Chapter 11

Water Availability for Synthetic Fuels Development

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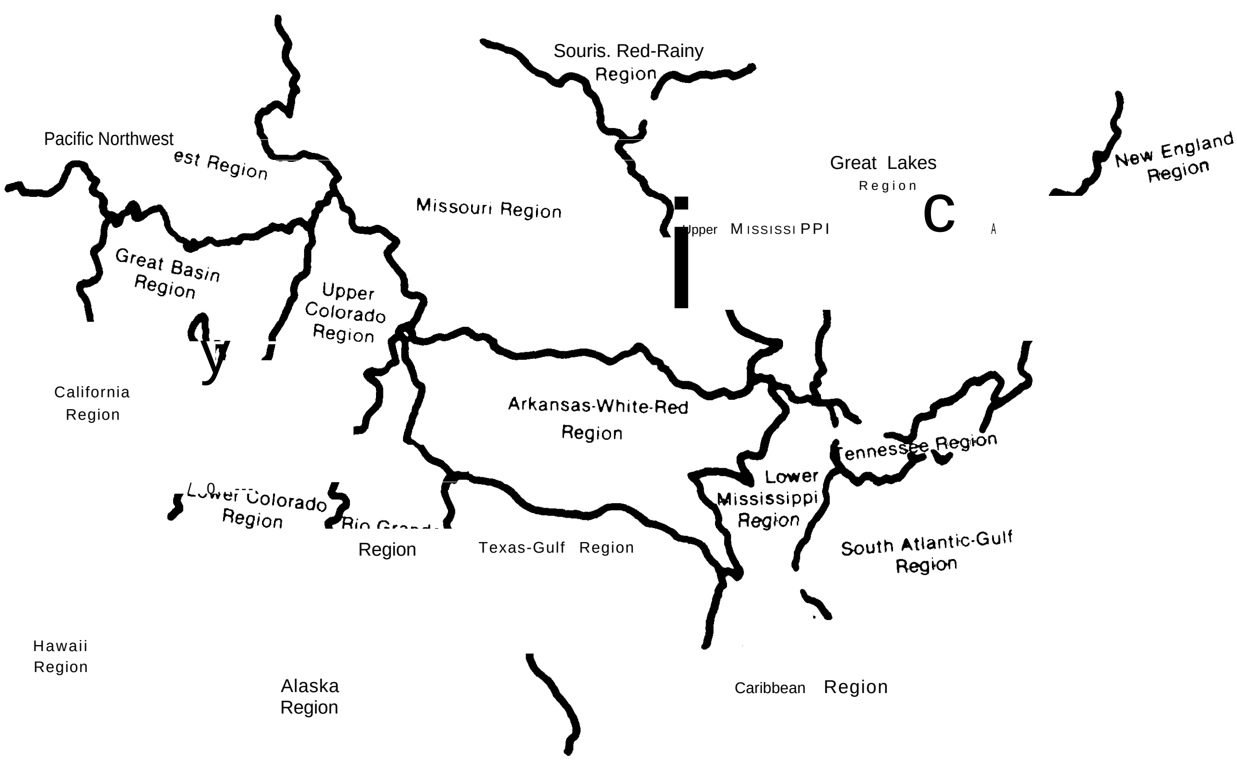
INTRODUCTION

Operation of a synthetic fuels plant requires a steady supply of water throughout the year for both plant and site activities. Availability of water will be determined not only by hydrology and physical development potential, but also by institutional, legal, political, and economic factors which govern and/or constrain water allocations and use among all sectors. This chapter expands the environmental discussion of the role of water in synfuels development and examines the major issues that will determine both water availability for synfuels and the impacts of procuring water supplies for synfuels on other water users. There are five river basin areas where oil shale and coal resources are principally located: in the eastern basins of the Ohio, Tennessee and the Upper Mississippi, and in the western basins of the Upper Colorado and the Missouri (see fig. 24).

Figure 24.—Water Resources Regions



SOURCE: U.S. Water Resources Council, *The Nation's Water* Resources 197S2000, vol. 2, pt. 1, p. 3,

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WATER REQUIREMENTS FOR SYNFUELS PLANTS

Estimates of the consumptive use requirements of generic synthetic fuels plants producing 50,000 barrels per day oil equivalent (B/DOE) of product are shown in table 80. In general, the actual amount of water consumed will vary according to the nature of the products produced, process methods, plant design, and site conditions. In coal conversion, the largest single component of total water consumption is typically for cooling, * with other major components being for hydrogen production, waste disposal, and revegetation. In producing synfuels from oil shale, retorting and upgrading require the most water; other major uses are for the handling and disposal of spent shale, and for revegetation.

*The amount of water consumed in cooling will depend on many factors, including the degree to which evaporative or "wet" cooling, or dry cooling, are used. Air or "dry" cooling is an alternative to wet cooling but is less efficient and generally more expensive.

Table 80.—Estimates of Net Consumptive Use Requirements of Generic Synfuels Plants (50,000 B/DOE)[a]

	Acre-feet/year	Barrels water/ barrel product
Gasification	4,500-8,000	1.9-3.4
Liquefaction.	5,500-12,000	2.3-5.1
Oil shale.	5,000-12,000	2.1-5.1

[a]Available estimates are based on theoretical calculations, conceptual designs, small-scale experimental facilities, etc. A range is shown for each generic process In order to reflect differences among process technologies (e.g., Indirect liquefaction will generally consume more water than direct liquefaction; modified-in-situ will generally consume less water than aboveground 011 shale processes), plant design options (e.g., alternative methods of water reuse, conservation, and cooling), and sites. Estimates also vary with the level of detail and state of development of the engineering designs. There are also at least two major elements of uncertainty surrounding these estimates. Firat, both the refinement and optimization of operational requirements are limited by the lack of commercial experience. Secondly, estimates commonly assume zero wastewater discharge, which Is to be achieved via the treatment and reuse of plant wastewater for cooling water makeup and boiler feed; however, the treatment processes to be used generally have yet to be demonstrated on a commercial scale. Although the estimates shown In table 80 may thus not be representative of actual consumptive use requirements In specific cases, the magnitude of the other uncertainties concerning water availability in general, as discussed In this chapter, will likely overshadow the question of how much water will be required for expected synfuels development. The following references provide additional details:

1. Office of Technology Assessment, An Assessment of *Oil* Shale Technologies, June 1980, ch. 9.
2. Ronald F. Probstein and Harris Gold, Water *In Synthetic Fuel Production,* MIT Press, Cambridge, Mess., 1978.
3. R. M. Wham, et al., *Liquefaction* Technology Assessment—Phase 1: Indirect *Liquefaction* of Coal to Methanol and Gasoline Using *Available* Technology, Oak Ridge National Laboratory, Oak Ridge, Term., February 1981.
4. Exxon Research and Engineering Co., EDS Coal Liquefaction Process *Development,* phase V, vols. 1, II, and Ill, March 1881.
5. Harris Gold and David J. Goldstein, "Water Requirements for Synthetic Fuel Plants;" and Harris Gold, J. A. Nardella, and C. A. Vogel (ads.), "Fuel Conversion and Its Environmental Effects," Chemical Engineering Progress, August 1979, pp. 58-84.

SOURCE: Office of Technology Assessment.

Synfuels plants will also generally require water for other process-related activities such as environmental control (e.g., dust control) and for associated growth in population, commerce, and industry (e.g., for water supply and sewerage). Plant activities will not all require water of similar qualities. As examples, high-quality water is required for processing; intermediate-quality water is required for cooling; mining, materials preparation, and disposal activities are the least sensitive to water quality characteristics.

Procuring water supplies for synfuels plants will represent a small fraction of total plant investment and operations costs (typically less than 1 percent). * * Thus, assuming that the overall economic feasibility of the plant has been established, the more critical industrial considerations in selecting a water source will be the ease of acquiring water of appropriate quality and the certainty of the yield. Major water sources for synfuels would include the direct diversion of surface water, the purchase or transferring of existing water rights, the use of existing or the construction of new storage, the use of tributary and nontributary ground water,*** savings from improved efficiency, reuse, and conservation by all users, and interbasin diversions.

The feasibility and attractiveness of sources will vary among sites according to environmental, social, legal, political, and economic criteria, and

**Obtaining reliable and comparable cost data on the procurement of water to the synfuels industry is difficult because of variation in the conditions surrounding each sale (e.g. water rights vary according to their seniority, historic use, point of diversion, etc.). As examples, annual costs per acre-foot of consumption vary between $50 to $300; water rights have sold for as high as $2,000/acre-foot (in perpetuity). Assuming a cost of $2,000/acre-foot, water rights costs would still represent a maximum of only 0.8 percent of the cost of a $2 billion plant with an average annual consumption of 8,000 acre-feet. Note that what is bought is the right to use water, not the water per se.

Costs are, nevertheless, important industrial criteria for evaluating alternative sources of water supply. Costs will also be important for water resources planning efforts, as they will help to determine the nature and extent of impacts on other water users from synfuels development.

***The development of deep, nontributary ground water, which is hydrologically unconnected to the surface flow, can be considered as an "additional" source of water. Development of tributary ground water, which is hydrologically connected to streamflow, does not represent an increase in supply and may alter the surface flow regime, it is therefore difficult a priori to predict how and which water “packages” will be assembled. Evidence suggests that the industry is conservative in planning for a plant’s water resource needs in order to ensure (both hydrologically and legally) that the plant obtains its minimum operating requirements. As examples, developers can secure several different sources of supplies; estimates of resource needs will include a margin of safety; and sources can be “guaranteed” by obtaining agreements not only with rights holders but also with upstream appropriators and/or potential downstream claimants. Synfuels technology modifications should also be forthcoming from the industry, if needed to reduce water needs.

IMPACTS OF SYNFUELS DEVELOPMENT ON WATER AVAILABILITY

In the aggregate, water consumption requirements for synfuels development are small. Achieving a synfuels production capability of 2 MMB/DOE would require on the order of 0.3 million acre-feet/year (AFY), which will be distributed among all of the Nation’s major oil shale and coal regions. This compares with an estimated (1975) total national freshwater consumptive use of119 million AFY, of which about 83 percent is for agriculture.[1] Table 81 shows the general hydrologic characteristics of the principal river basins to be affected.

Although in the aggregate synfuels water requirements are small, each synfuels plant, nevertheless, is individually a relatively large water consumer. Depending on both the water supply sources chosen for a synfuels plant and the size and timing of water demands from other users, synfuels development could create conflicts among users for an increasingly scarce water supply or exacerbate conflicts in areas where water is already limited or fully allocated. Sectors that will be competing for water will vary among the regions and will include both offstream uses (e.g., agriculture, industry, municipalities) and instream uses (e.g., navigation, recreation, water quality control, fish and wildlife, hydropower). Because energy developers can afford to pay a relatively high price for water, nonenergy sectors are not likely to be able to compete economically against synfuels for water. However, it is speculative to identify which sectors may be the most vulnerable to synfuels development.

Public reactions to proposed water use change and nonmarket mechanisms can be used to allocate and protect water for use by certain sectors depending on the region and State. Examples of nonmarket mechanisms include the assertion of Federal reserved water rights, water quality legislation, and State water allocation laws. While such mechanisms may prevent developers from always obtaining all the water they need, the synfuels industry is expected to obtain the major portion of its water requirements.

[1] U.S. Water Resources Council, The Nation Water *Resources*—1975-2000, December 1978. The assessment projects a total national freshwater consumption of 151 million AFY in 2000, of which about 70 percent would be for agriculture.

Table 81 .—Regional Streamflow Characteristics 1975[a] (millions acre-feet/year)

	Mean annual streamflow[b]	Consumption[c]		Low flow ratio[d]	Low flow month
		1975	2000		
Ohio	199	2.0	4.9	0.15	September
Tennessee	46	0.5	1.2	0.38	September
Upper Mississippi.	136	1.3	3.0	0.23	January
Upper Colorado.	11	2.7	3.6	0.12	July
Missouri	49	17.3	22.3	0.19	January

[a] U.S. Water Resources Council (WRC), The *Nation's Water Resources—1975-2000*.
[b] WRC, table IV-1. Note that all these outflows are inflows to a downstream river basin.
[c] WRC, table III-3.
[d] Ratio of the annual flow of a very dry year (that flow which will be exceeded with a 95-percent probability in any Year) to the mean annual flow. WRC, table IV-2.

SOURCE: US. Water Resources Council as tabulated by OTA.

Photo credit: Office of Technology Assessment

Competing uses will increase pressures on the Nation's water resources, especially in the arid West

The nature and extent of the impacts of synfuels development on water availability in general, and on competing water users, are controversial. The controversy arises in large part because of the many hydrologic, institutional, legal, and political constraints and uncertainties that will ultimately determine when, how, and if users will be able to obtain the water they need. Furthermore, analyzing these constraints and uncertainties is difficult because of many additional complex factors: the lack of dependable and consistent data, limitations of demand-forecasting methods, time and budget constraints, and the unpredictability of future administrative decisions and legal interpretations. In some cases, the uncertainties about water availability in general appear to be so large that they overshadow the question of how much water will be required for synfuels development.

OTA's study[2] found that there was considerable variation in the quality, detail, and scope of the water availability assessments that have been completed related to synfuels development. Few studies take into account all of the issues that will determine resource allocations and use; and studies rarely try to address the likely, cumulative water resource impacts of alternative decisions on reducing uncertainties and resolving conflict among competing water users. Decision makers need to be better informed about the assump-

[2]Wright Water Engineers, Inc., "Water Availability for Synthetic Fuels," prepared for the Office of Technology Assessment, June 1981.

tions and uncertainties upon which reports are predicated, so that estimates can be properly interpreted and tradeoffs can be evaluated.

Some of the major uncertainties about water availability for synfuels are discussed below. More informed decisions on water availability questions, however, can only partially be achieved by "improving" studies themselves; more informed decisions also depend on greatly improved water planning practices in general in the Nation. The present fragmentation of responsibilities for water policy, planning, and management effectively prevents an assessment of the cumulative impacts of water resource use on an ongoing and comprehensive basis. *

*The fragmentation of water-related responsibilities among agencies, States, and levels of governments arises in large part because river system boundaries rarely coincide with political boundaries. As a result, there can be major inconsistencies in water management practices across the country (e. g., inconsistent criteria for evaluation; the lack of integrated planning—including data management—for ground and surface waters, water quality and quantity, and instream and offstream uses).

WATER AVAILABILITY AT THE REGIONAL LEVEL

Eastern River Basins

In the principal eastern basins where energy resources are located (i.e. Ohio, Tennessee, and the Upper Mississippi), water should be adequate on the mainstems and larger tributaries, without new storage, to support planned synfuel development.[3] However, localized water scarcity problems could arise during abnormally dry periods or due to conflicts in use on smaller tributaries. The severity and extent of local problems cannot be fully ascertained from existing data and have not yet been examined comprehensively, * but, with appropriate water planning and management, these problems should be reduced if not eliminated.

There are, nevertheless, various uncertainties in the eastern basins that will influence water availability for synfuels development, and difficult local situations could arise.[4] For example, 7-day, 10-year minimum low flows are used to estimate water availability. * * These estimates are essentially based on recorded streamflow data which can be of varying quality. Furthermore, by using historical streamflow records directly, reports on water availability in the eastern basins characteristically underestimate the frequency of future critical low flows; i.e., as flow depletions increase in the future, the critical flow associated with the 7-day, 10-year frequency will actually occur more often in the future than the historical data would indicate.

The political, institutional, and legal factors that will determine water availability for synfuels in the eastern basins differ in type and complexity from those in the western basins. For example, the East and West have different regional hydrologic characteristics, with the East being relatively humid. There are also varying legal and administrative structures as shown in figures 25 and 26: riparian water law is generally applied in the East whereby riparian landowners are entitled to an equal, "reasonable" use of adjacent streamflow; the prior appropriation doctrine is generally applied in the West whereby water rights are based on "beneficial" use with priorities assigned according to "first in time, first in right. " Furthermore, in the East there is a general lack of treaties and compacts, and there are no major Federal (including Indian) reserved water rights questions.

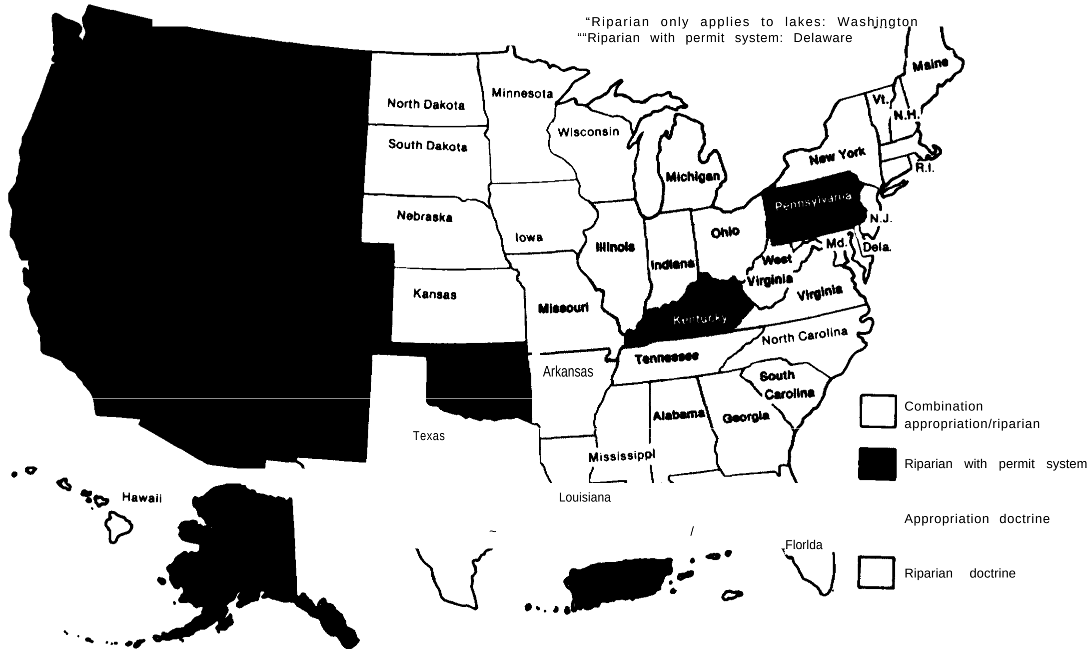
Although water may thus appear to be more readily available for synfuels development in the East (e.g., through the transfer of ownership of riparian land), eastern water law can result in significant uncertainty concerning the dependability of the supply: because all users have equal

[3] 1 bid.

"For example, available reports related to ynfuels for the Tennessee River Basin generally deal with specific project sites; the sparsity of comprehensive information with respect to cumulative impacts and possible water use conflicts is presumably because of the large quantities of water available at the regional level. The Ohio River Basin Commission study focuses on water availability for plants located on the mainstem, even though there are facilities being proposed for tributaries.

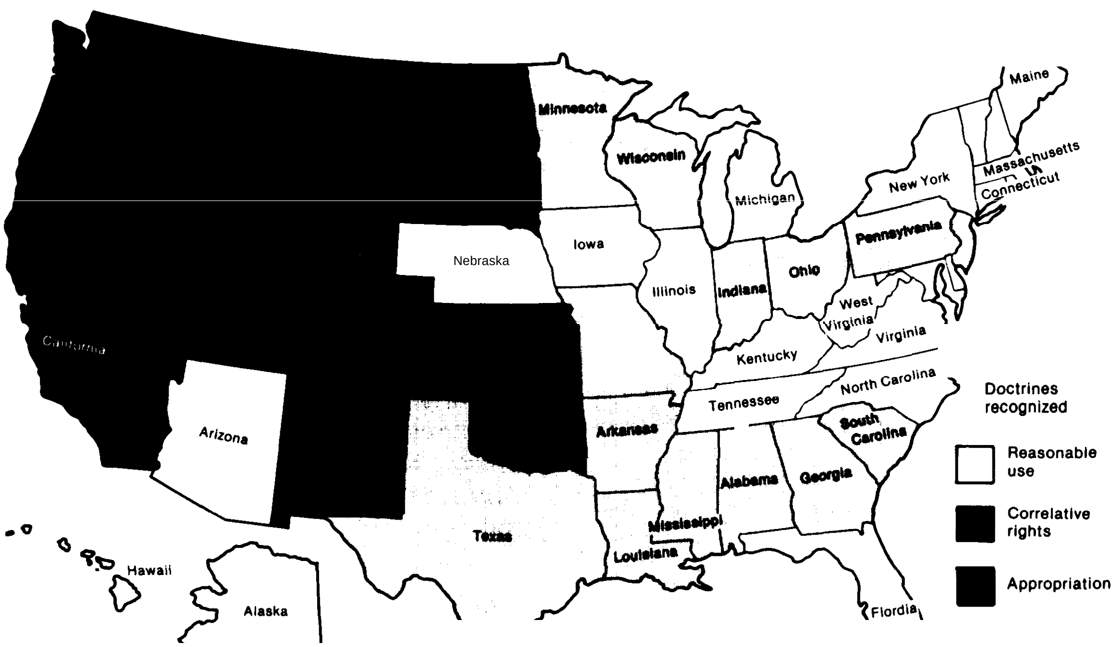
* *The use of the 7-day, 10-year minimum flow in the East is also the basis for water quality regulations and for estimating critical conditions for navigation in rivers with limited storage.

Figure 25.– The Nation's Surface Water Laws



SOURCE: U.S. Water Resources Council, (The *Nation's Water* Resources 7975-2000, vol. 2, **pt.** iv, P. 118).

Figure 26.— The Nation's Ground Water Laws



SOURCE: U.S. Water Resources Council, (The *Nation's* Water Resources 197%?000, vol. 2, pt. iv, p. 118).

rights under riparian law, the law does not protect given users against upstream diversions or against pumping by adjacent wells. * Uncertainty also arises because eastern water law has not been as well advanced through court tests as in the West. There are also questions in the East concerning the availability of water from Federal storage (i.e., in the Ohio River Basin) because of uncertainties regarding who has responsibility for marketing and reservoir operation.

The Western River Basins

Competition for water in the West already exists and is expected to intensify with or without synfuels development. There are potential sources of supply in both the Upper Colorado and the Missouri River basins that could support synfuels development. However, the issues determining whether and the extent to which these sources will be available for use differ between the two basins. These issues concern complex State water allocation laws, compacts and treaties, Federal including Indian reserved water rights claims, and the use of Federal storage. In addition, the use of "mean annual virgin flows" in both regions to characterize the hydrology results in the masking of important elements of hydrologic uncertainty.** However, and in contrast with the situation in the East, although the complex water setting in the West will probably make obtaining water difficult, the user will be more assured of a certain supply once a right is obtained.[5]

Missouri River Basin

The magnitude of the institutional, legal, political, and economic uncertainties in the Missouri River Basin, together with the need for major new water storage projects to average-out seasonal and yearly streamflow variations, preclude an unqualified conclusion as to the availability of surface water resources for synfuels development.[6] Ground water resources are not well understood in the basin, but are not likely to be a primary source of water for synfuels.

Major coal deposits for synfuels development in the Missouri River Basin lie within and adjacent to the Yellowstone River subbasin. The availability of water for synfuels from the Yellowstone subbasin, however, could be constrained by the provisions of interstate compacts, i.e., the Yellowstone River Compact. For example, at present all signatory States must approve any water exports from the basin (e.g., to the coal-rich Belle Fourche/Gillette area where water is scarce). Although export approval procedures are now being challenged in court and States have begun to modify approval procedures, such approvals are likely to take some time. Furthermore, additional storage would likely be required to develop fully the compact allocations.

Federal reserved water rights are often senior rights and have the potential of preempting current and future uses. These rights, however, have yet to be quantified and are a major source of uncertainty for water planning. The largest single component of Federal reserved rights are Indian water rights. There is a general lack of quantitative data concerning Indian water rights because of political controversy over which jurisdictions should be adjudicating the claims, varying interpretations of the purposes for which water rights reservations can be applied, and ongoing litigation.[7]

*For example, Federal storage has not yet been utilized in Illinois because delivery of the water from the reservoirs (e.g., to the synfuels plants) cannot be guaranteed along the river; riparian landowners along the way could intercept the released water. Energy companies are thus faced with having to build private pipelines.

**The accuracy of mean annual virgin flows is uncertain due to possible inaccuracies in the underlying data both on streamflows and on depletions. (Depletions are usually not measured directly for practical reasons.) Furthermore, virgin flow estimates are treated as both deterministic and stationary, rather than as time-varying, which prevents the variability of streamflows from being addressed accurately in areas lacking sufficient storage. Estimates of the mean annual virgin flow for the Colorado River at Lees Ferry vary from 12.5 million to 15.2 million acre-feet depending on the assumptions (in this case, the period of the historical record) used.

In general, the use of aggregated data, in the form of regional and basinwide averages, will mask the local and cumulative downstream effects of development on water availability. Such data do not provide information about either the seasonal variability of streamflows and demands or the relative positioning and hence interrelationships among users. These factors are important for identifying potential competition for water, especially in areas where water is scarce and subject to development pressures, as will often characterize locations for synfuels development.

'Ibid.

[6]Ibid.

[7]The only "official" Government estimates of Indian reserved water rights project depletions (i.e. requirements) of 1.9 million acre-

(continued on next page)

Other major uncertainties that could effect the availability of water for synfuels concern State water allocation laws. For example, Montana has established instream flow reservations in the lower-Yellowstone River of 5.5 million AFY to protect future water quality and wildlife. Over 500,000 AFY have also been reserved in the basin for future municipal and irrigation use. Additional storage would be required to meet these reservations during years of low flow, but Montana State officials generally do not advocate the construction of new mainstem storage, even if instream flow shortages were to occur otherwise, as this would interfere with the free-flowing nature of the river.[8 9] No determination has yet been made as to how these instream flow reservations would be accommodated under the Yellowstone Compact.

The transferring of water rights from existing (e.g., agricultural) to new (e.g., synfuels) uses in Montana is subject to administrative restrictions under primarily the 1973 Water Use Act, and State environmental and facility siting acts.[10] Because of these restrictions, water rights are not freely transferable from existing users, and, in effect, there is presently no economic market for rights transfers.

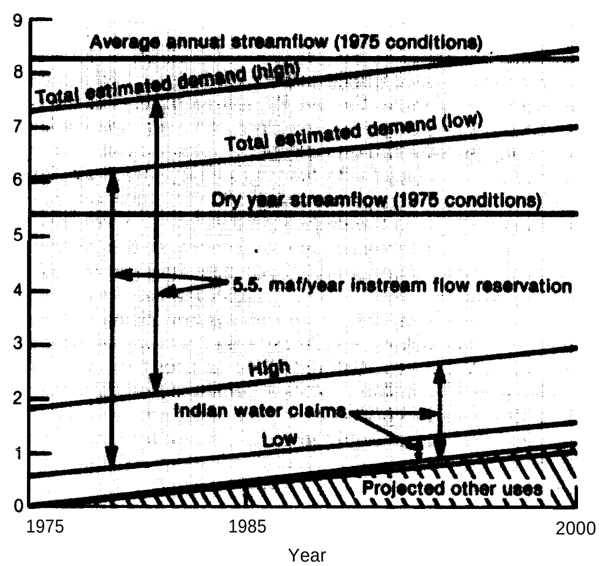
State water laws and statutory provisions in other Upper Basin States similarly could constrain water rights transfers to synfuels.11 As examples, water for irrigation takes precedence in these States over water for energy development, and the "public interest" is to be explicitly considered in approving water allocations. Alternatively, other laws could work to the disadvantage of nonenergy sectors, such as navigation in the Missouri region under the Federal Flood Control Act of 1944 (33 USC 701 -(b)).

Many of the water availability issues in the Missouri River Basin cannot be adequately evaluated because of a lack of supporting data and case law interpretations. Figure 27 illustrates the possible magnitude of uncertainty by superimposing the major projected consumptive uses (excluding synfuels) onto the availability of water in the Yellowstone River. As can be seen, assuming a low total estimated demand growth scenario, demands would not be met in a dry year without additional storage. Assuming a high-growth scenario, not only would demands not be met in a dry year without storage, but they would also exceed the average annual flow with additional storage.

Upper Colorado River Basin

Although water may not be available in certain tributaries and at specific sites, sources of water

Figure 27.–Streamflows and Projected Increased Incremental Water Depletions, Yellowstone River at Sidney, Mont.



SOURCE: "WaterAvailability for Synthetic Fuels," Wright Water Engineers, Inc., contractor report to OTA, June 5, 1981.

feet for the year 2020 in the Yellowstone. (U.S. Department of Interior, Water for Energy Management Team, Report *on* Water *for* Energy *in* the Northern Great Plains With Emphasis on the *Yellowstone* River Basin, January 1975.) A lower estimated value of 0.5 million acre-feet appeared in a 1960 background paper (for a larger framework study of the Missouri River Basin) by the Bureau of Reclamation. For a detailed discussion of Indian reserved water rights, the reader is referred to Constance M. Boris and John V. Krutilla, Water Rights and Energy Development in the *Yellowstone* River Basin, Resources for the Future, 1980.

8 Wright Water Engineers, Inc., op. cit.

9 Personal communications, Department of Natural Resources and Conservation, State of Montana.

10 For a detailed discussion of State water allocation laws see Grant Gould, State Water Law in the West: *Implications* for Energy *Development,* Los Alamos Scientific Laboratory, Los Alamos, N. Mex., January 1979.

11 Ibid.

generally exist in the Upper Colorado River Basin that could be made available to support OTA's low and high estimates of oil shale development through at least 1990. * However, the institutional, political, and legal uncertainties **in the basin make it difficult to determine which sources would be used, the actual amount of water that would in fact be made available from** any source to support synfuels development, and thus the water resource impacts of using any source for synfuels on other water users. Until major components of these uncertainties are analyzed quantitatively and start to become resolved, the extent to which synfuels production can be expanded beyond a level of several hundred thousand barrels/day (i. e., about 125,000 AFY) cannot be estimated with confidence.[12]

One potential source of water supply for synfuels is storage from Federal reservoirs. For example, approximately 100,000 AFY could be made available for synfuels from two Federal reservoirs on the western slope of Colorado (Ruedi and Green Mountain). However, the amount of water available is uncertain because of questions regarding firm yields, contract terms for water sales, which purposes are to be served by the reservoirs, competing demands, the marketing agent, and operating policy.

Under State water laws, water rights throughout the basin—in Colorado, Utah, and Wyoming—can generally be transferred (e. g., from agriculture) via the marketplace (i. e., sold) to synfuels developers who can afford to pay a relatively high price for water.[13] The degree to which developers rely on such transfers will determine the subsequent economic and social impacts on the users being displaced and, in turn, on the region. * The transfer process, however, is time-consuming and legally cumbersome, is constrained under State water law by the nature of the original right, and is subject to political and legal challenge.

Some provisions of the laws and compacts governing water availability to the States within the basin will not be tested and interpreted until water rights in the basin are fully developed. For example, procedures and priorities have not yet been developed for limiting diversions among the Upper Basin States when downstream commitments to the Lower Basin, under the Colorado River Basin Compact, cannot otherwise be met. There is also controversy about whether the Upper Basin States as a whole will be responsible for providing any of the 1.5 million AFY commitment to Mexico under the Mexican Water Treaty of 1944-45. Individual States within the basin, such as Colorado, have generally not yet developed procedures and priorities for internally administering their downstream delivery commitments for when the basin becomes fully developed; thus, the impacts of a State's allocation of available water to individual subbasins and users within that State, such as synfuels, cannot yet be determined. State water law also generally evolves through individual court cases, so that the cumulative effects of development are not known.

There are generally no institutional or financial mechanisms for obtaining water **for synfuels, either through conservation or through increased efficiency in water use in other sectors, as in other parts of the country.** In Colorado, for example, changes in agricultural practices to increase water efficiency are likely to be challenged legally, since downstream water rights appropriators are entitled to return flows resulting from existing albeit inefficient practices. It has been reported that basin exports for municipal uses could be reduced by as much as 200,000 to 300,000 AFY with improved water use efficiency .14

Other uncertainties that affect water availability for synfuels in the area include: Federal reserved water rights (e. g., for the Naval Oil Shale Reserve

*The low estimate for shale oil production in 1990 (see ch. 6) implies a range of annual water use of 20,000 to 48,000 acre-feet; the high estimate implies a range of 40,000 to 96,000 acre-feet. By 2000, annual water requirements would be, respectively, 50,000 to 120,000 acre-feet, and 90,000 to 216,000 acre-feet.

[12] Wright Water Engineers, Inc., op. cit.

[13] Gould, op. cit.

"irrigation requirements are determined by many factors, including climate, crop, irrigation methods, etc. Assuming that agriculture consumes 1.5 to 2.5 acre-feet/acre in the Rocky Mountain area, an average oil shale plant consuming 8,500 AFY would need to acquire water rights applicable to about 3,4oo to 5,7oo irrigated areas.

[14] Office of the Executive Director, 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, October 1979.

at Anvil Points, Colo.) have not yet been quantified; storage would have to be provided in the White River Basin (where the Uinta and Piceance Creek oil shale reserves are located) but prime reservoir sites are located in designated wilderness areas; there is as yet no compact between Colorado and Utah apportioning the flows of the White River; and in Colorado, in order to develop much of the deep ground water in the Piceance Basin, oil shale developers must prove that the ground water is nontributary, for which data are often lacking and difficult to obtain. The resolution of the uncertainties in the Upper Colorado could limit large-scale synfuels growth as illustrated in table 82, but "even at these highly aggregated levels for the entire Upper Colorado River Basin, the confidence limits or ranges that are placed on estimates of water availability are so broad that they tend to (overshadow) the amount of water needed for synfuels development."[15]

[15] Wright Water Engineers, Inc., op. cit., p. IV-38.

Table 82.—Preliminary Quantification of Uncertainties With Respect to Water Availability in the Upper Colorado River Basin

Annual amount available for consumption (millions of acre-feet)[a]		
	12.5 -15.2	Estimates of mean annual flow of the Colorado River at Lees Ferry
Subtract	7.5	Required delivery to the Lower Basin
	5.0 -7.7	
Subtract	0.75	Estimate of the Upper Basin's Mexican Treaty obligation
	4,25-6.95	
Subtract	.65	Estimated annual reservoir evaporation from Flaming Gorge, Lake Powell, and the Curecanti Unit Reservoirs
Total	3.60-6.30	
Annual projected consumptive demands (millions of acre-feet) In 2000[b]		
Total	4.10-4.78	(excluding synfuels)
Total	4.15-4.90	(including OTA low estimates for oil shale[c])
Total	4.19-5.00	(including OTA high estimates for oil shale[c])

[a] Does not make allowances for the quantification of Federal reserved water rights claims (the Naval Oil Shale Reserve at Anvil Points has claimed, for example, 200,000 AFY), the effect of potential environmental constraints (e.g., salinity control, protection of endangered species), or the availability of Federal storage.
[b] Estimates are for 2000 and exclude synfuels development (Colorado Department of Natural Resources, Section 13(a) Assessment of the Upper Colorado River Basin; 1975 estimate = 3.12 maf). Instream uses are not included.
[c] The low estimate for shale oil production in 1990 (see ch. 6) implies a range of annual water use of 20,000 to 48,000 acre-feet; the high estimate implies a range of 40,000 to 96,000 acre-feet. By 2000, annual water requirements would be, respectively, 50,000 to 120,000 acre-feet, and 90,000 to 216,000 acre-feet.

SOURCE: OTA based on Wright Water Engineers, Inc.