SECTION III
OHIO/TENNESSEE RIVER BASINS

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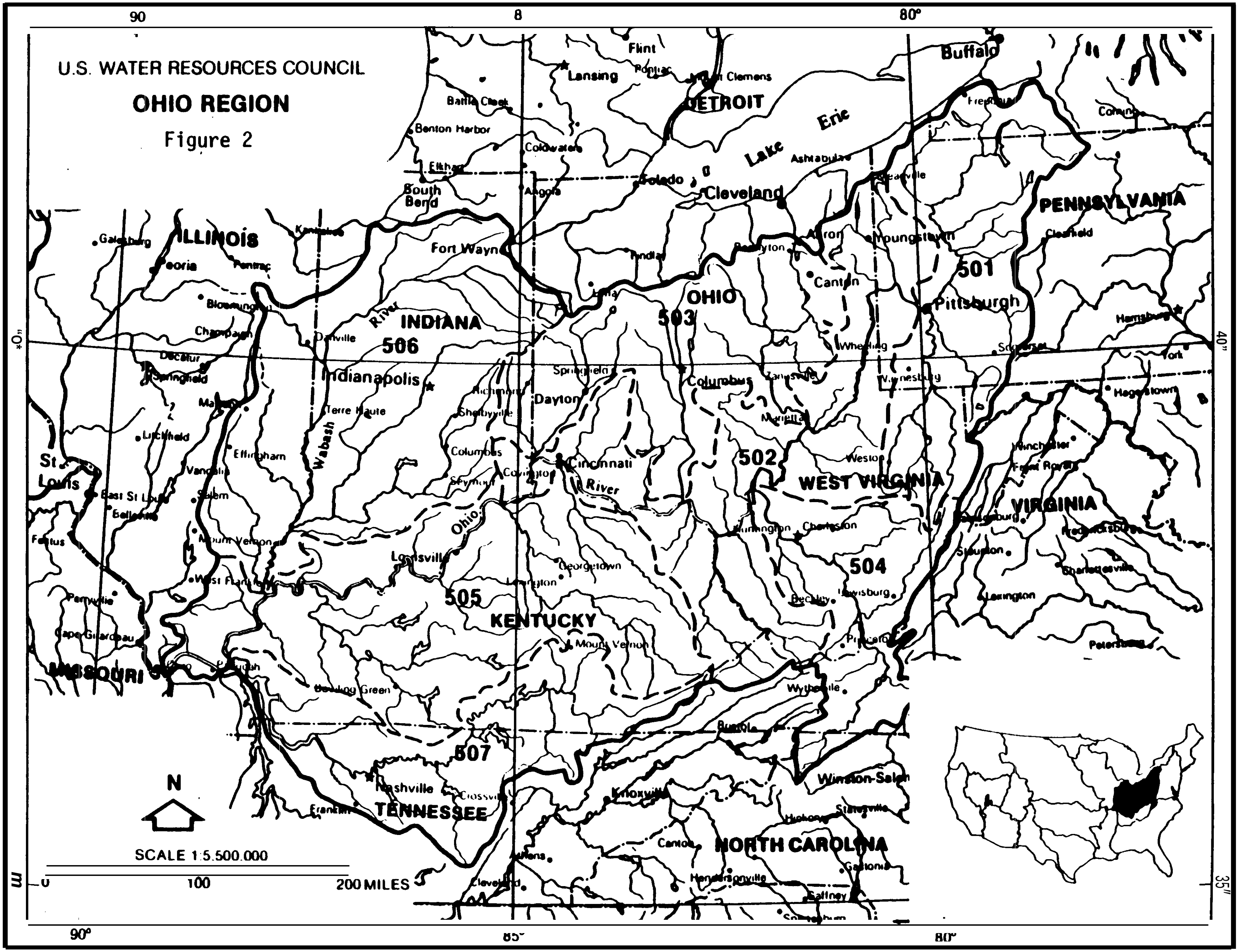
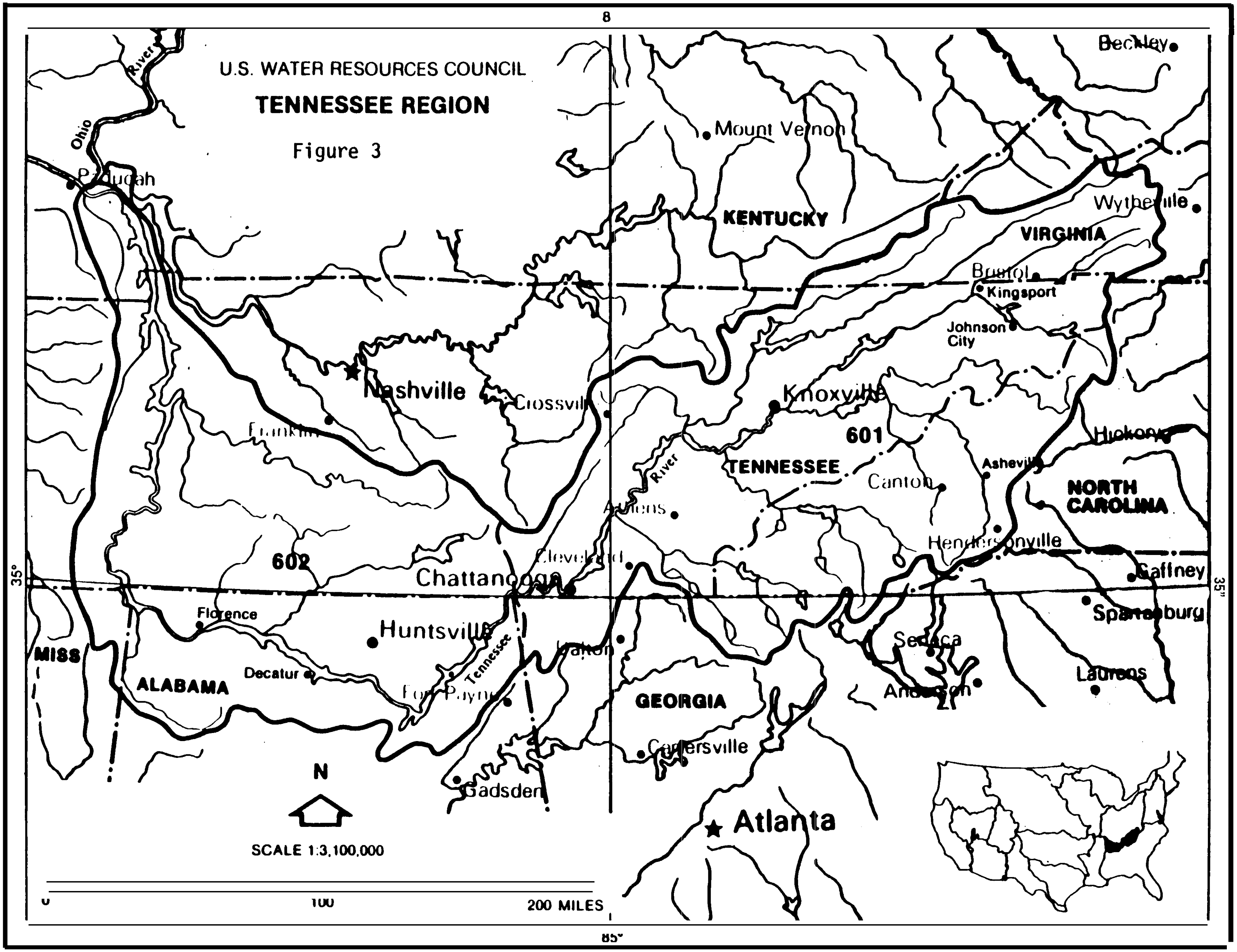
BACKGROUND

The Ohio River Basin covers 102 million acres in New York, Pennsylvania, Maryland, North Carolina, West Virginia, Ohio, Kentucky, Tennessee, Indiana, and Illinois (Figure 2). The Ohio River is formed by the confluence of the Allegheny and the Monongahela Rivers at Pittsburg and flows in a southwesterly direction to join the Mississippi at Cairo, Illinois. Overall, the basin has excellent potential for water supply (U.S. Water Resources Council 1978, Vol. 2, p. V-30) . The Ohio River contains vast coal resources, about 70 percent of the national reserves. Water withdrawals for mining of fuels are projected to increase from less than one percent of total withdrawals in 1975 to about two percent in 2000 (U.S. Water Resources Council, 1978, Vol. 2, p. V-30).

The Tennessee River Basin covers an area of 27 million acres (Figure 3). Seven major, and numerous small, rivers feed the Tennessee River as it makes its U-shaped course through the region. Parts of seven States are drained by the Tennessee River -- more than half of Tennessee and smaller portions of Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia. The Second National Assessment of the U.S. Water Resources Council indicates that estimated natural outflow from the Tennessee River Basin is about 46 million acre-feet per year. Estimated consumptive use of this total flow is less than one percent for 1975 conditions and about three percent for 2000 (U.S. Water Resources Council, 1979, Vol. 1, p. 55). In terms of monthly low flow conditions, consumptive use in 2000 is estimated to be about five percent of the monthly flow which on the average will be exceeded in 80 years of a 100-year period (U.S. Water Resources Council, 1978, Vol. 3, p.61). Because of the large available water supplies in the Tennessee Basin, there is little available information and no published reports concerning water availability for synfuel *or* energy development.



Source: Second National Assessment of the Nation's Water Resources



Source: Second National Assessment of the Nation's Water Resources

Based on the information and reports supplied by TVA (see below), it was concluded that no basin-wide problem existed in the Tennessee basin concerning water availability for coal conversion or synfuel development. If water availability problems do exist, they are of a local or site specific nature. The Tennessee Valley Authority has no published information concerning local water availability problems resulting, or expected to result, from synfuel development.

Therefore, this analysis concentrates on the Ohio River Basin and focuses on several investigations and published reports concerning water availability for synfuel and energy development in various areas of the Ohio Basin. Although the analysis herein concentrates on these investigations and reports, the resulting discussion and conclusions are applicable to the entire basin and the potential conflicts over water supply.

The major reports reviewed were:

1) Ohio River Basin Commission, "Synfuels in the Ohio River Basin, a Water Resources Assessment of Emerging Coal Technologies," (Prepared for U.S. Water Resources Council), January, 1980.

2) Ohio River Basin Commission, "Water Assessment for Monongahela Synfuel Plant," Ohio River Basin Commission, (Prepared for U.S. Water Resources Council.), June 6, 1980.

3) U.S. Water Resources Council, "Project Independence Report" (Tennessee Region 6), prepared for the Federal Energy Administration, November, 1974.

4) Tennessee Valley Authority, "Valley-Wide Assessment of Water Needs," 1974.

5) U.S. Water Resource Council, Second National Assessment of the Nation's Water Resources, 1975-2000. 1979.

In addition, the following two reports were reviewed for both the Ohio and Upper Mississippi Basins:

1) Brill, E. Downey, Jr., Glenn E. Stout, Robert W. Fuessle, Randolph M. Lyon, and Keith E. Wojarowski, "Issues Related to Water Allocation in the Lower Ohio River Basin," Vol. III-G, Phase 1, Ohio River Basin Energy Study, 1977.

2) Brill, Downey E. Jr., Shoou-Yuh Chang, Robert W. Fuessle, and Randolph M. Lyon, 'Potential Water Quantity and Water Quality Impacts of Power Plant Development Scenarios on Major Rivers in the Ohio Basin," Ohio River Basin Energy Study, 1980.

These latter reports form a major basis for the Upper Mississippi River Basin analysis herein since they cover the entire State of Illinois. General findings are not repeated in this section concerning the Ohio River Basin; only those findings specific to the Ohio are included.

The "Synfuels in the Ohio River Basin" report is a very broad report primarily useful for programmatic decisions concerning synfuel development in the Ohio River Basin. In contrast, the 'Water Assessment for the Monongahela Synfuel Plant" report is a site specific study useful for analyzing water demands and environmental impacts of this proposed plant.

Basin-Institutions

Ohio. In the Ohio River Basin, the relevant institutions are comparable to those in the Upper Mississippi (see Section II herein). For example, in the State of Ohio, the Federal agencies are the same and the water resources functions (research, data acquisition, regulatory, etc.) are concentrated in the Ohio Department of Natural Resources.

Tennessee. In the Tennessee River Basin, the Tennessee Valley Authority occupies a unique position in the management of water resources. As a result, Federal agencies, such as the Army Corps of Engineers, play a reduced role. State agencies, such as the Tennessee Department of Conservation, have responsibilities comparable to the agencies discussed in Section 11 herein.

Organization of Section

The analysis of the Ohio River Basin includes discussion of the physical availability; water quality; and institutional, legal and economic factors.

PHYSICAL AVAILABILITY AND WATER QUALITY

The major data base for the "Synfuels in the Ohio River Basin" and "Water Assessment for the Monongahela Synfuel Plant" reports primarily consists of 7-day, 10-year low flows. Use of a low flow parameter, such as the 7-day, 10-year low flows, rather than mean annual or mean monthly flows is desirable for rivers such as the Ohio and its tributaries which have relatively small amounts of storage in comparison to their annual flows. The 7-day, 10-year minimum low flow data are based on historical data and, as indicated in the review of the Upper Mississippi River Basin, will probably overestimate future minimum low flows of the same frequency because of future increased consumptive use in the Ohio River or its tributaries. The effect of this deficiency is not noted in either of these reports concerning the Ohio Basin.

The 7-day, 10-year minimum flow data are a convenient measure since this data base corresponds to criteria used in Federal water pollution control programs. The appropriateness of the 7-day, 10-year minimum flow as a statistical measurement of low flows is briefly discussed in Section II.

A major limitation of "Synfuels in the Ohio River Basin" is that it concentrates almost exclusively on plant sites on the mainstem of the Ohio River with little consideration of synfuel plant sites on the tributaries. While this assumption is apparently justified on the premise that it is cheaper to bring the coal to the water than the water to the coal, no information is presented in the report to support this premise. The report demonstrates the adequacy of mainstem flows for energy development and indicates that reservoir storage would be needed for tributary plant site water supply, but it provides few details. However, as demonstrated by the SRC-11 Plant at Morgantown, West Virginia, synfuel and other energy facilities are proposed for sites on the Ohio River tributaries. Consequently, this concentration on the mainstem of the Ohio significantly reduces the usefulness of the "Synfuels in the Ohio Basin" report.

The "Synfuel in the Ohio Basin" report states its purpose as: "...to define constraints and impacts relative to the development of emerging coal technologies in the Ohio River region." By limiting its scope to the Ohio mainstem, the report does not meet this stated objective. Furthermore, by limiting the scope of analyses to the mainstem of the Ohio, the conclusion of adequate water availability of synfuel development is nearly preordained because of the significant water availability in the mainstem. For example, the estimated mean annual discharge from the Ohio Basin is about 20 million acre-feet per year. Consumptive use for 2000 is expected to be about 0.2 percent of mean daily flow by the year 2000 or about 0.3 percent of low flow where low flow is the daily flow with a 95 percent chance of exceedence (U.S. Water Resources Council, 1980, Vol, p. 15) . With 20 million acre-feet per year average annual flow and a 0.3 percent consumptive use, severe water availability problems should not be expected to arise. Even the highly aggregated data for the Ohio tributaries in the Water Resources Council's Second National Assessment suggest that the real water availability problem for synfuel development will be in the tributaries and not the main stem. For example, consider the Wabash River, a tributary of the lower Ohio which has substantial coal deposits in Illinois and Indiana (Assessment subregion 506). Expected streamflow depletion during a dry, critical month at present (1975) is about 9 percent and is expected to increase to 21 percent by 2000 (U.S. Water Resources Council, 1978, Volume 3, Appendix II, p. 141). Comparison of this forecasted 21 percent depletion with the 0.3 percent on the mainstem tends to confirm the conclusion that the water availability problem will be in the tributaries.

Therefore, based on this aggregated data, it appears that the "Synfuels in the Ohio Basin" report ignored the area with potential water availability problems for synfuel development.

Both the "Synfuels in the Ohio River Basin" and the "Monongahela Synfuel Plant" reports are based on data aggregated by Water Resources Council water accounting units. This highly aggregated data is of limited use for individual siting decisions and for forecasting hydrologic impacts at the specific sites. The aggregated data is only useful for estimating water availability for the entire water accounting unit (generally a river basin).

Water quality data and analysis in the "Synfuels in the Ohio River Basin" report is somewhat superficial and would be of limited use in either programmatic or site specific decisions, Only very limited water quality data are presented in the "Synfuels in the Ohio River Basin" report for the mainstem of the Ohio, and none is presented for the tributaries. The data presented for the mainstem (pp. 20-22) is in conflict with comparable data presented by Bri 11, et al (1980, p. 7-13). It is also clear that more severe water quality problems occur on the tributaries and not the main stem (see Brill, et al., 1980, Table 7. 4, p. 7-11). This omission of water quality data further indicates that the "Synfuels in the Ohio River Basin" report ignores the real problem: water availability for synfuel development and water quality in the tributaries.

In the 'Water Assessment for Monongahela Synfuel Plant" report, a disparity between water quality data available for Pennsylvania and West Virginia is noted. The report indicates that the only water quality parameters considered significant for this assessment were dissolved oxygen, pH, and total dissolved solids. It appears that significantly less data and information are available for the West Virginia portion of the Monongahela basin than for the Pennsylvania portion. Furthermore, West Virginia has no standards for total dissolved solids, and the data presented do not clearly indicate what the impacts will be on TDS in West Virginia. Because of the disparity in data availability and standards between the two states, forecasts of future water quality impacts would appear to be somewhat uncertain and the report does not highlight this uncertainty.

As discussed in Section IV herein, the cost of water is probably not a major factor in developing a synfuel plant because the cost of necessary water is very low relative to other factors. Cost data for alternative sources of water supply, however, are probably the most important parameter--next to legal and physical availability--in deciding on water supply sources for synfuel development. Consequently, cost data are important in analyzing the various trade offs, among water supply sources. Dependable cost data, however, are not easily assembled and the “Synfuels in the Ohio River Basin” report contains only minimal cost data. The lack of data for specific tributary reservoir sites is a major deficiency.

The difficulty in estimating the cumulative effect of depletions on water availability is exacerbated by the interstate nature of the Monongahela Basin and the inherent problems in coordinating forecasts of future consumptive use between two states. If the estimates of cumulatative impacts of synfuel development and other consumptive users of water are to be useful to the decision- makers, then the many inherent assumptions and certainties in these estimates of cumulative impacts must be clearly spelled out. This is not the case in either the “Synfuels in the Ohio Basin” report or the “Water Assessment for the Monongahela Synfuel Plant.” There is a need for clearly indicating the accumulated impacts of future consumptive use and the uncertainties inherent in these estimates of future consumptive use, since any individual consumptive use, including that of a demonstration plant such as the SRC-11 plant, “is so small that it is difficult if not impossible to measure an adverse impact traceable solely to that use” (p.2 “Monongahela Synfuel Plant” Report).

Another complicating factor for forecasting future availability of water for synfuel development is the uncertainty surrounding future demand for lockage water on navigable rivers such as the Monongahela. Estimating demand for future lockage water is dependent upon complex projections of future demand for waterway transportation. The requirement for forecasting future in-stream demands for navigational lockage water, and the resulting uncertainty of this forecast, is a problem characteristic of eastern river basins. Navigation lockage requirements must be added to other instream demands (fish and wildlife habitat, recreation, and hydropower) when assessing water availability for synfuel development.

INSTITUTIONAL, LEGAL AND ECONOMIC FACTORS

The institutional and legal factors affecting water availability are less extensive and complex in eastern basins such as the Ohio than in western basins. This situation results because: (1) there are relatively few interstate compacts or Supreme Court decrees affecting water availability, (2) Federal or Indian reserved rights problems are absent, (3) riparian based state water law for Ohio Basin states is less complex than the appropriation doctrine of western states and (4) there are fewer entities (e.g., river districts, irrigation districts, Federal and State agencies, etc.) involved in water resources in the Ohio Basin states than in the west.

Institutional and legal constraints do, however, affect water availability for synfuel development in the Ohio Basin, but the reports reviewed do not address these constraints. Some consideration should have been given to this matter.

The operating policies of Federal reservoirs introduce institutional uncertainty into the assessment of water availability in the Ohio River Basin for synfuel development. Approximately 520,000 acre-feet of water supply storage exists in six Federal reservoirs in Ohio and Indiana (Ohio River Basin Commission, 1980, P.18). (In comparison, a 250 mi 1 lion scf/day coal gasification plant can be. assumed to have a consumptive use of about 15,000 acre-feet/year). The water marketing and operating policies for these Federal reservoirs can be surrounded with considerable uncertainty since the Federal government and the local project sponsor (generally the local or state government) share responsibility of water marketing and reservoir operation depending on the individual project. In the case of the SRC-11 coal conversion plant in the ‘Water Assessment for the Monongahela Synfuel Plant” report, reservoir operating and water marketing policies for the proposed Stonewall Jackson Reservoir are critical in analyzing the hydrological effects of water demands for the SRC-11 plant. Uncertainties surrounding the marketing of water from the Stonewall Jackson Reservoir (e.g. price, priority, and availability) and the operating policy of this reservoir are major sources of uncertainty concerning water availability and future water quality conditions in the Monongahela River below the SRC-11 plant.

Uncertainty over water availability also results because, in general, we do not have institutions or mechanisms to produce dependable and uniform data on water availability for river systems which cross state boundaries. This problem of reconciling data between two states and the resulting uncertainty is demonstrated in the Monongahela Synfuel Plant Report where there is a significant disparity between water quality data in Pennsylvania and West Virginia. Probably a more important problem resulting from this continuing lack of coordination among the states is the lack of dependable information and data concerning future cumulative impacts of synfuel and other development on water availability. What is needed is a mechanism to bridge the gap on a continuing basis between the site specific report and general basin-wide analysis.

None of the reports reviewed included economic data on the cost of developing reservoirs. Since the potential for siting synfuel plants on tributaries is ignored in the "Synfuels in the Ohio River Basins," and, consequently, no reservoir storage is required, the report concludes (p. 56):

> The ready availability of water in the basin requires no unusual expenditures for synfuel development; therefore, costs have not been estimated. If facilities are located where water is not available, the costs for providing that water, such as building a reservoir, are part of the economic trade-off analysis which must be made for each site specific plant.

CONCLUSIONS

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

The Ohio River Basin Commission "Synfuels in the Ohio River Basin" report is of marginal utility to realistic decision-making situations since it ignores the areas where water availability for synfuel development may be a problem, the tributaries of the Ohio River, and instead concentrates on the mainstem where there is no apparent availability problem. The report contains no economic data and no discussion of political, institutional, or legal factors affecting water availability.

The Monongahela Synfuel Plant report is a straight-forward and generally adequate assessment of water availability for the proposed SRC-11 plant in Morgantown, West Virginia.

The Brill, et al. reports (1977 and 1980) are more useful reports for assessing water availability and are discussed in the Upper Mississippi River Basin section herein.

SECTION IV
UPPER COLORADO RIVER BASIN
AND COLORADO RIVER IN COLORADO CASE STUDY

BACKGROUND

This section looks at synthetic fuel development in the Upper Colorado River Basin, which encompasses the Colorado River above Lee's Ferry (Utah, Wyoming, and Colorado) (see Figure 4). Within the Upper Colorado River Basin there is potential for both shale oil and high Btu and low Btu coal gasification. The richest oil shale deposits are located in the Piceance Creek structural basin (or the river basins of the White and mainstem Colorado in Colorado) and the Uinta structural basin (White River Basin in Utah). The coal is found primarily in the San Juan Basin in New Mexico and southern Colorado. A location map for the oil shale deposits is found on Figure 5 and a map of the coal deposits is found on Figure 6.

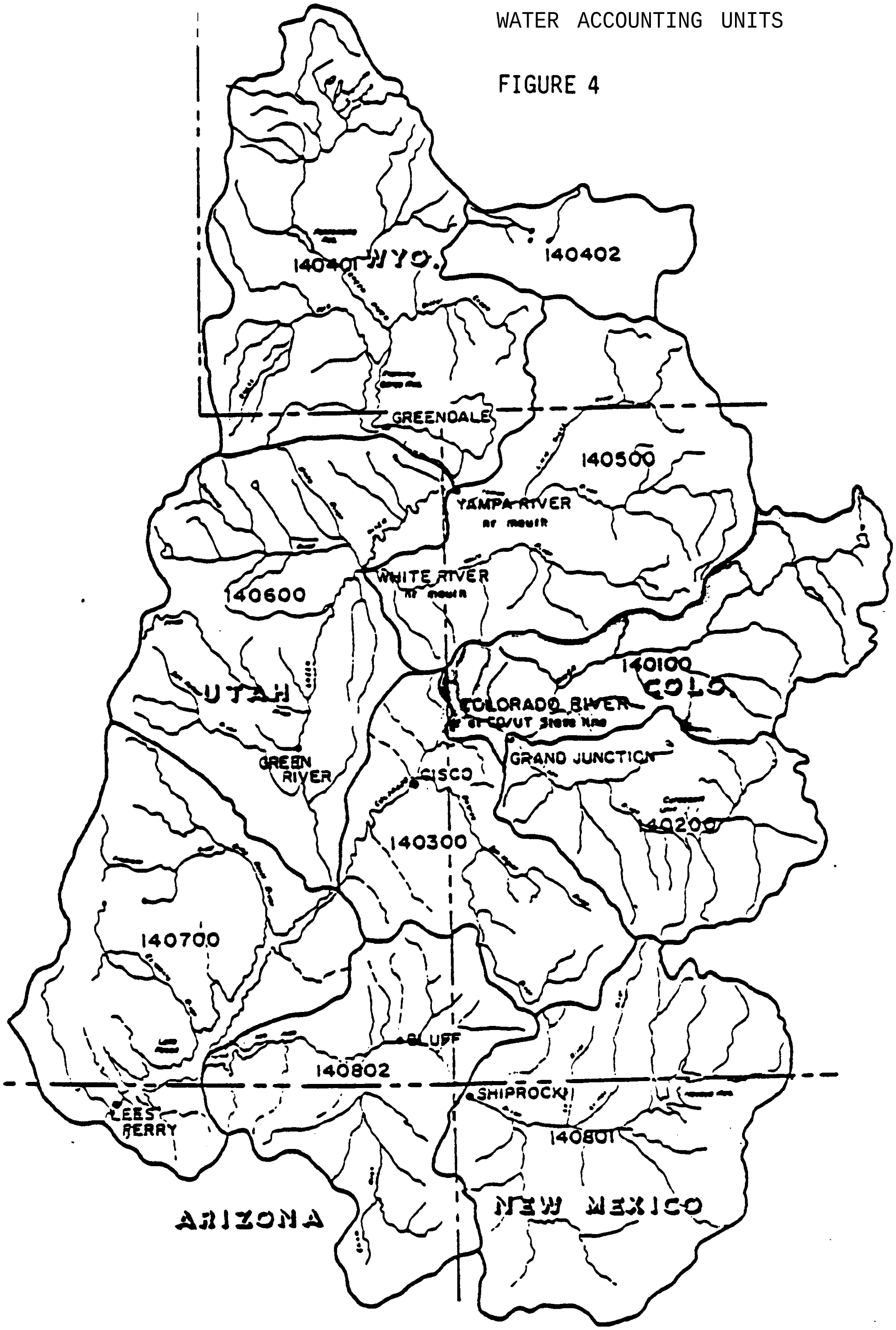
The Upper Colorado River Basin covers about one million square miles in four states: Colorado, Wyoming, Utah and New Mexico. These four states comprise the upper portion of what is the most complex, and disputed, water management system in the United States--the Colorado River Basin.

In order to meet the objectives of this study within the limits of available resources, it was necessary to select a portion of the Upper Colorado River Basin for detailed analysis. To attempt an assessment of water availability for synfuel development along with an analysis of existing data and information concerning water availability for the entire Upper Colorado River Basin would have led to a superficial and generality-laden report with little new information.

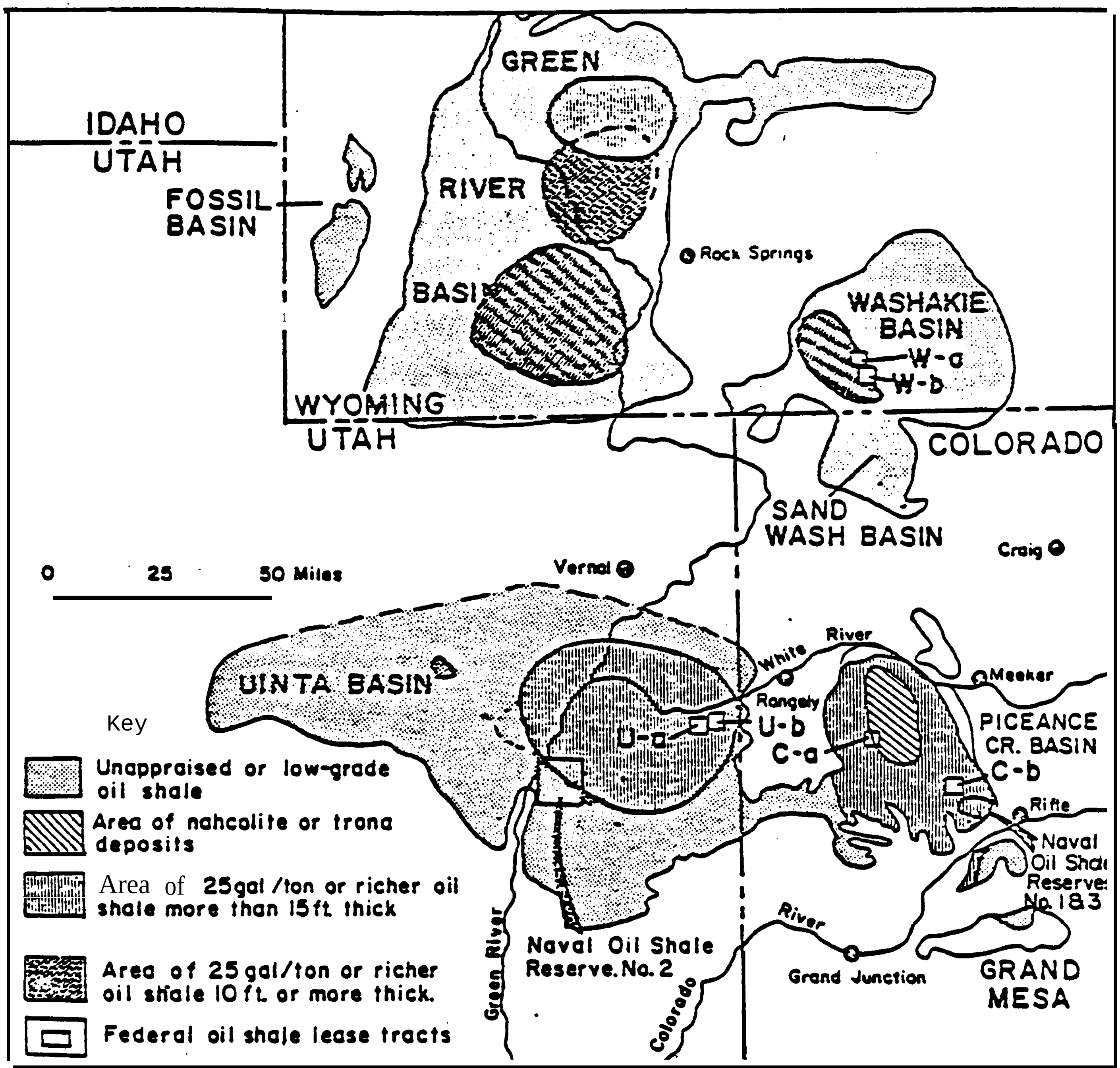
Consequently: the Upper Colorado River Basin in Colorado was selected for detailed analysis with particular focus on the impending oil shale development activity within the Upper Colorado River Basin above Grand Junction, Colorado and the new competition that it brings for water resources. This selection of the Upper Colorado River Basin in Colorado was made for several reasons:

UPPER COLORADO RIVER REGION AND
WATER ACCOUNTING UNITS

FIGURE 4



Source: Colorado Department of Natural Resources 13(a) Assessment



Source: Adapted from U.S. Geological Survey maps and Jaffee, F.C., "Oil Shale, Part II," Mineral Industries Bulletin, vol. 5, No. 3. Golden: Colorado School of Mines Research Foundation, Inc., 1962, p. 12.

Figure 5 GREEN RIVER FORMATION IN COLORADO, UTAH, AND WYOMING, SHOWING LOCATIONS OF NAVAL OIL SHALE RESERVES AND FEDERAL OIL SHALE LEASE TRACTS IN COLORADO AND UTAH

ANTHRACITE **& semi-anthracite**

Low-volatile bituminous coal

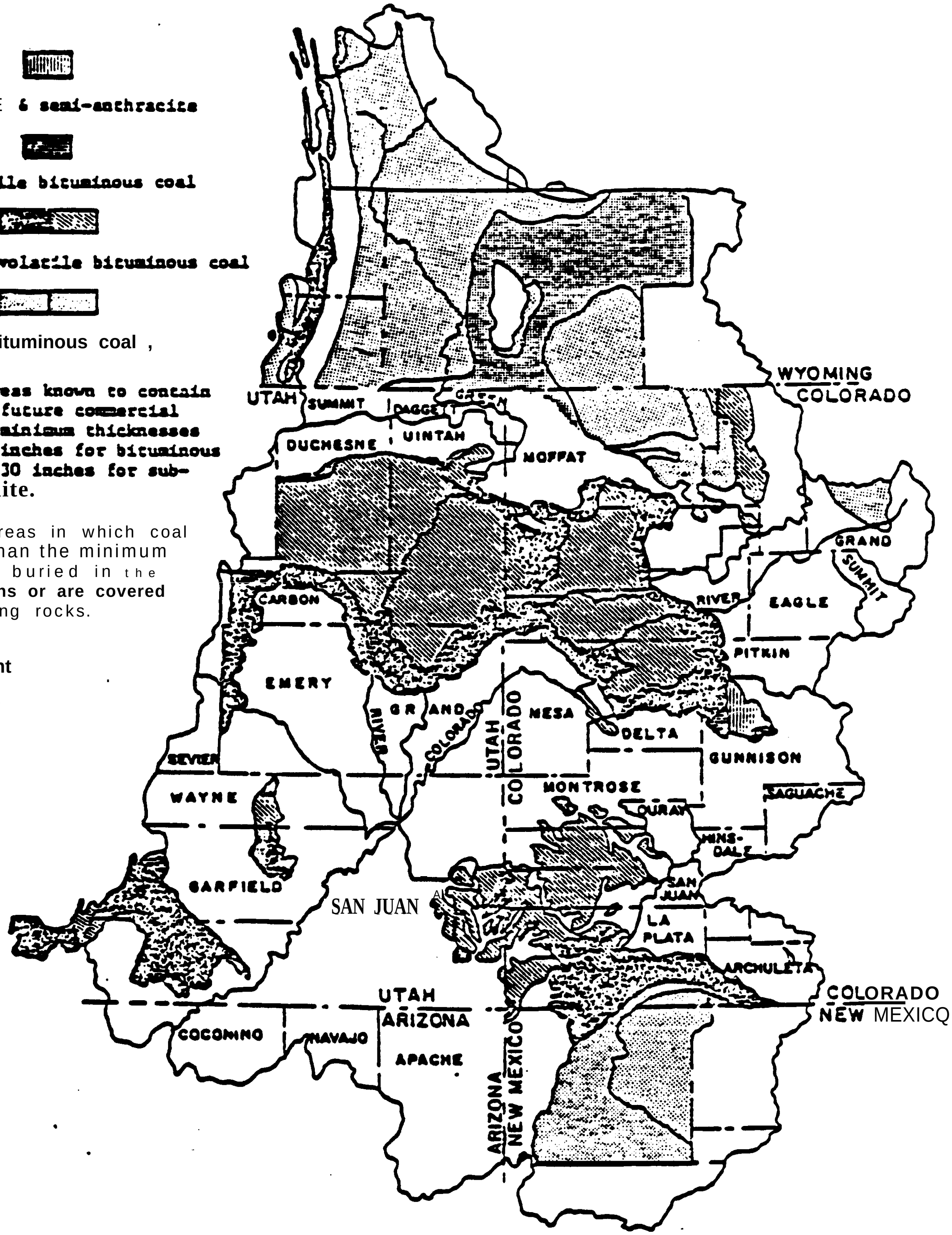
Medium & high-volatile bituminous coal

sub-bituminous coal ,

Dark color represents areas known to contain coal beds of present or future commercial value. In general, the minimum thicknesses of beds included are 14 inches for bituminous coal and anthracite and 30 inches for sub-bituminous coal **and lignite.**

Light color represents areas in which coal beds are generally less than the minimum thicknesses or are deeply buried in the **center** of **structural basins or are covered** by younger non-coal-bearing rocks.

NOTE: map is **from 1971, and more recent** studies in San Juan and **Rio Arriba counties, New** ***Mexico, show additional*** coal **deposits of** possi-**ble commercial value in that area.**



Source: Upper Colorado Region State-Federal Inter-Agency Group/Pacific Southwest Inter-Agency Committee/Water Resources Council, Upper Colorado Region, Comprehensive Framework Study, Appendix VII, Mineral Resources, June, 1971, p. 12.

FIGURE 6 GENERAL MAP OF COAL DEPOSITS IN THE UPPER COLORADO RIVER REGION

1. Major oil shale deposits are in this area and the Colorado River is viewed as the source of supply.

2. Oil shale development work is further advanced in this basin than elsewhere. For example, Exxon and Tosco are presently constructing the Colony Shale Oil Development. Work has advanced beyond the planning stage and application for Federal loan guarantee stage in the Upper Colorado River Basin in Colorado.

3. The Upper Colorado in Colorado is a more complex basin--with respect to institutions, economics, 'politics and legal matters--than other sub-basins in the Upper Basin that could have been chosen for in-depth analyses (e.g., the White River Basin).

4. The Upper Colorado River Basin in Colorado presents several interesting possible alternative sources of water for synfuel development. These alternatives are not available in other basins such as the White (e.g., reduction in municipal trans-mountain diversions through increased conservation measures and the use of the water "saved" for synfuel development). In summary, more conflicts and issues are presented in the Upper Colorado in Colorado.

5. More data, analyses and reports are available for the Upper Colorado in Colorado--probably as a result of the greater conflict and number of issues--than the other sub-basins.

Results of the analyses herein of the Upper Colorado River Basin in Colorado apply-with few exceptions to the remainder of the entire Upper Basin. The differences are primarily in degree of applicability. The institutional and legal systems with respect to water are very similar for the four states--a factor primarily responsible for the general application of the analyses results herein to the entire Upper Basin.

An effort has been made throughout this section to indicate the applicability of analyses results and conclusions based on the Upper Colorado in Colorado to other areas of the Upper Basin. Likewise, an effort has been made to indicate where these results should not be extrapolated.

An argument could be made for also studying the White River Basin in detail since the majority of oil shale in the Upper Basin is concentrated in that basin. The issues in the White River Basin, however, are fewer and less complex than in the Upper Colorado in Colorado. These issues primarily center around: (1) many of the same issues as in the Upper Colorado in Colorado (poor groundwater data, inadequate hydrologic data and interpretation of data, lack of adequate planning institutions, etc. and (2) the need of rational reservoir storage and conflicts over siting reservoirs in a wilderness area. This latter issue is quite similar to the new reservoir storage issue in the Yellowstone River Basin (see Section V), but on a much smaller scale. A subsection briefly focusing on the White River Basin and the problem of necessary new reservoir storage has been included at the end of the analyses of the Upper Colorado River Basin in Colorado.

Much of the discussion of the following case study is structured around existing reports" and published information concerning water availability for synfuel development in the Upper Colorado River Basin-inost notably the "Section 13(a)' report" completed by the State of Colorado. The structuring of the Upper Colorado River in Colorado case study around this material should not be confused with a "book review" of these reports and information. This structuring was done out of necessity to meet one of the objectives of this study: to analyze the adequacy of existing information and reports for decision-making concerning water availability of synfuel development.

The availability of water supplies in the Upper Colorado River-Basin has been the subject of dozens of studies and reports during the last 75 years. Some of the more important recent State and Federal studies include:

Colorado Department of Natural Resources, The Availability of Water for Oil Shale and Coal Gasification Development in the Upper Colorado River Basin Upper Colorado River Basin 13(a) Assessment, A Report to the U.S. Water' Resources Council, October; 1979.

Colorado Department of Natural Resources, The Ground Water Resources of the Upper Colorado River Basin, Denver, Colorado, October, 1979.

Colorado River Basin Water Problems: How to Reduce Their-Impact, May 4, 1979.

Comptroller General of the U.S., Water Supply Should Not be an Obstacle to Meeting Energy Development Goals, Report to the Congress of the United States, January 24, 1980.

In 1974, the final environmental impact statement for the Colony Development Operation (U.S. Department of Interior, 1977) stated:

> It is also realized that in drought years there may not be sufficient water available at all points of use in the Upper Basin to meet use requirements. . . . These shortages will generally be sustained by agricultural water users because they cannot economically pay the cost to provide enough storage regulation to eliminate all shortages in their water supply.

A 1979 General Accounting Office report on the Colorado River Basin (Comptroller General of the U.S., 1979) presented the following picture of water demand estimates:

> Based on most projections of future virgin flows, the allocations substantially exceed the river's dependable water supply.

In the 1979 Summary Report on Energy From the West prepared for EPA (U.S. Environmental Protection Agency, 1979), the University of Oklahoma commented upon water availability in the Colorado River Basin.

> When energy requirements for water are added to non-energy requirements for the year 2000, the total exceeds minimum availability estimates by as much as one million acre-feet per year. Even using , the most optimistic combination of these estimates of water requirements and availability, energy resource development will consume a large percentage of unappropriated surface water.

The Colorado Department of Natural Resources Section 13(a) Assessment, completed in October, 1979, and the January, 1980 GAO report to Congress (Comptroller General of the U.S., 1980) began to suggest that adequate water supplies exist in the Upper Basin through at least 2000. Little attention is given to supplies beyond 2000, most likely due to the inaccuracies inherent in such long-range predictions.

The reason why there are reasonable differences about water availability, as noted above, is that many uncertainties underlie the data, assumptions, and estimation methodology. Some of the issues underlying areas of uncertainty which will be reviewed and discussed in this analysis of water availability for synfuel development in the Upper Colorado River are:

(1) The data base and the methods used to establish the virgin flow (i.e., the total water resource available in the basin) are uncertain.

(2) The method for estimating current depletions from the basin is limited by the data base. Future consumptive use estimates are likewise limited.

(3) The effect of the Mexican Treaty of 1944-45 upon development of water supplies in the Upper Colorado River Basin is uncertain.

(4) Insufficient data exist to assess the contribution which non-tributary groundwater could make to the availability of supply.

In addition, the issues specifically related to the Colorado River above Grand Junction include:

(1) , The State of Colorado does not have a water administration plan developed to meet Colorado River Compact requirements once the Colorado River basin becomes fully developed. Therefore, the net water available to the sub-basins within Colorado is uncertain.

(2) Colorado water law is generally advanced by individual court cases and decisions, and the cumulative effect is uncertain.

Institutions in Basin

Within the basin water availability is governed by various institutions which-include the following:

Legal Institutions

State courts
Federal courts

Administrative/Water Management Agencies

State engineer (surface water and groundwater)

State natural resource departments
State water quality control authorities
U.S. Army Corps of Engineers (USACE)
U.S. Water & Power Resources Service (USWPRS)
Compact Commissions

Development Agencies

Water conservation districts "
State water development agencies
USACE
USWPRS

Organization of Section

This section is divided into three parts. The first part is the analysis of of the Section 13(a) Report as it specifically relates to the Colorado River in Colorado, as well as pertains to the entire basin. The second part is an analysis of three other reports pertaining to the Upper Colorado River Basin. The final part discusses the White River Basin and water availability for synfuel development in that basin.

SECTION 13(a) REPORT: THE UPPER COLORADO RIVER IN COLORADO AND THE UPPER COLORADO BASIN

The Upper Colorado River Basin in Colorado (see Figure 4 Water Accounting Unit 140100) is approximately 8,600 square miles in area, and much of it is located in mountainous country above 6,000 feet.

Physical Availability

Assessments of physical availability of water for synthetic fuel development in the Upper Colorado Basin and the Colorado River within Colorado have generally concentrated only on surface water supplies. Analyses of surface water availability have depended upon the following estimates:

- Estimates of virgin flows. Virgin flows are the natural streamflows undepleted by man's activity. These flows must be estimated from recorded streamflow data and estimates of depletions to the river. Virgin flow estimates are important data in assessing water availability because interstate compacts and water flow are predicated on virgin flow.

- Estimates of current and future depletions. Depletion is the difference between the amount diverted and the amount of water returned to the river ("return flow"). It is the amount of water removed from the system by evapotranspiration from plants, soil moisture absorption, reservoir evaporation, or other consumptive uses.

- Estimates regarding timing of water supplies. In the Colorado River Basin, surface water supplies can vary significantly from year to year. Within a year there s also considerable seasonal variation, with over one-half of the runoff occurring in the spring and early summer. Because of the year-round demand by synfuel plants, timing becomes an important factor in the availability of water, and estimates are made regarding the ability of reservoirs to smooth out the timing of water supplies. The long term stochastic nature of virgin flow is imperfectly understood. This results in difficulties in estimating statistical parameters (e.g. mean annual flow) of flow distributions.

Streamflow Data. Historic streamflow records for the Colorado River, one of the bases for determination of virgin flows, are probably the most accurate component in the various analyses of water availability. There are still, however, limitations to the quality of that data base caused by inaccuracies in measurement, icing at gaging stations in winter, and other recording errors.

Streamflow data are accumulated primarily by the U.S. Geological Survey, with additional gages operated by the State of Colorado and the Mater and Power Resources Service. In 1921 there were only 14 gaging stations within the study basin in Colorado, four of which were on the main stem of the Colorado River. The number of stations has grown to 121 in 1980.

Therefore, there are a limited number of long term records, and it may be impossible to estimate accurately the statistical properties of the streamflow distributions from the short term records.

The Section 13(a) report relies almost exclusively on mean annual flows for estimating water availability for synfuel development. For the mainstem, mean annual flow data provide a reasonable estimation of annual yields because of the significant amount of storage available to control river flows. However, for tributaries, where comparable storage volumes are not available, or will not be available in the near future, reliance on mean annual flow data is not adequate. In these circumstances, mean annual flow data provide little or no information to decisionmakers concerning the impacts of synfuel development water demands on low flows. Such data and information are important to assess water availability during low periods for meeting instream demands for fish and wildlife habitat, recreation, water quality and run-of-the-river hydropower.

Analysis of stream gage records does not give a good quantification or distribution of the virgin flow unless there are either no diversions upstream of the gage or the upstream depletions can be accurately measured. While there are many gages which measure virgin flow, these are in small, high mountain basins. In most cases the virgin flow is estimated from streamflow data and estimates of depletions. Depletions estimates, in turn, are another source of uncertainty in assessing water availability for synfuel development.

Historic Depletions. The Colorado Department of Natural Resources 13(a) Assessment estimates the average annual depletions in the Colorado River Basin upstream of Grand Junction (Water Accounting Unit 140100) for 1975/76 conditions to be 991,000 acre-feet, of which 454,000 acre-feet are in-basin depletions:

	Percent	Acre-feet
Thermal	1	1 000
Agriculture	43:5	432,000
Fish, Wildlife and recreation	.2	2,000
Minerals	. 7	7,000
Municipal & Industrial	1.2	12,000
Transbasin Diversions	54.2	537,000
		991,000

Future depletions for year 2000 exclusive of synthetic fuel uses are projected to be 1,138,000; 1,220,000; and 1,313,000 acre-feet for the low, medium and high scenarios in the Section 13(a) study.

These estimated historic depletions and forecasted future depletions comprise important data and information sets for estimating virgin flow, a fundamental parameter for determining water availability in the entire Upper Colorado Basin.

Of most significance to the estimation of depletions is the fact that the State Engineer's records (except in a few cases) do not and possibly cannot measure return flow to the stream, whether it is through wastewater outfalls, irrigation return flow or other sources of return flow to streams. Therefore, depletions must be estimated by indirect means. These estimated depletions subsequently form the basis for estimating virgin flows.

There are two methods by which depletions are estimated. The first and probably most accurate method is to correlate ditch diversion records with a depletion factor based upon type of use. For agriculture (the greatest source of in-basin depletions), ditch diversions would be correlated with the amount of land irrigated and type of crops to obtain an estimate of depletions. This method reflects the year-to-year variations in depletions as a result of changes in river flows. Since this method is extremely time-consuming on a basinwide study, a second method is used., This method identifies the amount of irrigated land by crop, usually from county agricultural statistics or aerial photos, and uses a unit consumptive use figure (e.g. , acre-feet per acre) to identify the total depletions. This, however, only provides generalized depletion estimates. This second procedure was used for the Upper Colorado Section 13(a) analysis: (1) crop acreages for the Upper Colorado Basin were obtained from agricultural census data, (2) evapotranspiration indices for the crops were developed for each year using a procedure such as the Blaney Criddle method, and (3) depletions were assumed to be equal to evapotranspiration.

Therefore, this discussion indicates that for the entire Upper Colorado River Basin and for the area encompassed in this case study: (1) estimated depletions are important parameters i n assessing water availability and (2) considerable uncertainty can exist in depletion estimates. Without a water use audit one cannot determine if depletions are over estimated or under estimated, let alone determine the magnitude of error.

Estimation of Virgin Flows. Virgin flow estimates are fundamental data for determining water availability in the Upper Colorado River Basin. -A look at the estimation of virgin flows for the entire Upper Colorado River Basin provides a good example of the deficiencies inherent in the quantification of natural flows.

Estimates of virgin flow for the Colorado River at Lees Ferry vary significantly according to the period of study:

Period	Years	Annual Virgin Flow
1906-1974	69	15.2 maf
1922-74	53	14.3 maf
1930-74	45	13.8 maf
1931-40	10	12.5 maf
1954-63	10	12.5 maf

The General Accounting Office study uses the 1906-74 period of record and assumes that the virgin flow of the Colorado River at Lees Ferry will average 15.2 million acre-feet per year (Comptroller General of the United States, 1980). The Section 13(a) Assessment identifies the range of 13.8 to 15.2 million acre-feet per year but chooses the 13-8 figure as the basis for its analysis. Studies by the Water and Power Resources Service in recent years (Comptroller General of the U.S., 1979) have used an annual virgin flow of about 14.8 million acre-feet, and the Denver Water Department in a 1975 report to the Colorado General Assembly quoted a flow of 13.0 million acre-feet per year.

Each of these studies confuses the sample mean with the population mean. A mean annual flow is a random variable just as annual flow is a random variable. Mean annual flow estimates have a statistical distribution. Mean values based on samples from this distribution (e.g., the 15.2 and 14.3 million acre-feet are only sample means and will have a considerable variance (in the statistical sense) about the population mean.

Therefore, 13.8 maf should not be taken as the population mean of the Colorado River; it should be viewed as only the arithmetic average of a series of annual river flows from 1930-1974. The mean of a future series of annual flows can, and probably will, vary considerably from this number.

The Section 13(a) report for the Upper Colorado River apparently makes the common mistake of treating the estimate of mean annual flow as a deterministic number when it is stochastic. Failure to emphasize this stochastic nature of mean annual flow estimates tends to make estimates appear more certain than they are.

Groundwater. Most analyses of water availability for oil shale development in Colorado and the entire Upper Basin ignore the potential contribution from groundwater because of the lack of sufficient quantitative data. Use of tributary groundwater, which by definition in Colorado law is a continuum of the surface water system, will not increase the available supply but can alter the timing of supplies. Use of tributary groundwater can provide non-structural storage of surface water by vacating the alluvium and providing storage for additional water to be pumped at a later date.

The use of non-tributary water, which is water not connected to the surface water system, can provide an additional source of water. The Section 13(a)" report indicates that between 2.5 and 25 million acre-feet are contained in the two deep aquifers underlying and overlying the oil shale deposits in the Piceance Creek Basin. The estimated average annual discharge from, and recharge to, the aquifer system associated with the Piceance Creek structural geologic unit ranges from approximately 24,000 to 29,000 acre-feet. Discharge occurs primarily by evaporation and by seepage to springs (Colorado Department of Natural Resources, 1979, p. 7-31). This amount of depletion would maintain an equilibrium in the aquifer while providing the water supply needs for four or five unit-sized (50,000 bb/d) shale oil plants exclusive of associated growth. However, there is controversy over whether the aquifers are tributary or non-tributary. This legal distinction affects the yield and legal availability of the water.

While non-tributary groundwater might be an attractive alternative supply for synthetic fuel development, knowledge and information about non-tributary groundwater is insufficient to use for reliable basin-wide planning. In general, groundwater data for tributary and non-tributary waters in the Colorado River Basin above Grand Junction are sketchy and inaccurate. One of the main sources of confirmation of hydrogeologic estimates in Colorado is the State Engineer's records on registered wells which records contain well completion reports. However, based on our experience it is believed that in some areas less than 50 percent of the wells are registered with the State.

The lack of a good tributary groundwater data base in the entire basin, both in the number of wells and well pumping data for alluvial wells, means that we cannot accurately estimate ranges of the cumulative effect of tributary wells on the alluvium and streamflow regime in the Upper Colorado River.

The lack of data regarding non-tributary supplies has great significance for basin-wide assessments of water availability. Should synfuel projects be able to obtain a significant portion of the water in the deep, non-tributary aquifers, this would lessen the burden on surface flows and provide back-up in times of water shortage. In effect, non-tributary groundwater is treated by water supply planners as a potential windfall source for energy development.