

Reports reviewed were:

1. Smith, William H., and John B. Stall, "Coal and Water Resources for Coal Conversion in Illinois," Cooperative Resources Report for Illinois State Water Survey and Illinois State Geological Survey, Urbana, Illinois 1975.

2. Brill, E. Downey Jr., Glen E. Stout, Robert W. Fuessle, Randolph M. Lyon, and Keith E. Wojnarowski, "Issues Related to Water Allocation in the Lower Ohio River Basin," Volume III-G, Special Study Report, Ohio River Basin Energy Study, Phase I, May 15, 1977, University of Illinois at Urbana-Chanpaign.

3. Brill, E. Downey Jr., Shou-Yuh, Chang, Robert W. Fuessle, Robert M. Lyon, "Potential Water Quantity and Water Quality Impacts of Power Plant Development Scenarios of Major Rivers in the Ohio Basin," Ohio River Basin Energy Study, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, November, 1980.

4. Illinois Bureau of the Office of Planning, "The Availability and Resource Cost of Water for Coal Conversion," Springfield, Illinois, May, 1979.

5. Relevant Sections of U.S. Water Resource Council% Second National Assessment of the Nation's Water Resources.

The two reports from the Ohio River Basin Energy Study are relevant to the Upper Mississippi Basin since these reports cover rivers throughout the entire state of Illinois and are not limited to just the Ohio River Basin portion of the state.

Institutions in Basin

Major institutions involved with the availability of water for synfuel development in Illinois are: (1) the U.S. Congress, (2) the U.S. Army Corps of Engineers, (3) the U.S. Geological Survey, (4) the Illinois State Legislature and the Governor of Illinois, (5) various state agencies including the Illinois E.P.A., Illinois Dept. of Conservation, Illinois Department of Transportation, Division of Water Resources, Illinois Water Survey, and (6) various local governments including county and city governments and local drainage and levee districts. Other states in the Upper Mississippi River Basin have a very similar group of institutions affecting water availability for synfuel development.

Organization of Section

The analysis of these reports is woven into the discussion in this chapter regarding physical availability of supplies and institutional, legal and economic constraints.

PHYSICAL AVAILABILITY

Illinois receives more than 30-45 inches of precipitation in the average year and has relatively abundant water resources. Total runoff to streams in Illinois exclusive of the Mississippi River is approximately 26 million acre-feet per year and with the Mississippi about 59 million acre-feet per year (Smith and Stall, 1975). (In comparison, the Colorado River has a Mean annual "estimated flow of 13.8 - 15.0 million acre-feet per year.)

The three major reports reviewed for this study were the Smith and Stall analysis and the two studies by Brill, et al. Comparison of these three reports produces some interesting contrasts in study method. The Illinois Bureau of the Budget document is very general and wide-ranging. Despite its title, it provides limited information on water availability in Illinois which is of practical use in assessing water availability. Consequently, a detailed review is not included herein.

Smith and Stall did not attempt to project future consumptive use by municipalities, industry, and agriculture, nor did they base their analysis on future scenarios of energy development. They basically took a “snapshot” picture of water availability at the present time for coal conversion in Illinois and looked at the potential for development of additional water resources using reservoir storage and groundwater. By not presenting estimates of future depletions due to municipal, industrial, agricultural and other demands, the Smith and Stall report avoids many uncertainties associated with making future demand projections for these sectors. This, however, leaves the report reader to his or her own devices for estimating future depletions. This method avoids the various problems inherent in predicting future consumptive use and assuming various scenarios for energy development. Smith and Stall analyzed low flow data for Illinois rivers based on the one day, 50-year low flow. The one day, 50-year low flow statistic is an estimate of an extremely infrequent event. The question of whether this is a “correct” or desirable statistic for decisioninaking purposes involving water supply is a complex question beyond the scope of this investigation. On the basis of these flow statistics, they demonstrate that a number of streams and rivers in the state have more than adequate flow at present, without additional storage, to support a synfuel or coal conversion industry.

For example, the Mississippi River on the western edge of Illinois was estimated to have a one-day, 50-year minimum low flow of 6,500 million gallons per day, an amount 100 to 1000 times greater than the consumptive use of a coal conversion plant. Along the southwestern part of Illinois, estimated one-day, 50-year minimum flows in the Mississippi River are between 20,000 and 23,000 mgd. Even on the smaller rivers in Illinois, the flow is adequate for a significant coal conversion industry. One-day, 50-year low flows for the Rock River in northern Illinois range from 60 mgd near the

Wisconsin state line to 500 mgd where the Rock River meets the Mississippi River. Even this relatively low flow of 60 mgd could easily supply several unit-sized synfuel plants (assuming 7500 acre-feet per year or about 6.7 mgd consumptive use for a unit-sized synfuel plant).

In addition, Smith and Stall present accurate and up-to-date information and data on groundwater which indicate that in 17 locations in Illinois a system of wells could be constructed to provide water supply of at least 14 million gallons per day. Detailed information on potential reservoir sites is referenced in the Smith and Stall report which indicates 228 potential reservoir sites with a yield of greater than 6 million gallons per day.

Water supply for synfuel development could be available from existing federal reservoirs (Shelbyville and Caryle Reservoirs in southern Illinois) for synfuel development. These reservoirs together could provide more than 40 million gallons per day for coal conversion.

Brill, et al. (1980), take a somewhat different-approach to forecasting water availability for synfuel development:

(1) Based on forecasts of consumptive use by municipalities and industry for the years 1975, 1985 and 2000, they estimate water availability from Illinois rivers for energy development. This approach does not require forecasting the number of synfuel plants for various river basins in Illinois.

(2) In addition, they employ several energy development scenarios to forecast future water availability for all uses in major Illinois river basins.

In preparing their estimates of future water use, Brill, et al, (1980) are quite candid concerning the problems inherent in their forecasts:

> ‘Water use is difficult to measure and even more difficult to project since projections depend on population, income, relative prices, and technological developments. Thus the

> figures presented here should be interpreted cautiously and are more likely to represent orders of magnitude than specific values. This is especially true, of course, for the longer range projections." (P III-G-57).

In implementing their first approach, Brill, et al (1980) estimate the number of power plants or coal conversion facilities which could be sited along the region's rivers without total municipal, industrial and power water consumption exceeding certain consumption limits (e.g. 5-10 percent of the 7-day, 10-year low flows.) This approach is somewhat similar to that used by Illinois Water Survey in that it does not require the assumption of specific scenarios concerning future energy development but differs in that forecasts of future consumptive use by municipalities and industry are required. This approach indicates the potential cumulative impact of potential synfuel development on specific river reaches, but it does not hypothesize various synfuel development scenarios In their second approach, Brill, et al. (1980) developed various scenarios for siting coal fired power plants (these could easily be coal conversion plants as well) throughout the State of Illinois. This method also permits forecasting cumulative impacts of energy development on the area's water resources but does have the disadvantage of overlaying the uncertainties of future energy development on the uncertainties of future municipal, industrial and agricultural consumptive use.

An interesting problem exists with the use of the 7-day, 10-year minimum low flows in that values for this statistical parameter are based on the historical record without attempting to correct for increased future depletions. If the 7-day, 10-year low flow of record occurred sometime in the distant past, the actual magnitude of a flow with this frequency will undoubtedly be less in the future because consumptive use will increase on most rivers and streams and will continue to increase in the future. This failure to correct the historical record for increased depletions in the recent past will bias frequency estimates of low- flows by underestimating the frequencies of low flow in the future. This failure to convert the historical record for increased depletions in the recent past will bias frequency estimates of low flows by underestimating the frequencies of low flows in the future. This apparent use of the 7-day, 10-year minimum low flow based on historical data, without attempting to correct the historical record for increased future consumptive use, appears to be characteristic of not only the reports reviewed for the Upper Mississippi River Basin but also for the Ohio/Tennessee River Basins. This failure to correct the historical record for increased diversions and consumptive loss in recent years before estimating the 7-day, 10-year minimum stream flows is apparently characteristic of eastern basins. In the western states, complex and tedious calculations incorporating many assumptions are used to transform the historical record into an estimate of "virgin flows," i.e., the estimated flow without any pumpage or diversions.

The Brill, et al. reports clearly specify the difficulties in estimating future consumptive use and developing scenarios for energy development. For example, a major problem in forecasting future consumptive use is that multiple sources of potential water supply exist in Illinois (as they do in many other areas). Consequently, assumptions must be made concerning whether future consumptive use will result from groundwater, direct diversions of surface water, or storage. Brill, et al, assume that the ratio of surface water to groundwater use for each county would be continued in the future. This is an example of the type of operational assumptions that must be made in order to assess availability of water for synfuel development, the importance of which may be ignored or misunderstood by decision-makers. It is difficult to say whether this assumption is adequate or not for general application. In northeast Illinois, this ratio will not remain constant in the future because communities and industry are changing to surface water supplies from groundwater because of the declining water levels in deep aquifers. Brill, et al.further assumed that groundwater withdrawal would not affect low flows; while incorrect hydrologically, this operational assumption may be acceptable for assessing water availability depending on local conditions. For example, in the 1980 Brill report (p.6-9), the demands of the Clinton Nuclear Power Plant in the Sangamon River Basin in central Illinois have not been included in overall consumptive use estimates for this basin since it is assumed that the plant will use stored water and would not affect minimum low flow on the Sangamon River, a major tributary of the Illinois River. In other words, a major power plant (approximately 600 megawatts) is assumed not to have any consumptive use depletions on the Sangamon River. The point of this example is not whether this assumption is correct or not, but rather to demonstrate that there are many options involved for determining future consumptive use demands on a river. Consequently, estimates of future water availability for power plant cooling or synfuel development could vary significantly depending on whether these plants are assumed to use surface water, stored water, or groundwater.

INSTITUTIONAL/LEGAL, ECONOMIC ASPECTS OF WATER AVAILABILITY

The institutional aspects of water availability for synfuel development in the Illinois portion of the Upper Mississippi River Basin are less complex than comparable institutional aspects in the western United States. This is also true for other states in the basin. For all practical purposes, there is no regulatory groundwater law in the State of Illinois. Surface water use and development is governed by riparian law, a less complex set of laws than exists in the western United States. There are no irrigation districts, water conservancy districts or similar entities in Illinois. There is only one state agency in Illinois charged with operational management and regulation of water quality. This is characteristic of other states in the basin. Fewer governmental entities are involved with water resources management, development and regulation than in the western United States. With the exception of a U.S. Supreme Court decree concerning diversion of Lake Michigan water, no interstate compacts exist in Illinois. There are no Federal or Indian reserved rights affecting water availability.

As a result, the reports reviewed for the Upper Mississippi River Basin are only minimally concerned with legal or institutional constraints to water availability for coal conversion or synfuel development.

The "laissez-faire" aspects of riparian based water law, however, do present constraints to water availability for synfuel development. For example, the State of Illinois owns a portion of the water supply storage in Shelbyville and Carlyle Reservoirs in southern Illinois. Both of these reservoirs are Corps of Engineers' projects. The State of Illinois has sought to sell this water for several years, thereby reducing its repayment responsibility to the Federal government. Energy companies have approached the State, but sales have not been made because of uncertainties with regard to delivery of the water. The most efficient scheme would be simply to release water from Carlyle and Shelbyville reservoirs and allow this water to flow down the Kaskaskia River to a convenient point for diversion to a synfuel or coal conversion plant. However, under existing Illinois riparian law, this water could be pumped from the river by any riparian land owner downstream from the reservoirs. Consequently, in order to insure delivery of this water, the energy companies would be faced with building an expensive pipeline for conveyance of the water directly from the reservoirs to the plant site. This conveyance problem, while having a direct engineering solution, poses an economic and legal obstacle to use of water stored in the Federal reservoirs for coal conversion purposes.

The lack of existing groundwater law also provides a constraint to water availability since development of a groundwater supply has very limited protection against over-pumping by adjacent wells under existing Illinois law.

The Smith and Stall report has especially good economic data on the costs of reservoir and groundwater development. This information and data is presented as a series of cost functions for development of various sources of water supply. While they must be used with caution, these cost functions should be very useful for programmatic analysis as well as initial screening of specific sites. In general, however, economic data on the cost of water for synfuel development, or any other use, is not available, except for site specific conditions or individual projects. There are no water rights to purchase so the cost of water is totally dependent on the cost of the riparian land and the costs of water control and conveyance facilities--all of which are site specific.

CONCLUSIONS

From a regional perspective water supplies for synfuel development in the Upper Mississippi River Basin are adequate. Localized problems, however, may result depending on the specific site for a synfuel plant. Water supply shortages and negative impacts on water resources are most likely to occur for synfuel sites on tributaries. These shortages and negative impacts can be eliminated or reduced by construction of reservoir storage on tributaries, conductive use of ground and surface water or other measures to reduce diversions from unregulated streams during low flow periods.

In general, there is relatively little available information and few reports on water availability for synfuel development in the Upper Mississippi Basin in comparison to that available for western basins where significantly more competition exists for water. The reports and information analyzed herein focus on Illinois since this is the area in the Upper Mississippi River Basin where synfuel development will most likely occur, and consequently the greatest demand for water for synfuel development. The results of the analysis are, however, generally applicable to other areas of the Upper Mississippi River Basin where synfuel development might occur because of the similarity in hydrology, water law and institutions, for all states in the basin.

The Smith and Stall report does a good job of presenting estimates of current water availability for coal conversion “or synfuel activities in Illinois. Since it does not forecast future consumptive use, it is of limited use for predicting future water availability. However, by limiting itself to present availability, it also avoids all of the significant uncertainties present in forecasting future consumptive use by the municipal, agricultural, and industrial sectors. In general, the Smith and Stall report should be of use to a number of decisionmakers and in a number of decisionmaking situations. It bridges the gap between the site specific and programmatic decision.

In comparison, the Brill, et al.reports present forecasts of water availability until the year 2000 and candidly indicate the difficulties and uncertainties in providing these forecasts. The portion of the Brill, et al. reports that do not depend on future energy development scenarios are probably more useful for site specific and programmatic decision-making than when the additional uncertainty of an energy development scenario is overlaid on the water availability estimates.