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Draft Final Report

Environmentally Based Siting Assessment for Synthetic Liquid Fuels Facilities

December 1979

Published January 1980

Prepared for:

U.S. Department of Energy

Assistant Secretary for Environment

Office of Technology Impacts

Division of Policy Analysis

Under Contract No. 03-79EV10287.000

MASTER

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TABLE OF CONTENTS

I	Introduction	I-1
II	Analytical Framework	II-1
III	Siting Characterization of Representative Synfuel Facilities	III-1
IV	Air Quality	IV-1
V	Water Availability	V-1
VI	Federal Land Management	VI-1
VII	Socioeconomic Capacity	VII-1
VIII	Ecological Sensitivity	VIII-1
IX	Environmental Health	IX-1
X	Summary and Conclusions	X-1

APPENDICES

A	Coal Availability	A-1
B	Hypothetical Environmental Regulations for Synthetic Liquid Fuels Facilities	B-1
C	Siting Characteristics of a Representative Fischer-Tropsch Baseline Plant	C-1
D	Siting Characteristics of a Representative Methanol-to- Gasoline Baseline Plant	D-1
E	Siting Characteristics of a Representative Direct Liquefaction Baseline Plant	E-1
F	Siting Characterization of Representative Direct Liquefaction Alternative Plants	F-1
G	Siting Characterization of a Representative Union Surface Retorting Baseline Plant	G-1

TABLE OF CONTENTS (Continued)

H	Siting Characterization of a Representative Paraho Surface Retoriting Baseline Plant	H-1
I	Siting Characterization of a Representative Occidental Modified In-Situ Surface Retoriting Baseline Plant	I-1
J	Summary of Changed in the Proposed PSD Revisions that Are of Potential Significance to Synthetic Fuel Development	J-1
K	Pollutant Emissions and Stock Parameters for Selected Synfuel Conversion Facilities	K-1
L	Analysis of Surface Water Flow by River Basin and Maps of River Basins Studied	L-1
M	Socioeconomic Impact Mitigation Issues Appropriate to the Siting of Synthetic Fuel Plants	M-1
N	Attitudes Toward Energy Development as Indicators of Community Receptivity to Synfuels Siting	N-1
O	Status of Disturbed Land Rehabilitation	O-1

I INTRODUCTION

A. Background

In the summer of 1979, and during the following months, as the nation once again became aware of its tenuous ties to foreign oil supplies, a number of initiatives were put forward by both the President and Congress to encourage the development of a synthetic fuels industry. These initiatives, ranging from tax credits and other financial incentives to the establishment of a federal Energy Security Corporation, envisioned a very rapid growth of synthetic fuels production capacity through the 1980's. The President's earlier program, for example, was geared toward a production goal of 2.5 million oil-equivalent barrels per day (oeb/d) by 1990, of which 1.0 million b/d would be coal liquids and 400,000 b/d would be shale oil.

The achievement of such high levels of production over such a short time would clearly involve numerous technical, institutional, and environmental difficulties in addition to the financial problems which were principally the focus of the presidential and congressional proposals. To address some of the institutional difficulties, an Energy Mobilization Board was proposed which would have the authority to expedite federal and state permitting procedures which were seen as impediments to rapid deployment of synthetic fuel facilities. These measures have naturally proved to be highly controversial, and many environmental groups have objected to the possibility of environmental laws being overridden by the EMB.

To address the concerns of Congress and others, the Office of Environment in the Department of Energy began to examine the extent to which environmental laws and policies could limit the development of a synthetic fuels industry. The results of that study, published in July

1979, indicated that deployment of synthetic liquid fuels facilities (based on first generation technology) on an accelerated schedule to 1990 would be feasible in terms of current environmental constraints, assuming application of the most effective environmental control technologies and practices. However, some regulations as yet not well-defined (e.g., hazardous waste, visibility) and the implementation of advanced technologies whose environmental impacts could be somewhat greater, could substantially alter those conclusions.

To complement and extend the initial DOE analysis, a more comprehensive study was undertaken by SRI International. This study was conceived as an update and refinement of an earlier SRI study "Synthetic Liquid Fuels Development: Assessment of Critical Factors" (ERDA 76/129-1, 2, 3, 4). That study, completed in 1976, was one of the first major assessments of the environmental, social and economic impacts associated with the development of a large-scale synthetic fuels industry. The factors assessed to be most critical to the development of such an industry were as follows:

- o Capital availability
- o Industrial marketing decisions
- o Resource depletion
- o Air pollution control
- o Water availability
- o Surface mine reclamation
- o Socioeconomic disruption

Since that study was completed, new developments have taken place at the regulatory and policy levels, in the energy marketplace, and in technology research and development, including environmental research. These developments must be incorporated into any current assessment of synfuels development. Because the financial and marketplace aspects of synfuels are by and large being addressed by governmental initiatives, it is primarily the regulatory, technological and environmental aspects of synfuels that are of interest here.

The focus of this work is on the environmental (including the social environment) and regulatory factors that would limit the potential for synfuels development on a regional basis. Its purpose is not so much to enumerate the many factors that would prevent the siting of synfuel facilities but rather to determine whether, when all these factors are taken into account, sufficient siting opportunities remain to develop a large-scale synfuels industry over the next ten to fifteen years.

In general, it is not possible in an assessment of this type to address in detail all the site-specific factors that would determine the acceptability of constructing and operating a synfuel plant in a particular location. However, it can serve as a site screening mechanism to locate areas that have the highest potential for containing favorable sites.

B. Objectives

The principal objectives of this work are to carry out a detailed assessment of the major environmental constraints to siting a synthetic fuels industry, and, using the results of that assessment, to determine on a regional basis the potential for development of such an industry with minimal environmental conflicts. A secondary objective is to assess the ability to mitigate some of the constraining impacts through alternative institutional arrangements, especially in areas that are judged to have a low development potential.

Much of the analysis of impacts that may constrain synthetic fuels development has been carried out previously and is reported in the ERDA volumes referenced earlier in this chapter. Therefore, the focus of this work is on updating the analysis contained in those volumes in the cases in which better information is available, additional regulatory actions have taken place, or external events have affected the overall context in which synthetic fuels development must be considered.

C. Limitations

There are several limitations on the study that must be taken into account when examining its results. First, the study has been limited geographically to well-defined boundaries that include the prime coal and oil shale resource areas. Other potential sites outside these boundaries were not considered. Second, the geographic level of the analysis was such that many site-specific factors could not be addressed. These factors could make synfuel plant siting more or less difficult than we have concluded for many areas. Third, not all conceivable environmental factors were considered. For example, neither the requirements of the Toxic Substances Control Act (TSCA) nor the Resource Conservation and Recovery Act (RCRA) were taken into account. This was because TSCA requirements were considered to have little relation to plant siting, and RCRA requirements were considered analyzable at only a more site-specific level of detail than we were able to undertake. Finally, much of the technology-based data used in the analysis is derived from early conceptual designs, rather than actual operating experience. Thus, the analysis is limited by both gaps in the data (e.g., emissions of toxic substances) and uncertainties in its accuracy.

Given the limitation outlined above, we have been conservative in drawing our conclusions, and have attempted to make no greater claims for our results than is warranted, given such limitations.

II ANALYTICAL FRAMEWORK

A. Overview

We constructed an analytical framework to use data associated with multiple impact criteria to reach conclusions about the relative ease of siting synfuel development in various areas. The framework itself does not constitute an impact analysis. Rather, it relies on the results of previous impact analyses (e.g., Dickson et al., 1976) for the background information and guidance required to assess constraints on synfuels. Thus, the impacts associated with the deployment of synfuel technologies serve as inputs to the analytic framework, rather than as results to be derived from its application.

The framework was not designed to provide absolute decisions about whether or not a synfuel plant could be sited in a particular location. Instead, it provides a stratification or ranking of areas in regard to their overall environmental suitability for siting. Therefore, an area that received an overall "low" ranking may, in fact, contain some suitable sites, and an area that received an overall "high" rating may contain a number of unsuitable sites. However, it can be concluded that the probability of finding suitable sites is significantly higher in a "high" ranking area than in a "low" ranking area, or alternatively, that it requires more effort in mitigating impacts in the "low" ranking areas.

The critical factors used in developing the framework were those derived in our previous work; they are discussed in Chapter I. The important components of each factor are discussed briefly below.

- o Air Quality--Of primary concern are Prevention of Significant Deterioration (PSD) areas, as defined in the Clean Air Act Amendments of 1977, and nonattainment areas.

- o Water Availability--Both physical factors (stream flows) and institutional factors (e.g., state allocation policies and Indian water rights) can affect the availability of water for synfuel production. In addition, the quantity and quality of waters that are to receive plant discharges are other important components of water availability.
- o Socioeconomic Capacity--The major concern is whether communities are able to successfully absorb the rapid population growth associated with constructing and operating synfuel facilities. Their ability to do so is reflected in such factors as their population size, infrastructure level, and growth history.
- o Ecological Sensitivity--Both the potential for reclamation of mined lands and the susceptibility of natural ecosystems to disturbance associated with large-scale industrial activity are important considerations.
- o Environmental Health--The potential for impairing human health in the work force and the population surrounding a synfuel plant is of concern. The risk factors are still largely undefined because knowledge is lacking about the kinds and quantities of toxic materials to be released from actual synfuel plants.

One additional factor, not addressed in our earlier work, was considered in this study--the management of federally owned lands. This factor is principally of importance in the West where the federal government is a major land holder. Traditional management practices on federal lands, as well as policies instituted under the Federal Land Policy and Management Act of 1976, may be in conflict with increased exploration and development of coal resources, as well as with the siting of synfuel facilities.

It is evident that the critical factors discussed above are associated both with institutional and with biological or physical environmental considerations, although all are concerned with environmental protection in general. The federal lands management issue, for example, derives almost entirely from legislative mandates for managing natural resources. On the other hand, the issue of ecological sensitivity, although it addresses some of the same resource

management questions, does so from the standpoint of minimizing ecosystem disruption. Other factors, such as water availability, have both institutional and physical components.

The degree of constraint imposed on synfuel development will differ among the six critical factors according to the level of legal or institutional sanctions associated with them. These differences must be kept in mind when carrying out the analysis and interpreting the results. However, these considerations should not be seen as diminishing the importance of those factors that do not have strong institutional sanctions. Many of those factors are gradually being addressed by legislation at the state and federal levels (e.g., siting laws in Wyoming and North Dakota that require plans for the mitigation of socioeconomic impacts), and nearly all of them are addressed in the EIS process mandated by the National Environmental Policy Act (NEPA).

B. Assumptions

Crucial to an understanding of the analytical framework and the results derived from it is a clear statement of the assumptions involved in its formulation and use. These assumptions are of two types: (1) those that bound the study by limiting the types of factors to be taken into account and (2) those that limit the range of physical parameters to be used in the analysis.

The first category includes three assumptions: (1) We did not consider factors that play a major role in siting decisions but that do not affect the environmental aspects of the problem. These factors included resource availability, transportation of resources and products, availability of markets, choice of conversion technology, and so on. (2) We assumed that, in the foreseeable future, environmental laws and regulations will not be relaxed. (3) Finally, we assumed that synthetic liquid fuels are the principal product of interest, and thus did not consider technologies that primarily produce gaseous fuels.

The second type of assumption relates mainly to conversion plant location and size. To limit the scope of the analysis to a manageable level, we assumed that coal would not be transported long distances from the mine site. In the West, the maximum distance allowed was 100 miles. This choice is arbitrary, except that it does represent a distance beyond which transportation costs become a significant fraction of the cost of the coal. Moreover, two examples of wholly-dedicated, specially built transportation facilities to move coal are in this general range; these two are the Black Mesa and the Lake Powell electric railroad (78 miles) and the Black Mesa to Mojave Power Plant slurry pipeline (273 miles).

In the East, because the resource is less concentrated than in the West, we recognized that for any plant location coal would have to be brought from several mines. Therefore, we assumed that coal would be converted within the region where it was mined.

The coal conversion plant sizes were chosen on the basis of current conceptual designs for commercial facilities. These sizes fall in the range of 40,000 to 60,000 b/d, oil equivalent. Although larger or smaller sizes are possible, it is generally considered that plants as small as 20,000 b/d are more appropriate as demonstration facilities and are uneconomical for commercial operation. Plants on the order of 100,000 b/d, although technically and economically achievable, tend to require a commitment of capital beyond that which most companies would be willing to devote to a single project.

Oil shale plant sizes were based on announced plans by companies for commercial projects.

C. Selection of Study Areas

We chose study areas by looking for a sufficient concentration of resource to support at least one plant over its lifetime. Figure II-1

FIGURE II-1. TOTAL U.S. COAL RESOURCES

illustrates the location of coal deposits throughout the country; it uses total coal resources per county as a measure of resource concentration. However, this map in itself is not sufficient for defining study areas, because not all the coal mapped is accessible (e.g., it may be in very deep or very thin seams) or extractable at an acceptable cost.

To help define the areas that contain sufficient, accessible coal to support synfuels development, we used the SRI Coal Resources Model (Dickson et al., 1977; Yabroff and Dickson, 1979). This model uses the USGS/USBM data base on coal resource characteristics, quantities, and locations (by county), and employs a sophisticated extraction cost model to compute extraction cost curves for more than 10,000 coal seams in the coterminous United States. The results of these calculations are displayed at a county level by means of extraction cost curves that display the quantity of resources available as a function of marginal extraction cost (see Figures II-2 and II-3 for examples). This procedure does not make the usual distinction between resources and reserves (reserves are usually defined as resources that are extractable at current prices using current technology); rather, it treats all resources as extractable in principle, with extraction cost varying with the resource characteristics (e.g., seam thickness and depth).

Using this model, the quantity of resource available at or below a certain extraction cost can be determined, and this was the procedure used to define the study areas. The minimum quantity of resource required is that needed to support a single plant over a 30-year lifetime. That quantity is approximately 250 million tons for the plant sizes considered in this study (see Chapter III). Because other demands will be made on the coal besides synfuel production, we required that twice that amount, or 500 million tons, be in place. We based the extraction cost cutoff on current contract prices for coal expressed in dollars per million Btu. For Western, surface-mined coal, the average price is about \$0.50/10⁶ Btu; Western underground coal is about \$1.00/10⁶ Btu. Thus, our requirement for coal concentration in the

FIGURE II-2. SURFACE COAL EXTRACTION COST CURVE-RICHLAND COUNTY, MONTANA

FIGURE II-3. UNDERGROUND COAL EXTRACTION COST CURVE—MARTIN COUNTY, KENTUCKY

West was that a county must contain at least 500 million tons of surface coal extractable at a cost of $\$0.50/10^6$ Btu or less, or 500 million tons of underground coal extractable at $\$1.00/10^6$ Btu or less,^a or some combination of the two, as long as the total added to 500 million tons.

Counties with coal resources meeting the criteria described above were termed "coal resource counties." These counties, plus those falling within the 100-mile radius discussed earlier, constituted our study areas in the western United States. These study areas are shown in Figures II-4 and II-5. The dark lines indicate the boundaries of the study regions, and the lighter lines indicate the coal resource counties. The shaded areas show the extent of coal deposits estimated by USGS. As expected, the USGS areas and the coal resource counties overlap considerably.

The three counties that contain the bulk of oil shale resources are indicated by dashed lines in Figure II-5.

Selecting study areas in the East proved to be a somewhat different process from that used in the West. The coal resource tends to be less concentrated in the East because seams are thinner there; furthermore, the counties, which are the geographical unit for reporting resource concentrations, are generally much smaller than Western counties. Therefore, we did not require the same degree of resource concentration in Eastern counties. The requirements in the East (which include midwestern coal states in our terminology) were (1) that a county contain 100 million tons (surface, underground, or a combination) of coal extractable at $\$1.00/10^6$ Btu or less, and (2) that it be adjacent to other counties meeting the first requirement. The second requirement is indicative of the fact that multiple mine sites will be required to

^aBecause the recovery factor for underground coal averages only 50-60%, we required that 1 billion tons of underground coal actually be in place at an extraction cost of $\$1.00/10^6$ Btu or less.

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FIGURE II-4. NORTHERN GREAT PLAINS STUDY AREA

support synfuel plants in the East; at the same time, however, it restricts the study area to counties where coal transportation costs and logistical problems could be minimized.

Figures II-6 and II-7 show the study areas selected using the above criteria. Counties surrounded by coal resource counties are included in the study areas for the reasons discussed above. No states other than those shown in Figures II-4 through II-7 contained sufficient concentrations of coal reserves to meet our criteria for inclusion in the study areas. We acknowledge, however, that economic or other pressures may make synfuel siting attractive in regions we did not study.

We did not address resource availability in terms of the complex issues of federal leasing, private ownership, or prior commitments of the coal. Furthermore, because the data on resource ownership and commitments are not consistently available, comparable analyses of these factors in all the study areas were precluded. Some of the important issues associated with resource availability are discussed in Appendix A.

D. Analytical Approach

After we had specified the major assumptions and the boundaries of the study areas, we next carried out region-specific and technology-specific analyses of the six constraining factors. The most recent and best available data on coal and oil shale conversion plant design were used to specify resource and labor requirements and pollutant emissions (see Chapter III and its associated appendices). These data were then used as inputs to the analyses of constraining factors, when appropriate.

It is important to note that the technology data played differing roles in the analyses of constraining factors. For example, in the analysis of air quality, the emission of criteria pollutants by synfuel plants is a crucial input in determining the changes in ambient air

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FIGURE II-5. FOUR CORNERS/ROCKY MOUNTAIN STUDY AREA

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FIGURE II-6. ILLINOIS BASIN STUDY AREA

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FIGURE II-7. APPALACHIAN STUDY AREA

quality near a plant, and thus in determining the relative difficulty of siting plants in different regions. On the other hand, the analysis of ecological sensitivity was based on the potential response of existing ecosystems to the general type of industrial development represented by synfuels, rather than on specific technology-based factors.

The other type of data required was that on current or projected environmental conditions within the study areas. These data consisted of information on parameters such as population, stream flow, air quality, and wildlife habitat. The data were obtained at the most disaggregated possible level consistent with a reasonable amount of data manipulation. Although many types of data were reported at the county level, it was also possible to obtain data on several factors at other levels of geographic aggregation. Water data, for example, were obtained for individual drainage basins.

Using the appropriate technology-specific and region-specific data, we analyzed the six constraining factors concurrently. Our analyses were directed toward elucidating those parameters that would tend to make the siting of synfuel facilities in a certain area more or less difficult than in other areas. Siting difficulty could result either from constraints imposed by the regulatory process or from the effort required to mitigate the impacts of development.

Once the relative degree of siting difficulty (or conversely, the relative ease of siting) had been determined for subareas within the four study areas and for all six constraining factors, the results were combined in a composite picture showing relative ease of siting based on environmental considerations.

E. Formulation of Results

Some of the major difficulties encountered in assessing the relative ease of siting, based on multiple constraining factors, are:

- o Varying geographic scale associated with each factor
- o Differing measures of impact associated with each factor
- o Differing degrees of legislative and regulatory support for determining acceptable impact levels.

To address the first problem area, we used maps to display the results of all the analyses. These maps allow the information to be displayed at a geographical scale that is appropriate for each constraining factor. Tabular display, on the other hand, would force the reduction of information to a common geographical unit (such as counties) that might be inappropriate for some factors. Finally, maps provide a strong visual guide to how a constraint varies within and among the study areas.

The second problem area was addressed by using a semiquantitative rating scale to represent the degree of siting difficulty associated with each factor. We chose a scale with five rating categories to represent the relative ease of siting: low, medium low, medium, medium high, and high. These categories indicate the potential for successfully siting synfuel plants in an area. However, the rating categories for one constraining factor are not strictly comparable with another factor: For example, a "low" rating for water availability does not necessarily imply the same degree of constraint as a "low" rating for ecological sensitivity.

The comparability of ratings of one factor with another leads logically to the third problem area mentioned above. That is, the differing legal and regulatory treatment accorded each of the six constraining factors, and the resulting differences in the levels of constraint represented by the factors. This problem becomes most apparent when trying to combine the ratings for all six factors into an overall rating for relative ease of siting for each area. It is customary in such analyses to weight the ratings according to the relative importance of each factor before combining them. However, that procedure is possible only if the ratings have a numerical value, which they do not in this case.

Another approach is weighting all factors equally by using a rough quantitative averaging procedure to combine them (i.e., a "high" rating for one factor, combined with a "low" rating for another factor, results in an overall "medium" rating). However, this method tends to conceal important information and fails to indicate that a "low" rating for one factor implies major constraints on siting that cannot be compensated for by higher ratings for other factors.

To overcome these difficulties in preparing composite ratings for the relative ease of plant siting, we took two steps. First, we prepared two composite maps. The first map depicts those three factors that would most constrain synfuel plant siting in terms of regulatory limitations or a combination of institutional and physical resource limitations. These factors include air quality, water availability, and federal land management. The second map depicts the three factors that are not affected by the institutional complexity of the first three factors and that therefore are conceivably less constraining for plant siting; however, these factors--socioeconomic capacity, ecological sensitivity, and environmental health--must still be viewed as major components of overall social and environmental impact. Finally, we prepared composite maps to show the combined effect of all six factors.

To address the relative weighting problem, we formulated a combining rule for use in the preparation of composite ratings. This rule reflects our concern that a composite rating that simply averages individual ratings does not reflect the true siting difficulties that would be encountered in an area with one or more "low" ratings. Thus, the combining rule for assigning composite ratings was as follows:

- o If an area has been rated "low" for two or more factors, it receives a composite "low" rating.
- o If an area has been rated "low" for any one factor, it receives a composite "medium low" rating.

- o Areas receiving no "low" ratings are assigned "medium low," "medium," or "medium high," based on rough averages of ratings for individual factors.
- o If an area has nearly all "high" ratings, and no ratings lower than "medium," it receives an overall "high" rating.

The methods of approach for addressing each critical factor, including the criteria used for assigning ratings, are found in Chapters IV through IX. The composite maps and the discussion of their significance for synfuel plant siting are presented in Chapter X.

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III SITING CHARACTERIZATION OF REPRESENTATIVE SYNFUEL FACILITIES

A. Purpose of the Siting Characterization

We have constructed representative synfuel plant types (or building blocks) that are representative of actual siting situations that will be encountered. These building blocks provide the basic data required to support regional analyses of air quality, water availability, and socioeconomic aspects of synfuel development.

Economics and technical risk consideration do not form parts of our characterization; we assume feedstock supplies and markets for products and byproducts to exist. We do not forecast "best" technologies and none is implied. Rather, the siting characterization affords a preliminary order-of-magnitude estimate so that the relative effort required to site a plant can be better understood. Eventually, we expect that when specific plants are constructed the technology chosen and the details of the process design will be greatly influenced by site-specific difficulties encountered. As a prelude to such site-by-site decisions, this preliminary analysis points up some of the problems and opportunities anticipated.

B. Selection of Representative Facilities

This study concerns two types of fossil fuel resources: coal and oil shale. Both near-term (1980s) and intermediate-term (1990s) technologies could be considered for the production of synfuels. Thus for coal, representative situations include both indirect and direct liquefaction; for oil shale, representative situations include surface retorting and modified in-situ retorting. The four basic situations

resulting for study are as shown in Table III-1. For each situation, one or more representative synfuel facilities must be analyzed for a siting characterization. A total of seven representative synfuels facilities were selected as shown in Table III-2.

1. Coal Based Facilities

For coal, no commercial size plants are currently scheduled for construction. In the absence of commercial plant designs, we have relied on detailed engineering studies. Two recent DOE-sponsored studies provide levels of detail well-suited for siting characterizations. "Research Guidance Studies to Assess Gasoline from Coal by Methanol-to-Gasoline and Sasol-Type Fischer-Tropsch Technologies" by Mobil Research and Development Corporation (1978) comprehensively describes indirect liquefaction technologies. "Exxon Donor Solvent Coal Liquefaction Commercial Plant Study Design" by the Exxon Research and Engineering Company (1978) describes direct liquefaction.

Other direct liquefaction technologies, such as Solvent Refined Coal (SRC) and H-Coal are quite similar to EDS insofar as siting characterization is concerned. Differences among these technologies are considered to be of less importance than the current uncertainties about plant siting assumptions and site-specific variations that will be encountered by the three technologies.

Therefore, to avoid misinterpretation of the relative merits of these three direct liquefaction processes that might be inferred from their relatively small siting differences, we selected the one with the most detailed and readily available engineering data--EDS--and used it to represent all direct liquefaction technologies.

We note that this selection does not constitute either prediction or endorsement of what types of plants should be built or where they should be built. Each type will probably be constructed in response to site-specific conditions to serve specific subsectors of demand for

Table III-1

REPRESENTATIVE SITUATIONS

1. Resource: coal
Technology: indirect liquefaction
2. Resource: coal
Technology: direct liquefaction
3. Resource: oil shale
Technology: surface retorting
4. Resource: oil shale
Technology: modified in-situ retorting

Table III-2

REPRESENTATIVE SYNFUEL FACILITIES

1. Coal indirect liquefaction
 - a. Fischer-Tropsch
 - b. Mobil Methanol-Co-Gasoline (M-Gasoline)
2. Coal direct liquefaction
 - a. Exxon Donor Solvent (Power Purchased Off-site)
 - b. Exxon Donor Solvent (Power Generated On-Site)
3. Oil shale surface retorting
 - a. Union
 - b. Paraho
 - c. TOSCO II
4. Oil shale modified in-situ retorting
 - a. Occidental

liquid fuels. Plant configuration will change as more operating experience is gained, as new components are developed, and as siting regulations mature.

2. Oil Shale Based Facilities

For oil shale, commercial size plants are already scheduled for construction, and thus plant designs offer more detailed, site-specific information than is the case for coal. For surface retorting, we selected the Union Oil and the Paraho projects as representative.^a We chose the Occidental project as representative of the modified in-situ processes. Like coal-based facilities, the shale-based facilities were chosen only to be representative of siting problems. Our selections are not meant to forecast what should be built or to endorse one technology or project instead of another. Indeed, other projects and advanced technologies are receiving attention and funding from government and industry.

C. Battery Limits Approach

To achieve comparable results, the plant battery limits (i.e., an imaginary line around the plant that separates all facilities and operations into either on-site or off-site categories) must be consistently established for the baseline plants representing the differing technologies. Thus, such operations as on-site power generation, cooling systems, raw materials storage, and solid waste disposal were investigated for each technology by reviewing the primary references. A plant description was prepared to identify the unit operations inside the plant boundaries. For coal-based plants, the

^aWe also characterized air pollutant emissions from the TOSCO II process. This characterization was based on our earlier work (Dickson et al., 1976) and updated emissions estimates from Colony Development operations.

mining and preparation operations were not included within the battery limits because we believed that for siting reasons some coal-based plants would not be at mine mouth. A simplified block diagram for the coal based plants is shown in Figure III-1. For oil shale-based plants, the mining and crushing operations were included within the battery limits because it is unlikely that raw shale will be transported. A simplified block diagram for oil-shale-based plants is shown in Figure III-2.

D. Baseline Plants - Methodology

Using the simplified block diagrams as a guide, we reviewed the primary references for information to define a set of baseline plants for use in assessing plant siting. We subdivided the baseline information into five categories:

- o Plant description
- o Resource use
- o Land and labor requirements
- o Product output
- o Residuals.

1. Plant Description

In describing the various types of plants, assumptions about plant capacities, on-stream time, cooling systems, thermal efficiencies, and the like, are noted and discussed. Plant size is described in terms of daily and annual product outputs. Assumptions about the baseline site location and characteristics are noted. The following information about plant descriptions was collected:

- o Prime input
- o Prime output
- o Days per year of normal operation
- o Overall thermal efficiency

FIGURE III-1. SIMPLIFIED BLOCK DIAGRAM FOR COAL SYNTHETIC LIQUIDS PLANT
PLANT BATTERY LIMITS ANALYSIS

FIGURE III-2. SIMPLIFIED BLOCK DIAGRAM FOR OIL SHALE SYNTHETIC LIQUIDS PLANT BATTERY LIMITS ANALYSIS

- o Assumed site for baseline plant
- o List of process unit operations included within the battery limits
- o List of pollution control units and/or environmental design standards that apply to the plant waste streams
- o List of cooling system units and/or design philosophies that apply to the plant water requirements.

2. Resource Use

Next, in quantifying resource use we reviewed the following topics:

- (1) Coal Use. We identified relevant chemical and physical properties assumed for the coal feedstock received at the plant. We specified the annual and daily consumption for both conversion and on-site power generation, and described coal handling, storage, and preparation requirements where possible.
- (2) Water Use. We specified the annual and daily consumption for both conversion and cooling. We assumed water conservative plant designs if the baseline location was west of the one-hundredth meridian. We identified the quality of incoming water and whether treatment or storage before use was required.
- (3) Chemical/Catalyst Use. We specified the annual and daily consumption for both conversion and environmental cleanup. Assumptions about storage, handling, and recovery were noted.
- (4) Purchased Power. We specified the portion of electric power to be purchased and the portion generated on-site by using feedstock, products, or by-products.
- (5) Other. Other consumed materials relevant to the resource use analysis were also specified.

3. Land and Labor

In arriving at land and labor requirements we investigated the following topics:

- (1) Land Requirements. We specified the area needed for all facilities within the battery limits. We noted

requirements for facilities for feedstock storage, solid waste disposal, and water impoundment/treatment.

- (2) Labor Requirements. We prepared curves showing the construction labor as a function of time and operating labor as a function of time.

4. Product Output

Next, we quantified the product output under:

- (1) Primary Products. We specified the volumes, Btu content, and composition of those output components marketable as fuels.
- (2) Salable By-products. We specified the volumes and compositions of nonfuel by-products for which markets are assumed to exist.

5. Residuals

Finally, we quantified residuals. The following residuals were considered:

- (1) Air Emissions

SO_x, NO_x, Particulates, Hydrocarbons, CO, and others (e.g., trace elements, organic substances, H₂S, CS₂).

- (2) Water Pollutants

Total waste water volume (if any) and composition, to the extent known were specified.

- (3) Solid Waste

Ash, char, biological treatment solids, spent catalysts, spent shale, others (e.g., nonmarketable by-products). On-site disposal was differentiated from off-site disposal.

When possible, we identified the various pollutant streams with specific sources within the plant to allow a detailed analysis of point sources and emission patterns.

E. Control Technology versus Regulatory Standards

A circular argument often ensues with regard to available technologies versus proposed regulatory standards. Developers of technologies sometimes take the position that any standard can be met, given enough money; regulatory analysts sometimes take the position that the standards should be based on the best control possible. To avoid such circular arguments, two steps were taken. First, we used the control technology described in the primary references wherever possible. Second, the Energy and Environmental Systems Division of Argonne National Laboratory undertook a separate study of emissions regulations based on existing similar facilities. The results of the Argonne study are discussed in Appendix B.

F. Siting Characterization of Seven Representative Plants

Using the baseline plant methodology and the results of the Argonne regulatory study, we made siting characterizations for seven representative synfuel plants. The result of these siting characterizations are contained in the following:

Appendix C:	Siting characterization of a Representative Fischer-Tropsch Baseline Plant.
Appendix D:	Siting Characterization of a Representative Methanol to Gasoline Baseline Plant
Appendix E:	Siting Characterization of a Representative Direct Liquefaction Baseline Plant
Appendix F:	Siting Characterization of Representative Direct Liquefaction Alternative Plants

Appendix G:	Siting Characterization of a Representative Union Retort Baseline Plant
Appendix H:	Siting Characterization of a Representative Paraho Retort Baseline Plant
Appendix I:	Siting Characterization of a Representative Modified In-Situ Baseline Plant

The information contained in the siting characterizations is arranged into the following categories:

Plant Description

General Plant Data
List of Process Unit Operations
List of Pollution Control Units
Water System Design

Resource Use

Feedstock
Water
Chemicals and Catalysts
Energy

Land and Labor Requirements

Land
Construction Labor
Operating Labor

Product Output

Primary Products (Fuel)
Salable By-products (Nonfuel)
Alternative Product Slates

Residuals

Air Emissions
Aqueous Effluents
Solid Residuals

References

G. Limitations of the Siting Characterizations

Two main limitations should be kept in mind regarding the siting characterizations. First, they are based on early conceptual designs for plants which have yet to be built and for which a great number of changes will eventually be needed to meet specific site conditions.^a Thus, while the siting characterizations are representative, they should not be considered definitive (i.e., there is still an uncertainty range around each of the numbers used for the characterizations). Second, the characterizations are focused specifically on environmental issues and thus do not address the many other siting issues such as production economics, technical readiness, product markets, regional incentives, costs of environmental controls, and national energy policy goals, all of which will also enter into the plant site selection and technology selection process.

In addition to these two main limitations, which we mention as a cautionary note to potential users of the characterization data, a number of lesser problems arise in each of the five categories analyzed:

- o Plant description
- o Resource use
- o Land and labor requirements
- o Product output
- o Residuals

1. Plant Description Limitations

The plant size is often quoted in terms of barrels per day oil equivalent (oeb/d). While this helps in comparing total energy production capacity, it also is misleading in that "oil equivalent" can include a full range of products from premium motor fuels to heavy oils, tars, and gaseous products. Frequently, the design days per year of

^aThis strictly applies only to coal liquefaction plants. Oil shale plants are better defined and the site conditions are well known.

operation are also different, with the result that two plants of the same nominal size (in terms of barrels per day oil equivalent) will have much different annual production capacities in terms of barrels per year of liquid transportation fuels, for example. And optimum plant size for specific sites may be larger or smaller than the baseline studies.

Setting the battery limits is difficult to do in a consistent way. For example, on-site power generation, feedstock storage and preparation, product storage and upgrading, cooling system design, and inclusion or exclusion of the mine are all considered somewhat differently in the baseline engineering studies used as primary references.

2. Resource Characterization Limitations

Neither coal nor oil shale are of uniform composition, and from one sample to the next they vary considerably in chemical and physical characteristics. For example, the following six coals demonstrate the regional range of coal types and characteristics (typical analyses vary as much as $\pm 25\%$ within a single seam):

Eastern Province Bituminous

Pittsburgh No. 8 Seam
13,800 Btu/lb, 7% ash, 2.2% sulfur

Interior Province Bituminous

Illinois No. 6 Seam
11,000 Btu/lb, 10% ash, 3% sulfur

No. Great Plains Province Subbituminous

Rosebud Seam
8,750 Btu/lb, 8.5% ash, 0.75% sulfur

Rocky Mountain Province Subbituminous

Navajo Group
9,200 Btu/lb, 20.4% ash, 0.72% sulfur

No. Great Plains Province Lignite

Beulah-Zap Seam
7,800 Btu/lb, 8% ash, 0.55% sulfur

Gulf Province Lignite

7,800 Btu/lb, 9.5% ash, 0.9% sulfur

The type of water resource available may impact the plant design at a specific site (for example, water treatment facilities for brackish ground water). Site conditions such as temperature, humidity, and elevation also affect water system design and water resource consumption estimates.

3. Land and Labor Characterization Limitations

When actual plants are built and operated, labor productivity will vary for both construction and operation due to variables in site management, labor availability, nearby labor markets, etc. Thus, the total work force during construction and operation is difficult to estimate for a hypothetical plant.

In addition, many decisions will be made regarding off-site and on-site activities, and overall construction and starting schedules, which will impact the total on-site labor force required at any particular stage of plant construction and operation.

4. Product Output Characterization Limitations

In addition to the limitations of describing plant output in barrels per day oil equivalent as mentioned above, there are also limitations in interpreting the product slate shown for the baseline characterizations. At additional cost, most of the plant designs could be changed to produce more, higher-grade, transportation fuels. There is a trade-off between the types of fuels produced, the costs involved, and the markets for each. Nearly every synthetic liquid plant is a multi-product operation in which the product slate can be modified to

emphasize certain products over others if justified by overall plant economics. Simple comparisons of plant production based only on energy content and not accounting for product quality differences and end uses can be extremely misleading.

5. Residual Characterization Limitations

To the extent that all of the above limitations affect plant design, they also have an effect on the residuals that must be controlled in an environmentally sound manner. These plant design uncertainties, when combined with uncertainties regarding environmental standards and best available technology, result in considerable difficulty in estimating the volume and content of residual waste streams and the control technologies required. Because the plants have not yet been built, many of the raw waste stream characterizations are only inferred from small-scale tests or from similar processes in other industries. Little actual test data on raw residual streams is yet available, and regulations for some residual streams are just now being formulated.

For purposes of siting analysis, the baseline characterization of residuals must be further interpreted to add assumptions about point source locations, stack heights, flow rates, temperatures, etc., so that modeling of air quality conditions can be accomplished. It must be kept in mind that the results of such modeling are based on representative (but uncertain) characterizations and on reasonable assumptions; different results could be obtained using different criteria.

6. Use of the Characterization Data

With the limitations of the data in mind, we believe that the siting characterizations provide a basis for identifying the major regional siting problems that would be encountered in locating synfuels plants. The data should prove useful in identifying the additional

information needed regarding the plants and processes as well as focusing attention on subregional issues that must be resolved and on regulatory uncertainty that must be clarified.

IV AIR QUALITY

A. Introduction

Current air quality regulations suggest regions within the study areas where increasingly severe constraints will be imposed on the siting of synfuel plants. In some areas, air quality problems will necessitate further emissions reductions that will increase plant costs, or regulations may prohibit development because plant emissions exceed statutory limits. Today's regulations, however, can only provide a guide to future siting problems; in estimating future regulations and constraints we must rely on trends in implementing current laws and on developing regulatory approaches. Additional uncertainty is imposed by court-required changes that may apply to such specific regulations as those warranted by the Clean Air Act (CAA) and its amendments (CAAA). Because of these trends and potential regulatory changes, each possible site for synfuel development will have to be evaluated in relation to the regulations and air quality in effect when air quality permits are sought for a plant. Certainly, the emissions from synfuel plants will be controlled regardless of the site; however, the degree of emissions control and the emissions themselves will largely depend on the conversion technology, the resources used (e.g., the sulfur content of the coal), plant size, location, and the date when the plant is approved. We have attempted to include current conditions and trends in performing the air quality analysis.

We performed the air quality analysis in two steps. First, we modeled air pollutant concentrations that will result from selected synfuel operations only pollutants currently regulated were modeled. Although trace element emissions are of major environmental significance, they are not now regulated and therefore were not modeled in this analysis. We modeled the annual and worst case 24-hour average

particulate (TSP), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) concentrations, and the 3-hour worst case SO_2 concentrations under meteorological conditions that correspond approximately to those that might be encountered in the study areas. These calculations are not a substitute for site and plant-specific modeling; however, they are suitable for this analysis, given the uncertainties about the future. We also modeled peak 24-hour SO_2 concentrations under meteorological conditions that produce the highest downwind concentrations to determine how facilities might affect the air quality in a nearby Class I Prevention of Significant Deterioration (PSD) Region.

The second step of the analysis entailed examining current air quality regulations discussing with state and federal air quality officials trends in state and federal attitudes regarding possible regulations, and documenting current legal challenges to the regulations. In particular, the team examined current air quality, and the status of proposed and suggested Class I PSD regions. We also tried to define those parts of Appalachia where steep valley terrain would make siting difficult because pollutants would be trapped, resulting in high pollutant concentrations.

The air quality findings presented here differ from SRI's earlier work (Dickson et al., 1976) for two principal reasons:

- o Revised emissions estimates have changed the calculated ambient pollutant concentrations
- o Revisions to the CAA, State Implementation Plans (SIPs), and court challenges to various regulations have altered the earlier regulatory situation. In particular, the CAAA have resulted in new PSD increments for Class I and Class II areas.

In addition, the CAAA designated Class I, Class II, and discretionary Class I PSD areas, and outlined procedures for establishing new Class I areas. In response to the CAAA, states are now in the process of preparing SIPs designed to achieve air quality that meets the federal primary and secondary National Ambient Air Quality Standards (NAAQS).

The SIPs are particularly important for determining the regulations that must be met by synfuel plants. In areas that do not meet the NAAQS, regulations will generally mean that emissions must be further reduced by applying controls better than the Best Available Control Technology (BACT).

The results of this analysis may well not conform with the real future situation because of:

- o Better air quality in some regions of the country due to increased emission controls, or to worsened air quality caused by increased levels of pollutant emissions.
- o New or altered regulations resulting from successful court challenges to existing regulations or stemming from attempts to solve air quality problems.
- o Air quality regulations called for by the CAAA that EPA has not yet completed; for example the requirement that EPA set PSD increments for oxides of nitrogen (NO_x).

A recent example of periodic changes is the EPA proposed revision of the SIP regulations in September 1979. The proposed revision stems from several factors, including the court decision, Alabama Power versus Costle^a. Appendix J summarizes some of the key changes in the SIP regulations. Among the changes is a new definition of the date on which the baseline pollutant concentrations are decided for use in determining the available PSD increment remaining. Instead of August 7, 1977, the date to be used is the first day on which a complete application is filed for locating a "major stationary source" or a "major modification" of an existing facility.

^aFederal Register, Vol. 44, No. 173, September 5, 1979.

B. Modeling Methods Used to Estimate Air Quality Impacts

1. The Climatological Dispersion Model (CDM)

The basic model that we employed to calculate air pollutant concentrations is the CDM (Busse et al., 1973), a computerized model in EPA's UNAMAP library of air quality models. This model was developed to calculate average pollutant concentration patterns resulting from multiple sources. Multiple sources can include a mixture of point sources and area sources, but in this application only point sources associated with the various configurations of synfuel plans were considered. Although the model was originally developed for calculating long term (seasonal or annual) distributions of average concentrations, it also serves for calculating the shorter term averages discussed here. We also developed additional computer programs to display pollutant isopleths.

The CDM is a steady-state, Gaussian plume model that assumes that the spatial distribution of pollutant concentration at any given time is the steady-state concentration for the continuously emitting sources being considered. The Gaussian plume assumption is used for downwind distances to the point where the plume expansion encounters restrictions to vertical diffusion. When vertical diffusion is restricted, the model assumes a uniform vertical concentration distribution but retains a Gaussian horizontal cross section.

The model calculates pollutant concentration for all combinations of stability class, wind speed, and wind direction for each specified measurement (receptor) location. The averages for the period in question are then determined from a weighted average of the concentrations calculated for each of the combinations of stability and wind. The weighting is determined by the relative frequency of occurrence for each combination of weather factors. For long-term averages, the STAR program of the National Climatic Center in Asheville, North Carolina is used to determine the relative frequency of occurrence

of the various combinations of stability, wind speed, and direction from historical data collected at an appropriate location.

Concentrations were calculated for : SO_2 , NO_2 , and particulates. For purposes of calculating the concentrations, NO_2 and particulates are assumed to be inert; hence changes in concentration resulted only from transport and dilution. SO_2 is assumed to be transformed to sulfate by a first-order chemical process; the CDM provides for exponential decay of the pollutants. A 3-hour half life for SO_2 was used for these calculations.

The calculated long-term averages can be compared with the ambient air-quality standards for annual averages, but there are also shorter-term ambient air quality standards for SO_2 (24-hour and 3-hour) and for particulates (24-hour). To compare projected concentrations with these shorter term standards, it is necessary to determine the combination of meteorological conditions that will produce the highest short-term concentrations. The determination of these "worst case conditions" is discussed in a later section.

The version of the model used for these calculations has been modified slightly from that originally disseminated by the EPA (Busse et al., 1973). The original model treats only two pollutants at a time; the version used here allows the calculation of concentrations for three pollutants. The original computer code did not provide for treating diffusion under stable atmospheric conditions, because the primary applications were intended to be in urban areas where the urban heat island effect generally prevents the formation of low-level stable layers at night. However, in open areas where the synfuel plants are likely to be located this is an unsound assumption because stable atmospheric conditions frequently occur at night. The original user's manual discussed the appropriate parameters for use with stable conditions, and the STAR Program output includes frequencies of occurrence for such stable categories. As a result, this feature was readily incorporated into the model.

2. Data Sources

The CDM model requires two types of data. First, a complete description of the pollutant sources is required. Second, meteorological data are required. The model requirements and the sources of the data that have been used are discussed below.

Emissions Estimates for Synfuel Plants. In general, each plant type has several point sources. These sources may be arranged in an array covering the plant area. The model requires the following information for each of the point sources:

- o The coordinates of the source
- o The source emission rate for each of the three pollutants
- o The stack height of the source
- o The diameter of the stack
- o The exit speed of the gases leaving the stack
- o The temperature of the gases leaving the stack.

The last three items are required for calculating the height to which the plume will rise (using Briggs' formula, 1979). The emission rates for the three pollutants must be given for each stack because some stacks do not emit all of the pollutants, and because their relative emission rates vary from stack to stack. The coordinates that were used were given relative to the center of 400 km by 400 km square within which the concentrations were calculated.

Appendix K lists the emissions parameters for the selected technologies. Chapter III and Appendices C-I describe the data sources and general assumptions used in calculating the emission rates and stack parameters. When only emission rates were known, stack parameters were chosen by the same method as in SRI's earlier work (Dickson et al., 1976). Because all technologies have advanced emission controls applied to them (BACT), the plants represent well-controlled sources.

Meteorological Information. As noted before, the model requires the relative frequency of occurrence of the various combinations of atmospheric stability, wind speed, and wind direction in the period of interest. These data, which were used to calculate annual averages and worst cases are discussed below. In addition to detailed information, the CDM requires estimates of afternoon and nocturnal mixing heights. These values were obtained from the maps of annual average values prepared by Holzworth (1972). Mean atmospheric temperatures, which were required for estimating plume rise, were obtained from U.S. Naval Weather Service (1970) summaries of climatic data.

Three areas of the country were of interest: the western and eastern coal-producing regions, and the oil shale producing counties. We used meteorological conditions recorded at one reasonably typical station within each of these areas to characterize the long-term averages. Obviously, not all locations measure and report the appropriate weather parameters to the National Climatic Center in a form suitable for input to the STAR computer program. In addition, the exacting schedule of this project further limited the selection to those sites for which data were readily available. Fortunately, earlier studies (Dickson et al, 1976) had made use of data from two appropriate locations, Moorcroft, Wyoming, for the western coal-producing regions and Grand Junction, Colorado, for the oil shale counties. The output of the STAR program was also available for Pulaski, Virginia, in the eastern coal-producing region. Moorcroft, Wyoming, which is about 40 km east of Gillette, is in the coal basin that lies in the topographic depression between the Black Hills and the Big Horn Mountains. Because it is near possible plant sites, its meteorology should thus provide reasonably good approximation of the meteorology of the surrounding area.

The meteorological data required to apply CDM were unavailable from a site within the oil shale region. Data from Grand Junction, Colorado, have therefore been used because this is the weather station to the Piceance Basin for which we have data. Grand Junction is about

90 km southwest of Rio Blanco. The surface topography of the oil shale region has been eroded into valleys with ridges between, all oriented generally north-northeasterly to south-southwesterly. The steep-sided valleys would not be suitable for locating plants and one would expect that conditions on the ridges would be less affected by the channeling of air flow that takes place in the valleys. Therefore, the Grand Junction meteorological descriptions probably give a reasonably valid approximation for the surrounding area if attention is confined to the ridges and the broader valleys and plateaus.

We used the meteorology of Pulaski, Virginia, which lies about 75 km west-southwest of Roanoke, Virginia, to represent eastern coal regions. Because the region is characterized by valleys and ridges, it is unlikely that any one station can provide observations that satisfactorily represent the entire region. However, wind speeds and stabilities should be similar from valley to valley, although wind directions will be strongly influenced by the orientation of the local valley. Given that many of the ridges and valleys in the region are parallel and run generally from northeast to southwest, the wind direction channeling effects at similar locations in nearby valleys should be similar. In any event, the data from Pulaski should reasonably represent the general shape of the pattern and the magnitude of the greatest concentrations, although the orientation of the pattern will change from location to location in the region.

Worst Case Meteorology. Two approaches exist for determining the highest pollutant concentrations that the emissions from a given configuration of sources will produce in a selected averaging period. One can calculate the concentrations at a large number of receptors on an hour-by-hour basis for an extended period (e.g., 1 year) and then select that period during which the highest average concentrations were observed. A different approach can be used for a shorter averaging period (e.g., 24 hours or less); in this approach, the worst possible combination of wind speed, wind direction, and stabilities that could occur during an averaging period is determined. Constraints limit the

hours per day that any given stability class can occur. Other constraints prevent certain combinations of wind speed and stability from being observed. These constraints and how they are used to determine the worst possible conditions are discussed later in this chapter.

Determining worst-case conditions is fairly simple if all the pollutants are emitted at the same height, especially at ground level with little or no plume rise. However, in the cases considered here, in which the sources consist of several elevated stacks each of which has different characteristics, the determination of worst-case meteorology becomes quite complicated. For example, the sequence of meteorological conditions that produces the highest pollutant concentrations when the source is a tall stack with an appreciable plume rise will be quite different from the worst-case sequence for a shorter stack that releases pollutants at ambient temperatures so that little plume rise occurs. In addition, the worst-case conditions for plants that contain both types of stacks such as those considered here may be quite different from those for individual stacks.

Simmon (1976) developed a program for estimating worst-case meteorological sequences by considering:

- o Multiple sources
- o Elevated sources
- o Plume rises
- o Source emission rates
- o Distances from the source.

The program uses actual hourly meteorological data to calculate pollutant concentrations at as many as 320 locations for 1 year. If only one plant type and only one pollutant were considered and if the hourly sequence of meteorological observations were available, the use of this program to determine worst-case sequences would be feasible. However, with nine plant types, three pollutants, and three possible siting areas, coupled with inappropriate data summaries, such an was beyond the scope of this study.

However, Simmon used some approximations for determining worst-case conditions that have been exploited in this project: All the sources were assumed to be colocated. Then hourly concentrations were calculated to determine the worst sequence of meteorological conditions that has been observed.

Then, for the final calculations a more comprehensive model (e.g., CDM) is used to account for differences in location of the different sources.

In this project, we have used Simmon's simplified Gaussian formulation with co-located sources to determine the concentrations at 10 downwind distances ranging from 3 to 20 km for all combinations of atmospheric stability class and wind speed class as defined in the STAR program output. Six wind speeds and six stability classes were considered. The results of these calculations provided information about which combinations of wind speed and stability produce the highest concentrations at each of the downwind locations. Using this information, we then determined the highest concentrations that occur during the course of 3- or 24-hour averaging periods.

As noted before, not all stability classes can occur at any time of day, and certain restrictions apply to the joint occurrence of certain wind speed and stability classes. Table IV-1 shows the definitions of the stability categories based on Pasquill's work (1961). The work of Ludwig and Dabberdt (1976) was used as a basis for defining the solar radiation categories as a function of solar elevation and cloud cover. Once this has been done, it is possible to estimate the maximum number of hours per day that can fall into strong, moderate, or slight insolation categories. It is also possible to estimate the maximum number of nighttime hours for a given latitude. We did this for 40° latitude and used as a basis for determining the maximum number of hours per day that could fall into each of the combinations of wind speed and stability that CDM employs.

Table IV-1

STABILITY CLASS DEFINITIONS PROPOSED BY PASQUILL (1961)

Wind Speed (m/s)	Daytime Isolation			Overcast Day or Night	Thinly Overcast (4/8 Cloud Cover	Nighttime (3/8 Cloud Cover
	Strong A	Moderate A-B	Slight B			
2	A	A-B	B	D		
2-3	A-B	B	C	D	E	F
3-5	B	B-C	C	D	D	E
5-6	C	C-D	D	D	D	D
6	C	D	D	D	D	D

Key: A = extremely unstable
 B = moderately unstable
 C = slightly unstable

D = neutral
 E = slightly stable
 F = moderately stable

Table IV-2

MAXIMUM NUMBER OF HOURS PER DAY POSSIBLE FOR
DIFFERENT COMBINATIONS OF WIND SPEED AND
STABILITY (40° LATITUDE)

Wind Speed (kt)	Stability Class					
	A	B	C	D	E	F
0-3	11	15	0	24	0	15
4-6	9	11	15	24	15	15
7-10	0	9	15	24	15	0
11-16	0	0	11	24	0	0
17-21	0	0	0	24	0	0
21	0	0	0	24	0	0

Table IV-2 shows the maximum number of hours per day that can fall into each of the possible combinations of stability and wind speed. Note that units of wind speed are given in knots (the input required by CDM). A computer program was written that looks at the concentrations at each location that are associated with each combination of stability and wind speed as determined by Simmon's simplified model. Then, Table IV-2 is used to determine the maximum number of hours in the averaging period for the highest calculated concentrations (e.g., per 24 hours) that could be included in the average. The program continues examining the concentrations for each stability/wind speed combination to determine how many hours of the next highest concentration can be included, until all hours of the selected averaging period (e.g., 24 hours) have been accounted for.

As an example, if the highest concentrations at a given location were associated with some combination of class D stability and with any of the wind speed groups, the worst possible case would involve 24 continuous hours in that category. However, if the highest concentration were produced by 4- to 6-knot winds and class A stability, then a 24-hour average could include no more than 9 hours of that type; if the second highest concentration was associated with the same wind speed group but class B stability, then 2 more hours (making a total of 11) of that category would be incorporated, and so forth.

After the computer program has determined for each location the number of hours for each stability class wind speed group, and the average associated with the period, it ascertains which location has the highest worst-case average concentration. The combination of hours in each stability/wind speed category for that location is defined as the "worst case" for that averaging period and is used as input for CDM calculations.

The variability of wind direction is another factor that affects maximum concentrations. It is obvious that the highest concentrations will always be associated with cases where the same wind

direction prevails throughout the averaging period. Otherwise, the sites with the highest concentrations would have missed the plume for some of the averaging period and hence have an overall lower average for the period.

We relied on the output of the STAR program for selecting the wind direction to be used. The STAR output gives the frequency of occurrence of various combinations of stability and wind speed class for each wind direction. For the worst case, we used the wind direction most frequently observed with the most important combinations of wind speed and stability class.

After the hour in the different stability/wind categories that will produce the highest possible average concentrations has been defined, the number of hours is used as input to the CDM. By using the CDM for the final calculations, we obtain a much more detailed and refined description of the spatial distribution of the concentrations downwind of the site. Note, however, that the combination of conditions that produces the worst case for one of the three pollutants frequently differs from those for the other pollutants.

Note, also that the method described above defines the worst possible case. Hence, it provides a conservative estimate of the impact because it may well be that these worst conditions do not occur very frequently. For example, the worst cases for 24-hour averages cited by Dickson et al. (1976) were based on historical sequences of meteorological observations. In those historical sequences, the wind direction was the same for 22 of the 24 hours; this would reduce the average concentrations below what would have been observed had the wind remained constant for the full 24-hour period.

Finally, as noted before, we chose meteorological worst cases on the basis of concentrations calculated for sites from 3 to 20 km downwind. The site with the highest concentration was used as a basis for determining the meteorological conditions. Frequently, the highest

concentrations are found at sites close to the sources. The assumption that the sources are colocated is least accurate for these closer receptors. When CDM is used, the plumes may not be superimposed as was assumed in the screening process. Therefore, the worst cases must be considered to be only approximate; we can be reasonably confident however, that although they may not be absolutely the worst, they are certainly close to the worst possible.

In determining worst cases, the highest calculated concentrations, regardless of where they are observed, may also be used in determining the worst likely conditions at other, perhaps more distant locations. In some instances, the meteorological conditions producing the highest concentrations at more distant locations have been identified and used to estimate worst-case long-range impacts.

Worst Case Concentrations Far Downwind. The meteorological conditions that produce the highest concentrations within a few kilometers of a plant are not necessarily the same as those that cause the highest concentrations at greater distances. As discussed elsewhere, "worst-case" conditions are those that produce the highest average concentrations, regardless of location. It is important to estimate the greatest 24-hour impacts at distances of 20 km or greater.

Although the complete CDM model has not been run for the worst cases at the more remote distances, estimates of the effects have been obtained for most cases during the course of applying the worst-case screening model. The assumption that all sources are co-located should be more reasonable at these greater distances than at the closer locations, but the results from the worst-case screening model will tend to be overestimates of the concentrations because of the assumption that all sources are at the same point. The simple model will tend to overestimate effects at these greater distances because, although the effects of mixing height are ignored in the simpler model, they will usually be smaller effects than the effects of stack separation, which reduces the estimated concentration.

Another source of overestimation occurs when the simple screening model is applied to SO_2 ; the transformation of SO_2 to sulfate is not considered. This overestimation can be considerable at large distances. For instance, at 20 km the travel time might easily be 4 hours; for a 3-hour half-life this would result in overestimation by a factor of about 2.5. Therefore, in Table IV-3 we have expressed the concentrations in terms of SO_x as well as SO_2 . The latter are rough estimates based on the 3-hour half-life and the average wind speed.

Table IV-3

WORST-CAST CONCENTRATION ESTIMATES FROM A SIMPLIFIED SCREENING
MODEL FOR LOCATIONS 20-km DOWNWIND, 24-HOUR AVERAGE
(micrograms/ m^3)

Plant Type	SO_x	TSP	NO_x	Approximate SO_2 Concentration Adjusted for Transformation
Occidental MIS (100,000 b/d)	2	1	18	1
TOSCO II	13	46	53	6
EDS without Elect. plant	37	2	12	28
EDS with Elect. plant	42	2	18	35
Occidental MIS (60,000 b/d)	1	1	14	1
C-a Tract	4	7	33	3
Coal-Methanol Gasoline	4	0	7	3
Fischer- Tropsch	4	a	8	4

^aNot calculated

Table IV-3 summarizes the worst case concentration estimates at 20 km from the center of a plant. The concentrations at greater distances will be less. The graphs given by Turner (1970) indicate that the concentration will fall by a factor of about 1.5 to 3 for each doubling of distance from the plant. The lower factor applies when vertical mixing is restricted by an elevated inversion; the higher factor applies for the less stable cases without an upper bound to the plume expansion. Of course, the SO_2 concentrations will fall even more because of the increased conversion to sulfate at greater distances.

The results of the rough screening model shown in Table IV-3 were used to pick the technologies to run with the CDM model. Clearly, the EDS process has the greatest SO_2 concentrations. Also, the Fischer-Tropsch process has a greater effect than the Methanol-to-Gasoline process. Likewise, of the oil shale technologies, the TOSCO II process has the greatest impacts. EDS, Fischer-Tropsch and TOSCO II were therefore chosen for more detailed analysis using the CDM model.

Figure IV-1 shows estimated concentrations versus distance for several of the technologies. The curves in the figure represent a refinement of the rough concentration estimates provided by Table IV-3, described above. Because the CDM model takes into account more factors than the crude estimates, the curves presented on the figure are lower and more realistic. We have used the figure to estimate the effects of these plants on downwind Class I PSD regions. Although the CAAA allow 24-hr SO_2 concentrations to rise by 5 micrograms/ m^3 , concentration increases in PSD regions are likely to come about from many different pollution sources, only some of which are possible synfuel plants. Thus, when actual siting takes place, even smaller increases than the allowed 5 micrograms/ m^3 are likely to be considered important in the permitting process. (In applying for PSD permits, both Colony Development Operation and Union Oil have calculated increases in ambient SO_2 concentrations at levels well below the 5 microgram level to show how much of the PSD increment in nearby Flattops Wilderness Area would be consumed by their plants.)

FIGURE IV-1. DOWNWIND SO₂ CONCENTRATIONS FOR SELECTED TECHNOLOGIES
(All Others Examined Produced Lower Concentrations)

Synfuel development in all areas will be constrained by how much PSD increment is available. We suggest that if the available PSD increment is affected by as much as 1 microgram/m³ of SO₂ then plants will encounter siting difficulty. Thus, we have chosen the smaller of 50 km (the distance beyond which EPA suggests model results are too inaccurate to be useful) or the distance at which concentrations fall to 1 microgram/m³ of SO₂ as the distance that will trigger concern for downwind effect on PSD Class I regions. In practice, any potential development of synfuels will be evaluated on a case-by-case basis for effects on Class I and Class II PSD regions. Control requirements at individual sites are impossible to predict at this time.

Topographic Effects. CDM does not account for topographical effects. As noted before, this is probably not particularly important for sites on relatively smooth terrain (e.g., in the western coal producing regions) or even for sites on plateaus in the more rugged terrain found in the oil shale regions. However, if plants were situated in the valleys of the Appalachian coal producing regions (where ridge siting appears impractical), topographic variations could produce serious effects. Thus, valleys, if at all possible, should be avoided as sites because emissions would frequently be trapped in the stable layers that form from cold air drainage into the valley. These pollutants will occur in high concentrations at the valley walls or be mixed quickly and fumigate the area at the onset of heating during a day following a night of accumulation.

The stable atmospheric conditions associated with high concentrations within the plume are also conducive to air flow that tends to be heavily influenced by local terrain. Thus, under such conditions the air flow might be expected to parallel the axis of any valley in which the plume might be located. If the sources were located near the center of the valley, the impacts that occurred at the valley walls would not be particularly great until the plume was about as wide as the valley itself. If plume width is defined as being about four

times the standard deviation of the Gaussian cross-section, then, according to curves published by Turner (1970) under stable conditions its width will reach 1 km at about 6 to 9 km downwind, and expand to 4 km at about 25 to 45 km downwind. For valleys that are wider than 10 km, the impacts of the plume on valley walls during stable conditions should be rather small within the first 100 km or so downwind. Beyond 100 km, concentrations should have been reduced considerably by dilution.

Note that some synfuel plants will have stacks separated from one another by hundreds of meters or more. This separation will effectively widen the plume and increase the incidences of impacting on the valley walls. Location of the plant near the side of the valley will also increase the frequency at which the valley sides will be subjected to the high concentrations within the plume. Accurate evaluation of such effects will be essential but must await the selection of specific locations and plant configurations.

Although the effects of direct impact on the valley walls should not be great or frequent for a very wide valley, the problem of fumigation still remains. Fumigation occurs in the smoother areas in addition to rough terrain. It is not a problem that can be analyzed by any of the commonly used steady-state models such as CDM. It is generally a short-lived phenomenon confined to the morning at the onset of heating when the compact nighttime plume is mixed groundward by the onset of daytime turbulence.

At this time, it is impossible to estimate the effects of fumigation accurately. Fumigation could easily raise concentrations above the calculated values by a factor 3 or 4, but should be limited to relatively short durations. Like the topographical effects, the problem deserves further attention before final siting decisions are made.

C. Results of Dispersion Modeling

Using CDM as described in our earlier report (Dickson et al, 1976) and as revised here, we calculated pollutant isopleths and peak concentrations for the selected conversion technologies. We used the most readily available meteorological data to represent possible meteorological conditions at hypothetical plant locations. Joint probability distributions based on hourly meteorological data for wind speed, direction, and stability for three areas were used for the various technologies:

- o Pulaski, Virginia
 - Exxon Donor Solvent (EDS) process
- o Moorcroft, Wyoming
 - Fischer-Tropsch process
 - Mobil Methanol-to-Gasoline process
- o Grand Junction, Colorado
 - C-a Tract (Combined Modified In-Situ and TOSCO II processes)
 - Colony (TOSCO II process)
 - Occidental Petroleum (Modified In-Situ)
 - Union Oil Co. process

Results for the 24-hour particulate and SO_2 and 3-hour SO_2 worst case concentrations were derived for probable atmospheric conditions that resulted in the highest concentration for the relevant pollutant and averaging period. These atmospheric conditions are different for each technology, pollutant, and averaging period. Table IV-4 summarizes the peak concentrations that were calculated. Table IV-5 shows the applicable air quality standards, including the PSD increments for SO_2 and particulates. In all cases, the pollutant concentrations are below the Class II PSD increments. For the case of the EDS process, it is clear from the table that the 24-hour SO_2 concentrations will be the major determining factor in siting the plants in Class II areas or in proximity to Class I areas (unless the plant is sited in an area that is nonattainment for particulates, but has a substantial PSD increment left for SO_2). For the coal conversion technologies selected for the West,

the concentration increases due to both Fischer-Tropsch and Mobil Methanol-to-Gasoline are well below the Class II increments for particulates and SO_2 . The various oil shale conversion technologies also produce particulate and SO_2 concentrations that are well below the Class II increments on an individual plant basis.

Figures IV-2 through IV-9 show annual average and 24-hour worst case concentrations from the EDS process with and without on-site electricity generation. The results are not too different for the two plants because of the relatively tall stack of the electricity plant (50 m), although there is a significant change in total SO_2 emissions.

Figures IV-10 and IV-11 show the concentrations from a complex of 4 plants for the Fischer-Tropsch and Mobil processes. These cases are shown because of the strong possibility that plants will be sited in close proximity due to the concentration of resources in the western coal regions, particularly the Powder River Basin. The wind direction there is often south to north and would result in maximum plume addition. Peak 24-hr concentrations would be about 20% higher with four plants than with one plant. Dickson, et al (1976) discuss this siting situation in greater detail. Even four plants would have concentrations that are well below the Class II PSD increment.

Figure IV-12 shows the SO_2 concentrations from the entire complex of oil shale conversion facilities currently planned. The peak concentration would be about 35 micrograms per m^3 , which is well below the Class II PSD increment.

Figure IV-13 shows an example of NO_x concentrations from the TOSCO II process. This example was chosen because, of the plants examined here, the TOSCO II process yields the highest NO_x concentrations.

Table IV-4

SUMMARY OF POLLUTANT CONCENTRATION INCREASES
FROM COAL AND OIL SHALE CONVERSION TECHNOLOGIES

Plant Type	Meteorology	Peak Annual Average Concentrations micrograms/m ³			Peak 24-hour Concentration Worst Case 24-Hour Meteorology micrograms/m ³			Peak 3-Hour SO ₂ Concentrations micrograms/m ³
		Particulates	SO ₂ 2	NO _x 2	Particulates	SO ₂ 2	NO _x 2	
Oil Shale								
C-a Tract (Combined Modified In-situ and TOSCO II Processes) (76,000 b/d)	Grand Junction, Colorado	0.32	0.24	1.3	2.5	2.6	12	3.4
Colony (TOSCO II Processes) (50,000 b/d)	" "	5.0	1.4	4.8	18	15	71	31
Occidental (Modified In-situ) (57,000 b/d)	" "	0.06	0.07	0.62	0.7	0.6	14	—*
Union (50,000 b/d Unit) (2 units planned)	" "	3.0	2.0	8.5	—*	24	—*	—*
Coal Liquefaction								
45,000 eob/d Methanol-to-Gasoline	Moorecrafft, Wyoming	0.007	0.06	0.10	0.6	5.3	9.3	—*
Fischer-Tropsch (45,000 eob/d)	" "	2.1	0.07	0.15	—	5.3	10	—*
EDS Without on-site electricity generation (60,000 b/d)	Pulaski, Virginia	0.4	7.2	2.3	2.3	31	9.3+	—*
EDS with on-site electricity generation (60,000 b/d)	" "	0.4	7.3	2.4	2.3	28	9.1+	67

*See discussion in text

—*Not Calculated

Table IV-5

NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutants	Averaging Period	Maximum Concentrations (micrograms/m ³)	
		Primary	Secondary
SO ₂	3 hr*	--	1,300
	24 hr*	365	--
	Annual	80	--
NO ₂	Annual	100	200
TSP	24 hr	260	150
	Annual	75	60
CO	1 hr*	40,000	40,000
	8 hr*	10,000	10,000
Lead	3 mo avg.	1.5	1.5
Hydrocarbons (nonmethane)**	3 hr*	160	160
Ozone	1 hr**	0.12 ⁺	0.12 ⁺

PSD Increments

Maximum Allowable Increment
³
 (micrograms/m)

Pollutant	Class I	Class II	Class III
Particulate matter			
Annual mean	5	19	37
24-hr maximum	10	37	75
SO ₂			
Annual mean	2	20	40
24-hr	5	91	182
3-hr	25	512	700

*Peak concentrations not to be exceeded more than 1 time per year.

**Peak 1-hr concentration not to be exceeded on more than 1 day per year.

⁺Concentration expressed as parts per million.

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FIGURE IV-2. ANNUAL AVERAGE PARTICULATE CONCENTRATIONS FOR A 60,000 B/D EXXON DONOR SOLVENT PLANT WITHOUT ONSITE ELECTRICITY GENERATION

(Note on Figure IV-2 through IV-13 that the small + indicates the plant location and that the 3 or 4 digit number near it is a code for the plant type that was used for computing purposes only.)

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FIGURE IV-3. ANNUAL AVERAGE PARTICULATE CONCENTRATIONS FOR A 60,000 B/D EXXON DONOR SOLVENT PLANT WITH ONSITE ELECTRICITY GENERATION

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FIGURE IV-4. ANNUAL AVERAGE SO_2 CONCENTRATIONS FOR AN EXXON DONOR SOLVENT PLANT WITH ONSITE ELECTRICITY GENERATION

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FIGURE IV-5. ANNUAL AVERAGE SO_2 CONCENTRATIONS FOR AN EXXON DONOR SOLVENT PLANT WITHOUT ONSITE ELECTRICITY GENERATION

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FIGURE IV-6. 24-HR WORST CASE PARTICULATE CONCENTRATIONS FOR AN EXXON DONOR SOLVENT PLANT WITH ONSITE ELECTRICITY GENERATION

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FIGURE IV-7. 24-HR WORST CASE PARTICULATE CONCENTRATIONS FOR AN EXXON DONOR SOLVENT PLANT WITHOUT ONSITE ELECTRICITY GENERATION

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FIGURE IV-8. 24-HR WORST CASE SO₂ CONCENTRATIONS FOR AN EXXON DONOR SOLVENT PLANT WITH ONSITE ELECTRICITY GENERATION

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POLLUTANT ISOPLETH

SULFUR DIOXIDE

24-HOUR WORST CONCENTRATION IN MICROGRAMS PER CUBIC METER

FIGURE IV-9. 24-HR WORST CASE SO₂ CONCENTRATIONS FOR AN EXXON DONOR SOLVENT PLANT WITHOUT ONSITE ELECTRICITY GENERATION

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FIGURE IV-10. 24-HR WORST CASE SO₂ CONCENTRATIONS FOR FOUR FISCHER-TROPSCH PLANTS

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FIGURE IV-11. 24-HR WORST CASE SO_2 CONCENTRATIONS FOR FOUR MOBIL METHANOL TO GASOLINE PLANTS

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FIGURE IV-12. 24-HR WORST CASE SO₂ CONCENTRATIONS FOR BASE CASE OIL SHALE DEVELOPMENT

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POLLUTANT ISOPLETH

OXIDES OF NITROGEN

24-HOUR WORST CONCENTRATION IN MICROGRAMS PER CUBIC METER

FIGURE IV-13. 24-HR WORST CASE NO_x CONCENTRATIONS FOR A TOSCO II PLANT

It is important to note that all of the technologies meet the requirements of having concentration increments that are well below the Class II PSD increments. Thus, in principle, these plants could be sited anywhere within Class II regions so long as they do not result in violations of the available PSD increments in Class I or Class II areas or violations of the NAAQS. The next section examines some of the regional siting issues.

D. Ease of Siting on a Regional Basis

1. Methodology

The CAA, CAAA, and state air quality regulations define the following categories within the study areas: Current and proposed Class I PSD areas and Class II PSD areas. The CAAA specifically state how much the short- and long-term concentrations of SO₂ and particulates can increase because of industrial development. It will be extremely difficult to site synfuel plants in PSD Class I regions because emissions from the plants will generally result in concentrations that exceed the PSD increments for Class I regions. The CAAA also specifies that Class I areas not be adversely affected by nearby development. In addition, many areas with Class II designation are in violation of NAAQS for one or more air pollutants. These factors lead to a clear overall ranking for the regions:

- o Class II PSD regions that are not in violation of air quality standards will be the easiest in which to site new facilities
- o Class I PSD regions will be the most difficult in which to site new facilities

Figure IV-14 shows the method for ranking the regions within the study areas. Other studies have relied on a similar method.

Several areas within the study regions may become Class I because they are now designated as discretionary under the CAAA, because the

federal land manager has suggested they become Class I, or because the RARE,II process may result in wilderness designation and subsequent Class I proposal.

As described below, the political and regulatory climate within each state have also been taken into account in determining whether a proposed Class I region is likely to become a Class I region. These determinations are based on discussions with EPA regional offices and with state air quality officials. Proposed or potentially proposed Class I regions that now have state support are treated in this analysis as actual Class I regions. Those potential Class I regions that appear likely to lack support from the states for Class I designation for political or regulatory reasons are treated as Class II regions.

Class II regions were separated into three categories with respect to ease of siting. In the first category, those areas that have valley terrain, with valleys less than 10 km wide, those where the PSD increment is already consumed, or those where the NAAQS are exceeded for more than one pollutant are all ranked medium low for ease of siting (low if NAAQS are exceeded for more than two pollutants). In these areas, to site a plant will require (1) additional controls on emissions of more than one pollutant (better than BACT controls), or (2) emissions offsets (which ensure that total emissions are reduced from a company's own facilities or by purchase of emission controls for nonowned facilities). Siting in the medium low areas will change if implementation the SIPs succeeds in meeting the NAAQS; however, it is likely that new industry in areas that are bordering on violation of the NAAQS will be required to meet strict emission control limits. Our discussions with state air quality officials indicated that many states in the Illinois Basin and Appalachian study areas are encouraging industrial development in nonattainment areas because of perceived economic benefits, although offsets must be acquired. Officials in such states often indicated state willingness to help locate offsets. Thus, synfuel development cannot be ruled out in the medium low areas without site-specific analysis.

FIGURE IV-14. METHOD FOR RANKING THE CONSTRAINTS ON EASE OF SITING

The second category, ranked medium in siting difficulty, includes those areas that are near a Class I region or are in violation of one of the NAAQS. In this category, we include cases where the 24-hr worst case SO_2 concentration from a conversion plant would increase the concentration in a nearby Class I region by more than 1 microgram/ m^3 . We created around each Class I PSD region a buffer zone of sufficient size to ensure that no more than this partial utilization of the maximum increment occurs. To determine the radius of such a buffer zone from the edge of the Class I region, we referred to the modeled downwind SO_2 concentrations as shown in Figure IV-1. We selected the shorter of two distances: the distance at which the SO_2 concentration falls to 1 microgram/ m^3 or 50 km. For the Fischer-Tropsch technology, which was used as an example of a technology for converting western coal, the radius was about 25 km. For the TOSCO II plants, the radius was 35 km.

The regions ranked medium ease of siting difficulty around Class I regions only approximately indicate siting difficulties. The CAAA provides for a number of exceptions in deciding impacts on Class I regions, particularly in regions of high terrain. (Detailed procedures for evaluating impacts on Class I regions are still being developed by EPA, particularly with respect to protecting visibility.)

Synfuel plants located in areas in violation of one of the NAAQS (non-attainment areas) would face difficulties because they would need emissions offsets and additional emission controls (better than BACT) from those described here and are also ranked in the "medium" category. EPA also required that a source outside a non-attainment area not be allowed to affect the goal of attaining NAAQS in that area. A "significant increment" concept is used to define the conditions under which an outside source would affect that goal. For SO_2 and TSP, the significant increments are 5 micrograms/ m^3 , 24-hour average and 1 microgram/ m^3 , annual average. We therefore defined buffer zones around non-attainment areas for SO_2 and TSP similar to those used around PSD Class I areas. We used a radius that represented the distance from the plant to the downwind point at which the significant

increment is attained. However, for TSP, the significant increment is never attained at any distance, (see Table IV-4), except for Fischer-Tropsch which reaches it within a few kilometers. For SO_2 , only EDS exceeds the significant increment. The 24-hour increment is reached at about 35 km (see Figure IV-1) and the annual average increment is reached at about 25-30 km (see Figure IV-4). Thus, only SO_2 non-attainment areas in the eastern study areas (where use of EDS technology is postulated) were given buffer zones. For ranking purposes, siting difficulties were assumed to be similar to those within the non-attainment areas, resulting in a rank of medium ease of siting. (EPA's policy toward sources adjacent to non-attainment areas is currently undergoing revision. See the Federal Register of September 15, 1979).

Areas in which the buffer zone interrupted a non-attainment area for another pollutant were considered to have medium low ease of siting, by analogy with non-attainment areas for two pollutants.

The final category (ranked high ease of siting) is the Class II PSD regions that are not in violation of the NAAQS nor fall into the other categories. Note, however, that, even in Class II areas that are not in violation of the NAAQS, PSD permit review will be required for synfuel plants. This permit process is elaborated in the CAAA. Clearly, it is impossible to simulate the air quality siting process adequately for each potential synfuel site at this time.

2. Synfuel Plant Siting in the Northern Great Plains and Four Corners Regions

Discussion of the air quality constraints on the siting of synfuel facilities is particularly problematic at this point, especially in relation to western sites. Many of these areas are subject to the PSD provisions of the CAAA. Several of EPA's regulations under the PSD legislation were successfully challenged in the recent Alabama Power v.

Costle case. EPA has proposed new regulations in response to the Washington, D.C., Circuit Court's slip opinion in Alabama Power V. Costle, but final regulations cannot be issued until the court hands down its final decision.

Moreover, most western states do not have EPA-approved PSD regulations, thereby compounding the confusion surrounding PSD policy, because EPA must administer the program pending approval of a state's regulation. In turn, approved PSD regulations and those currently being processed may have to be revised in light of Alabama Power v. Costle.

Also, EPA and the states have found it difficult to develop modeling and monitoring techniques for determining both baseline concentration and increment consumption--two fundamental bases of PSD regulation.

Consequently, the present administration of the PSD provisions is characterized by confusion, ambiguity, and controversy. When federal PSD policy is finally settled, state-level issues will arise to become a primary concern in the development of synfuel facilities. However, because most western states limit air pollution regulatory authority to one state-level agency, few problems should be encountered with varying and inconsistent local air quality decisions. Furthermore, most western states limit the rulemaking authority of the air pollution control agency, either by legislation or administrative decision, in setting air quality standards and increment levels stricter than those in parallel federal provisions.

Yet, administrative discretion does remain, and the most significant discretionary decisions in any given state will probably concern PSD increment allocation, because the states must decide how emissions are to be allocated. Will the state decide who can site in a PSD area? Will "first-come, first-served" procedure be retained? If so, how will authorities deal with the problems arising when one source requires all of the increment or when not enough increment exists to

accommodate all sources wishing to site in an area? Perhaps a marketable permit approach or a quota system will be adopted, but if that is the case, each will undoubtedly have its own attendant problems.

Although every state in the nation will have to deal with the emission allocation issue, the potential for redesignating Indian lands, however, is a decidedly Western concern. A tribe's decision to redesignate its reservation as a Class I area could significantly affect the development potential of surrounding areas. Even without redesignation, the scope of tribal authority in managing energy-related and environmental matters on the reservation is far from clear.

The problems and issues delineated here cut across the regions of the West. In turn, each region has its own criteria and peculiarities affecting air quality considerations. These are considered below.

Northern Great Plains. The most significant potential air quality constraint on the siting of synfuel facilities in the Northern Great Plains is the status of PSD increment consumption. Discussions with air quality officials in each state suggest that they have little information concerning the status of PSD increment consumption they cite EPA administration of the PSD program and deficiencies inherent in existing modeling and monitoring techniques as the source of the problem.

In fact, because of the lack of sufficiently sophisticated modeling and monitoring capabilities, determinations of increment violation are generally challenged; for example, industries in Mercer, Dunn, and Oliver Counties in North Dakota are attempting to demonstrate that SO₂ emissions from those counties are not actually affecting the northern unit of Theodore Roosevelt National Park (a Class I area). The 1979 status of air quality is shown in Figure IV-15. (Refer to the Federal Register for more details.) Figure VI-16 summarizes the results of the air quality analysis and shows the areas that have fewest constraints on development.

FIGURE IV-16. RELATIVE EASE OF SITING BASED ON AIR QUALITY

Given the uncertainties concerning the effect of existing development on PSD increment status, it is extremely difficult to anticipate the impacts of planned development on air quality in PSD areas. Nonetheless, it would appear that, except for small local pockets near mine sites, only two areas have potentially significant increment problems. If Colstrip Units 3 and 4 are sited where Units 1 and 2 are located (Rosebud County, Montana), the 3-hr SO₂ increment could be exceeded. Moreover, authorities view the Trona area in Sweetwater County, Wyoming, as a potential problem area.

Technical uncertainties about increment consumption are compounded by the absence of policies to address a number of crucial issues. None of the states in this study have resolved the issue of the best method for allocating PSD increments. In addition, although North Dakota anticipates problems of interstate pollutant transport with increased coal development in Montana, no procedures are being developed to deal with the situation. The power facility development at Scoby, across the Canadian border in Saskatchewan, could result in a major international pollutant transport problem that, although recognized, is not being addressed.

As the Northern Great Plains states begin to administer their own PSD programs in 1980, policies will be developed to deal with increment allocation and transport problems. However, legal, regulatory, and technical uncertainties regarding the PSD program could hamper policy formation. The ambiguities shrouding the PSD program are also generating a good deal of hostility at the local level, in the agencies, and among the public. Although this tendency is not so pronounced in the Northern Great Plains as in other areas, it could ultimately affect the stringency of local air quality standards. For example, it seems likely that, North Dakota's Class II increment for particulates, which is currently stricter than the federal standard, may be relaxed to parallel the federal provision.^a

^aWyoming's ambient standards for SO₂ and particulate are also currently stricter than the federal NAAQS.

That North Dakota could well follow the lead of other states in enacting "no stricter than federal standards" legislation is borne out by the attitude towards industrial development in the state is evidenced by our discussions with state officials. Of the four Northern Great Plains states, North Dakota seems to be the most pro-development, and is willing to employ "any legal method available" to limit air quality restraints on industrial siting. Attitudes in Wyoming and Montana appear to be more ambivalent, although the feelings are hard to gauge because authorities are guarded in their comments. This reluctance to comment appears to corroborate the conventional wisdom that Wyoming and Montana officials are not enthusiastic about development in their states.

A final issue crucial to the assessment of air quality constraints is Indian views on synfuel development, because the various tribes have the authority to designate their reservations as Class I areas. Only one tribe, the Northern Cheyenne of Montana, has exercised this option, and that redesignation is currently being challenged in court. EPA is firmly supporting the Cheyenne action.

Generally, it appears that none of the other Great Plains tribes is prepared to redesignate its lands at this time. Most, however, are obtaining EPA grants to study the possibility. Although air pollution impacts are an issue, the primary concern appears to be the socioeconomic effects of large-scale, energy-related development. Some tribes seem to approve of developing coal and mineral mining industries, but little support has been gained for conversion facilities located on the reservations. The Indians will quite likely demand authority to formulate and administer strict air quality control programs for the reservations.

Four Corners/Rocky Mountains. As in the Northern Great Plains states, the status of PSD increment and of PSD policy in general appear to be the major air quality constraints on synfuel development in the

Four Corners/Rocky Mountains study area. No cases of increment violation have been reported in the area. Planned and anticipated developments do not appear to pose a threat of increment depletion, although problems could evolve in a few areas, particularly in the oil shale regions. The 1979 status of air quality is shown in Figure VI-17. Figure VI-18 shows the results of the analysis.

Emissions from oil shale processing in northwestern Colorado will consume part of the Class I increment in the Flattops Wilderness Area. In northeastern Utah (Uintah County), continued oil and gas development and plans for an 800-MW electric power plant, could ultimately constrain the siting of synfuel facilities.

Utah and New Mexico will soon be delegated PSD regulatory authority from EPA, but EPA approval of the Arizona and Colorado PSD regulations is more problematic because of legal and regulatory uncertainties, as well as bureaucratic delays. However, even in the absence of explicit provisions, it is possible to assess the outline of PSD regulation in the Four Corners/Rocky Mountain area.

All four states either have laws or implicit policies against state-level PSD increment levels stricter than federal standards. Only New Mexico and Arizona have ambient air quality standards that are more stringent than federal provisions (New Mexico: TSP, SO₂, NO₂, H₂S; Arizona: TSP, O_x). None of the states has addressed the interstate pollutant transport problem. However, the states are attempting to grapple with the issues inherent in increment allocation. Utah intends to consider local viewpoints when reaching allocation decisions. New Mexico plans to implement a policy requiring construction to begin within 1 year of permit approval or else the allocation will be forfeited. Colorado authorities are particularly interested in the emission density zoning concept.

Dissatisfaction with PSD policy appears to be growing, particularly in Utah. There seems to be hostility in Utah to the Class I concept, which is seen as the major constraint on industrial

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FIGURE IV-17. 1979 AIR QUALITY STATUS IN THE FOUR CORNERS/
ROCKY MOUNTAINS
(The Large Numbers are AQCR Numbers)

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FIGURE IV-18. RELATIVE EASE OF SITING BASED ON AIR QUALITY

development in the state. For example, the governor has threatened to sue the federal government if Dinosaur National Monument, a discretionary Class I area, is redesignated a mandatory Class I area. The governor will also sue if any more wilderness areas are redesignated Class I. Finally, the state is currently embroiled in a controversy with the National Park Service (NPS) over visibility criteria. NPS maintains that the standard for assessing visibility impairment should be how far one can see from within a Class I area, whereas the state claims the appropriate criterion is what can be seen. Until federal visibility regulations are promulgated, it is unlikely that the dispute can be resolved.

Given the antipathy in Utah to PSD policy, it is not surprising that the state is the most pro-development in the Four Corners region, with Arizona running a close second. However, because retired and elderly people have moved to Arizona in increasing numbers, no-growth forces particularly concerned about the health effects of air pollution are gaining political strength. New Mexico appears to have a benign attitude towards energy-related development, whereas Colorado has taken a cautious, slow-growth stance. Public concerns about socioeconomic impacts and well-organized efforts on the part of Front Range environmentalists underlie the Colorado position.

Potential redesignation of Indian reservations does not appear to be a major constraint on siting, although the Northern Utes are considering the possibility. Oil shale beds of unknown quantity and quality have been discovered in the Hill Creek Extension area of the reservation, which has been designated a wild and scenic area by the tribe. No decision on redesignation will be made until the nature of the resource is ascertained.

Although redesignation is not a major concern, Indian policies about how and when energy resources should be developed are extremely significant, especially in light of a recent federal district court opinion upholding the power of the Navajo nation to levy a charge on

SO₂ emissions. Indian tribes throughout the West, and the Navajo in particular, are likely to consider tribal needs to be of more importance than national and regional concerns in developing energy-related and environmental priorities and policies.

3. Synfuel Plant Siting in Appalachia and the Illinois Basin

Air quality issues in these study areas are in flux because of the many nonattainment regions, each of which requires a special approach to achieve NAAQS and because of pending SIP revisions as a result of Alabama Power v. Costle. Generally, the states in these study regions welcome development and will assist in the siting process (e.g., by helping to locate offsets in nonattainment areas). However, future air quality problems resulting from industrial development and from extensive valley terrain in Appalachia will make siting difficult if additional emissions controls or offsets cannot be developed to meet air quality regulations. The 1979 air quality status is illustrated in Figures IV-19 and IV-20. Industrial development will probably keep many of these nonattainment areas close to the NAAQS, and PSD review for synfuel development will be an important issue. Figures IV-21 and IV-22 summarize the results of the air quality analysis. Note that an examination of USGS topographic maps (1:250,000) showed extensive ridge and valley terrain throughout much of Appalachia with no valleys wider than 10 km. Siting may not be impossible in this terrain, but it will nevertheless be difficult owing to the possibility of violation of the NAAQS or the PSD Class II increments described earlier.

Although the states in these study areas generally support industrial development, they do not believe that they have adequate tools for evaluating the air quality impacts in valley areas. EPA-approved models still cannot adequately treat valley terrain, and stack height guidelines do not yet satisfy all air quality officials. Also, the states have not developed the data to determine how much of the PSD increment remains available.

The shaded areas indicate and summarize the nonattainment status for the study area.
This map does not capture the detailed information listed in the FEDERAL REGISTER.

FIGURE IV-20. 1979 AIR QUALITY STATUS IN APPALACHIA
(The Large Numbers are AQCR Numbers)

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FIGURE 21. RELATIVE EASE OF SITING BASED ON AIR QUALITY

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FIGURE IV-22. RELATIVE EASE OF SITING BASED ON AIR QUALITY

Factors Affecting Synfuel Siting in Indiana. Coal deposits are found in the southwestern portion of Indiana, particularly in AQCRs 77 and 84. In AQCR 77, Vanderburgh and Dubois Counties are nonattainment areas. In AQCR 84, only Vigo County is designated as a nonattainment area. The entire state is a Class II area for purposes of PSD regulations.

According to the Indiana Air Pollution Control Board, most of the point sources in the coal regions are older industrial facilities "grandfathered" under CAAA with few controls. In Vigo County, most major sources are power plants. The Board apparently believes that offsets will be possible for the first new sources that seek them but will become increasingly difficult to acquire.

Vanderburgh County does not appear to have large individual sources of oxidant precursors according to the National Emissions Data System (NEDS). Thus, a new source would have to reach agreements with many small sources to obtain the needed offsets. This may prove extremely difficult. Dubois County violates the NAAQS for particulates. However, much of the particulate emissions are from electric generating plants that burn bituminous coal. Therefore, offsets may be feasible in Dubois County.

Note that states are also required to bring nonattainment areas into attainment. To do so, some existing point sources will have to institute controls to make the area comply with the standard. This will reduce the amount of offset that is easily available.

Factors Affecting Synfuel Development in Illinois. Illinois coal resources are mostly concentrated in the southwestern two-thirds of the state, and in five counties along the eastern border. Twenty-four counties in the state have nonattainment problems. Most of these are clustered around Chicago in the northeast, Peoria in the center of the state, and East St. Louis, in the southwest portion of the state along

the Missouri border. The Illinois Air Pollution Control Board suggests it would be nearly impossible to site major new sources in those three areas.

Although Chicago is not itself in the study area, meteorological conditions could cause siting problems southwest of Chicago in AQCR 71, a coal area. The area around Peoria in AQCR 65 has alignment problems with TSP, CO, O_x , and SO_2 , and is in the midst of a coal resource area. AQCR 70 (the St. Louis metropolitan area) does not meet the standards for TSP or O_x , and is also in a coal region.

According to the Board, major sources can emit no more than $1.8 \text{ lb}/10^6 \text{ Btu}$ of SO_2 . Many sources achieve this by using low-sulfur, western coal. According to the Board opportunities for offsets are better in the southern part of the state.

Factors Affecting Synfuel Siting in West Virginia. Air quality officials in West Virginia are awaiting the final outcome of Alabama v. Costle before they formulate PSD rules. Currently, officials are considering many approaches to the PSD issue (e.g., they are considering taxing air pollution rights). They indicate that West Virginia should be in full attainment of NAAQS by 1982, an achievement which will simplify synfuel siting somewhat.

West Virginia has a long history of concern about air quality. Yet, because many industrial facilities were retrofitted to meet clean air goals of the early 1970s, further retrofitting requirements likely meet considerable resistance by industry.

State officials believe that current models cannot adequately calculate air quality impacts in rough valley terrain and are uncertain how they will deal with the valley issue. Valley terrains are steep enough that very tall stacks are needed to disperse pollutants, but most plants cannot be fitted with extremely tall stacks because the CAAA rules them out.

Factors Affecting Synfuel Siting in Kentucky. Kentucky has already sited several pilot-scale synfuel plants:

- o A liquefaction plant in Catlettsburg
- o Two gasification plants
- o An SRC plant.

Although the liquefaction plant is in a nonattainment area, it is allowed to operate because its emissions are kept below the 100 ton/yr limit. Should the plant be scaled up, offsets would be required.

Support for synfuel development is highest in the eastern part of the state, which is already dominated by a coal-based economy.

Factors Affecting Synfuel Siting in Ohio. Currently, PSD siting is based on a first-come, first-served basis. Ohio generally is looking for markets, such as synfuels, for their high-sulfur coal. After its SIP is approved, Ohio will assume the PSD permit responsibilities that EPA Region V currently performs. Air quality officials indicate that they would work with companies to find offsets for plants located in nonattainment regions of the state. Currently, Ohio has many nonattainment regions, a fact that officials attribute to the more widespread monitoring of rural air quality than in many other states.

Factors Affecting Synfuel Siting in Pennsylvania. Allegheny County is the only area in the state with severe SO₂ problems. Air quality officials indicate that they expect all other areas of the state soon to be in compliance with the SO₂ standards. They also anticipate compliance with the particulate standards. The entire state is in violation of the O_x standards because of hydrocarbon emissions. Pennsylvania has already developed an offset policy for particulates:

	<u>Reduction Factors</u>	
	<u>Stack Emissions</u>	<u>Fugitive Emissions</u>
To attain primary standards	1.3:1	5:1
To attain secondary standards	1.1:1	3:1

The high offset ratios for fugitive emissions have been chosen because these emissions are difficult to quantify, and it is desirable to leave a safety factor if the calculations are incorrect.

EPA Region V has indicated to Pennsylvania that it prefers to use terrain-dependent models for calculating the air quality effects of sites in mountainous terrain. Pennsylvania has some experience in siting pilot gasification facilities.

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V WATER AVAILABILITY

Water has been identified as a critical limiting factor for development of coal and oil shale conversion industries--particularly in the West. As a result, many studies have evaluated the availability of water resources, as well as constraints imposed on the development of energy resources. Analysis of the availability of water resources is highly complex and reaches beyond science into the complicated realm of institutions and law. The first section of this chapter discusses our approach to assessing surface water flows, or physical water availability. The next section discusses the trends for regulating the availability of water at the state or federal level. The third section assesses the potential for water quality problems in the East, and the final section combines these three assessments in developing an overall ranking of water availability.

A. Surface Water Flows

1. Background

Because of the early stage of development of many approaches and techniques in water resource analysis, each such analysis must be based on a series of assumptions that vary, depending on the objectives of the particular study. Thus, each study has a slightly different approach. These approaches usually vary with respect to the way in which uncertainty in the water resource is included. The most common approach has been to make estimates of virgin flow assuming average annual conditions. In other words, the streamflow that is expected to occur over 50% of the time, assuming no upstream diversions of water, is determined for various points within a river basin. Although estimates of virgin flow are useful to obtain a more accurate understanding of the

hydrologic system in a particular river basin, such analyses are time-consuming and costly.

Recent studies have developed hydrologic models for major river basins to simulate various levels of future water withdrawals and to explore the effects of alternative water management schemes. Most of these studies base their assessments on the median streamflow experienced for some selected period of record. The Missouri River Basin Commission (MRBC), for example, recently used a modified version of this approach for their assessment of water for coal development in the Upper Missouri River Basin (1978). They used a U.S. Bureau of Reclamation (USBR) model based on virgin flows and evaluated available monthly streamflows at the median and 80% exceedance levels (i.e., the flow equalled or exceeded 80% of the time). They found generally adequate supplies in the Yellowstone River to meet projected water requirements for energy development, but insufficient water in the Tongue and Power Rivers.

The Colorado Department of Natural Resources (DNR) recently completed a similar study for the Upper Colorado River Basin (1979). They used a USBR model to simulate streamflows assuming two separate periods of record and operating conditions of the reservoirs sufficient to allow release of 8.23 million acre-feet of water from Lake Powell to meet legal water compact requirements. The 50% exceedance flow for the Upper Colorado River Basin varied, depending on the period of record selected--15.2 million acre-feet using data from 1906 to 1974, or 13.8 million acre-feet using data from 1930 to 1974. The results of the DNR study show that substantial energy development can take place assuming large capital investments are made to improve storage and distribution of water. One interesting portion of their analysis indicates that, given the specified level of energy development, the compact obligations at Lake Powell can be met 50% of the time, assuming the 1906-1974 period of record, or less than 25% of the time, assuming the 1930-1974 period of record. This result underscores the problems associated with water supply projections and the importance in understanding the assumptions used in each assessment.

A technology assessment for Western energy development was recently completed by the University of Oklahoma (Draft, 1977). Their approach was identical to that used in the Westwide Study (USBR, 1974). Basically, they subtracted 1975 water use, including "surface-related groundwater" and mined groundwater from average annual streamflows to determine the estimated future water supply.

The first attempt to compile consistent nationwide statistics on water resources was made by the U.S. Water Resources Council (WRC), Second National Water Assessment (Draft, 1978). Figure V-1 illustrates the location and relative size of the basins studied (shaded areas are the basins analyzed in this chapter). These basins are called aggregated subregions or ASRs in the WRC study. Although some inconsistencies and inaccuracies are apparent in the WRC assessment, generally the data are valuable for making broad comparisons among regions. The assessment includes data on 1975 and projected water demands, withdrawals, groundwater use and storage, instream flow requirements, economic conditions, and streamflow projections.

The national laboratories conducted an assessment of the National Energy Plan, which included an assessment of water availability (Argonne National Laboratory, 1979). This was one of the first studies addressing water supply issues in the East as well as in the West. They used ASRs defined by the WRC as their basic geographic unit of comparison. Their estimates of water availability were based on the flow that will be exceeded 90% of the time in each critical month, adjusted for the 1975 level of upstream depletion of surface water. Although this study provided a good regional comparison of water availability, the size of the basins studied is too large to allow comparisons below the regional level.

The most recent assessments have tended toward using a short-term low flow-- $7Q^{10}$, the low flow experienced for 7 consecutive days and recurring once in 10 years--as the basis for their analysis (Shepherd, 1979; MRBC, 1978). This quantity focuses on the water resource during

FIGURE V-1. LOCATION OF MAJOR RIVER BASINS STUDIED

critical low-flow periods and is particularly useful in evaluating the streamflow required to maintain fish and wildlife habitat. However, the major difficulty in this type of analysis is in determining comparable water demand projections for comparison. If a large number of gaging stations must be evaluated, the task becomes onerous to make 7-day demand projections for a specific month. Therefore, this technique is more often applied to a limited geographic region.

2. Major Assumptions

Our analysis of streamflows was based on several key assumptions:

- o Surface water will provide the primary water supply.
- o Some risk exists that surface water will not be available at all times.
- o Supplemental water supplies may be required.

Surface water, an abundant renewable resource in much of the United States, is a logical primary source of water supply for synfuel plants. Our analysis concentrated on assessing streamflows in each study area in order to rank individual river basins. As a corollary to this assessment of surface water supplies, we assumed that ground water would only be used as a supplemental supply. The pumping rates required to sustain a fully operating synfuel plant are substantial, ranging from 6,000 to 9,000 gallons per minute (gpm). These rates of groundwater withdrawal would severely deplete many groundwater systems and could cause permanent aquifer damage. Such possible damage might include reduction of long-term storage capacity, reduction of hydraulic conductivity, and permanently lowered water tables. These irreversible changes in the groundwater regime can be largely avoided by relying on surface water for the primary water supply.

Some risk exists that surface water will be unavailable for portions of each year. Simply stated, the more water demanded from a

stream, the higher the potential risk that the demand cannot be met. Even in the absence of upstream demands for water, some risk exists. The degree of this risk depends on variability in precipitation and watershed characteristics such as the size of the drainage basin, elevation, steepness of topography, bedrock geology, and reservoir storage. For this general, broad-based assessment, we selected acceptable levels of risk that are based on a probability analysis of streamflows known as flow duration curves. These curves represent historical streamflow at a particular stream gage, indicating the percentages of time that certain flows took place in the stream. Thus, the degree of risk is measured by the percentage of time that upstream demands can be met.

Our last assumption follows from this assessment of risk--supplemental water supplies may be required at some time during the life of the plant. Operators of large, water-using facilities acknowledge this concept of risk and the necessity for supplemental supplies. Consequently, most facilities have adjunct reservoir storage, groundwater wells, or municipal water supplies to guarantee their water supply. We have assumed that similar arrangements will be required for synfuel plants in each of the study areas. In fact, our system of rankings from high to low is partially an indication of the expense expected for guaranteeing a source of water. An area ranked low would require a substantial investment in water storage and transport facilities, whereas an area ranked high would require only minimal investment. Although a facility will probably operate at least 80% of the time, downtime can rarely be planned, and small likelihood exists that plant closures for maintenance can be timed to coincide with periods of low streamflow.

3. Method of Approach

Our method of approach consisted of four main steps:

- o Obtaining streamflow records
- o Summing water demands
- o Determining the percentage of time the demands are met
- o In marginal river basins, determining whether a stream can support an impoundment.

Obtaining Streamflow Records. We initially selected 100 U.S. Geological Survey (USGS) gaging stations whose drainage basins covered the entire area of the four study areas. We attempted to select gages with historical records of at least 30 years and with a moderate-sized drainage basin (at least 100 mi²). In some areas, however, no gages were available to meet those two criteria.

We then assessed Lawrence Berkeley Laboratory's (LBL) GETUSGS data base, which contains the entire historical record, statistical information, and the flow duration curve for each gage. From these records, we found some of the gages to be unusable. Our final selection contains approximately 80 stream gages.

We then constructed maps for each study area showing where each stream gage is located, with the outline of the drainage basin upstream from each gage indicated. Copies of these maps are presented in Appendix L. In areas for which stream gages were unavailable, we used the nearest gage representing similar watershed characteristics as an analog.

Summing Water Demands. We were next concerned with the ability of a stream to meet instantaneous demands. We not only considered demands for diversions of water, but also assessed demands for maintenance of fish and wildlife habitat (i.e., "instream flow requirements"). For this latter case, in particular, the instantaneous flow of a stream is of prime importance. As a result, we chose to evaluate "withdrawal demands"--the amount of water withdrawn from surface water to meet demands at any one time. The Missouri River Basin

Commission (MRBC) also used this approach in its assessment of water availability for energy development in the Upper Missouri River Basin (1979).

In determining competing water demands, we included water used for agriculture, industry, mining, thermal electric generation, municipalities, and rural development. In addition, we also considered water lost by evaporation or export out of the drainage basin. As shown in Figure V-2, the relative importance of each of these competing demands differs significantly from eastern to western basins. Figure V-2 compares two Water Resources Council (WRC) regions--the Upper Colorado and the mid-Atlantic. In the West, irrigation accounts for the largest withdrawal of water by far, whereas steam electric generation is the largest water user in the East.

We used the best data available for determining water withdrawals in each drainage basin. Annual water withdrawals depend on climatic conditions, as well as on economic factors. For example, irrigation withdrawals may decrease in a particular year, not because rainfall has increased, but because prices for wheat have dropped. Consequently, levels of water withdrawal can vary considerably from year to year. With that qualification in mind, we selected 1975 as the base year for the analysis, primarily because an abundance of data exists for that year. As a result of the 1975 National Water Assessment (WRC, 1978) and other more recent assessments (Colorado Department of Natural Resources, 1979; MRBC, 1978).

We then obtained projections of competing water demands for 1990. In most cases, these projections resulted from using a simple linear regression equation to obtain 1990 estimates. Table V-1 lists the source of the water use data for each major river basin.

We disaggregated the 1990 water use projections to individual stream gages by using a ratio--the size of the drainage basin of the stream gage (in square miles) divided by the size of the drainage

WEST
(Upper Colorado)

EAST
(Mid-Atlantic)

FIGURE V-2. EXAMPLES OF COMPETING WATER DEMANDS

basin (also in square miles) for which water use data are available. In some cases, (e.g., the Northern Great Plains region for which quite detailed information was available), the match was exact. In other cases, the drainage basin of the stream gage represented perhaps 10% of the area of the major drainage basin for which data were available, indicating considerable uncertainty about the water use projections for those latter cases. A brief discussion of each data source follows.

The drainage basins that WRC used as the basis of analysis (1978) are in most cases too large for the type of assessment we require (see Figure V-1). However, as indicated in Table V-1, WRC remains the best source of data for a large portion of our study regions. Unfortunately, during this assessment we discovered substantial discrepancies between the WRC data and those in other sources. In particular, the 1975 water use data published for each WRC water resource region by the USGS (1977) differed from the WRC data by as much as 100%. Because few other sources of data were accessible, it was necessary to use the WRC data; we note apparent discrepancies that were encountered.

The MRBC (1978) recently completed a study for the WRC authorized under Section 13(a) of the Federal Non-nuclear Energy Research and Development Act of 1974, which specifically addressed the availability of water for coal gasification and oil shale development. We employed the 1975 estimates of water use contained in that report for our assessment. Note, however, that the MRBC report did not tabulate estimated projections. In addition, that study evaluated only tributaries to the Missouri River, and did not consider water availability in the Missouri mainstem, Musselshell, or Milk Rivers. We adjusted 1985 and 2000 WRC projections to reflect the discrepancies in the two sets of 1975 data and estimated an adjusted 1990 figure.

Although the Comprehensive Framework Study for the Missouri River Basin is rather outdated (MRBC, 1972), it nevertheless provides valuable reference material. We relied on estimates of

Table V-1

SOURCE OF WATER USE BY MAJOR RIVER BASIN

<u>Coal Resource Region</u>	<u>River Basin</u>	^a <u>Sources of Data</u>	
		<u>1975</u> <u>Water Use</u>	<u>1990</u> <u>Projection</u>
Appalachia	Susquehanna	WRC	WRC
	Allegheny	WRC	WRC
	Monongahela	WRC	WRC
	Kanawha	WRC	WRC
	Ohio	WRC	WRC
Illinois Basin	Wabash	WRC	WRC
	White	WRC	WRC
	Illinois	WRC	WRC
	Mississippi	WRC	WRC
	Ohio	WRC	WRC
	Kaskaskia	WRC	WRC
Northern Great Plains	Yellowstone	13a	WRCa
	Milk	CFS	WRCa
	Missouri #1 and #2	CFS	WRCa
	Western Dakota		
	Tributaries	13a	WRCa
	Platte	CFS	WRCa
	Missouri #3	CFS	WRCa
Four Corners - Rocky Mountains	Green	DNR	DNR
	Platte	CFS	WRCa
	White	DNR	DNR
	Yampa	DNR	DNR
	Colorado	DNR	DNR
	Delores	DNR	DNR
	San Juan	DNR	DNR
	Rio Grande	WRC	WRC
	Virgin	WRC	WRC

^aKey to sources -

WRC, U.S. Water Resources Council (1978)

13a, Missouri River Basin Commission (1978)

WRCa, projections based on adjusted WRC data

CFS, Comprehensive Framework Study, Missouri River Basin Commission (1972),

DNR, Colorado Department of Natural Resources (1979).

pre-1970 water use in the Hydrology Appendix of that study for adjusting those WRC estimates that were grossly inaccurate.

The Colorado Department of Natural Resources (DNR, 1979) is completing its 13(a) assessment for the Upper Colorado River Basin. We used DNR's 1975 estimates of water use. We estimated 1990 projections by simple linear regression using the DNR 2000 projections of their medium case, which is based on the best estimate of all the Upper Colorado River Basin states.

The estimated 1990 competing water demands for each river basin are given in Appendix I. The tables shown there also contain each stream gage analyzed, stream gage number, drainage basin size, and average streamflow at the gage.

We formulated a hypothetical synfuel demand for each river basin by assuming that one synfuel plant can be supplied by each coal resource county within the basin in the West, or by groups of five coal resource counties in the East. In those basins that did not intercept coal resource counties, we assumed one or two plants would be supplied, depending on the size of the basin. We based oil shale demands on announced plans of companies that intend to use surface water supplies.

The water demands for each type of synfuel plant are given in Appendices C through I. In the West, the average demand per plant, based on Fischer-Tropsch and Mobil Methanol-to-Gasoline technologies, was 13 cubic feet per second (cfs). In the East, it was 19 cfs, based on EDS technology. The oil shale developments that plan to use surface water supplies are Union Oil (11 cfs, Colorado River), Colony (10 cfs, Colorado River), and Utah Ua and Ub Tracts (12 cfs, White River).

Note that hypothetical synfuel demands were used for purposes of a basin-by-basin analysis. No attempt was made to project a

total synfuel demand for all basins in a study area. In essence, each basin was considered in isolation.

In light of current concern to preserve and maintain critical fish and wildlife habitat, we included an instream flow requirement in our determination of total upstream water demand. This means that a portion of the water in a stream is "allocated" for the continual maintenance of fish habitat and therefore unavailable for meeting other water demands.

Methods for determining this requirement are still being developed. Although site-specific assessments are far preferable, the U.S. Fish and Wildlife Service (FWS) has developed several approaches using flow duration curves as a reasonable alternative for more general studies of the resource (Stalnaker et al, 1976). FWS research has identified streamflow percentiles that relate to various levels of maintenance for fish habitat (see Table V-2). Because of the general absence of legal requirements for any specified amount of instream flow, we selected the 90% exceedance flow (i.e., the streamflow that is equalled or exceeded 90% of the time), which is the minimum requirement for survival of aquatic species. Note, however, that some states (e.g., Montana) have appropriated much higher flows for maintenance of instream values.

These three demands--competing water demands, synfuel demands, and instream flow requirements--were summed to determine the total demand upstream of each gage in 1990. Appendix L presents the results of these calculations.

Determining the Percent of Time the Demands Are Met. For each river basin (as defined by the location of the stream gage), we obtained the flow duration curve and compared the estimated total upstream demand to that curve. By this approach, we determined the percentage of time that the demand could be expected to be met, given the historical streamflow pattern at the gage. An illustration of this procedure is given in Figure V-3 for one river basin.

Table V-2

INSTREAM FLOW REQUIREMENTS FOR VARIOUS
LEVELS OF MAINTENANCE OF FISH HABITAT

<u>Streamflow Required (%)^a</u>	<u>Level of Maintenance</u>
17	Flushing
40	Spawning
70	Preservation
80	Food production
90	Survival

^aPercent exceedance flows as determined from flow duration curves.

Source: Stalnaker et al., 1976.

In Marginal River Basins, Determining Whether a Stream Can Support an Impoundment. If demands could be met less than 60% of the time, we added another analytical step to determine whether the stream could support an impoundment. Because of our assumption that supplemental water supplies will probably be required, we decided to investigate whether the operators of synfuel facilities could construct an impoundment on a stream. The impoundment had to meet three criteria:

- o Provision of water for synfuel facilities only
- o Release of water at a rate to meet the instream flow requirement of the gage
- o Size that could be feasibly constructed by an energy concern (50,000 acre-feet or less).

For this analysis, we used a standard engineering approach known as "Mass Curve Analysis." Figure V-4 presents an example

V-15

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FIGURE V-3. EXAMPLE OF FLOW DURATION CURVE

of this analytical technique at one gaging station. We used the computer to search the historical streamflow record and determine the 5 consecutive years of lowest flow conditions. The streamflow was then converted to acre-feet and plotted cumulatively over the 5-year period to produce the "supply curve." We summed the instream flow requirement and the synfuel demand, and determined the 5-year cumulative demand in acre-feet. This demand curve was then plotted on the graph. To determine the size of the reservoir required to meet demand during this period of low streamflow, the slope of the demand curve was reconstructed at several points on the graph to determine at which point the maximum departure of the demand curve from the supply curve occurs. In our example, the maximum departure of these two curves equalled 70,000 acre-feet. In other words, a reservoir with an active storage capacity of 70,000 acre-feet must be constructed to meet estimated demands during a period of drought similar to the one experienced in the historical record. However, a reservoir of this size is generally too large to be constructed by an energy concern without governmental assistance. Therefore, according to our assessment, the ranking of this river basin would not be upgraded.

3. Results

Relative Ease of Siting. We ranked each river basin as high, medium, medium low, or low on the basis of the percentage of time the estimated upstream demand can be expected to be met. Table V-3 defines each category of the ranking. Because we were concerned with developing an overall ranking that could be applied to all four study areas, we selected a somewhat conservative ranking system in the sense that it allows for less risk. Many studies use annual average or median streamflows for their baseline analysis of water availability. These are approximated by the 50% exceedance flow on the flow duration curves that we used in our assessment. Another way to look at this is that those streamflows are equaled or exceeded 50% of the time. Thus, our use of 60% is somewhat more conservative. However, when ranking widely divergent river basins in the country, we believe our approach makes

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FIGURE V-4. EXAMPLE OF MASS CURVE

Table V-3

CATEGORIES OF RANKING FOR SURFACE WATER FLOW

High	Water demands met at least 80% of time.
Medium	Water demands met 60-80% of time.
Medium Low	Water demands met less than 60% of time, but streamflow can support impoundment of less than 50,000 acre-feet.
Low	Water demands met less than 60% of time.

sense in that it better differentiates between river basins where water is abundantly and cheaply available versus those where substantial capital investments in storage and diversion projects are required to maintain an assured supply.

The relative ease of siting, based on surface water flow in each coal resource region, is shown in Figures V-5 through V-8. Note that the Appalachian and Illinois study areas have river basins that are predominantly ranked high and that few are ranked low or medium low. This is in contrast to the Four Corners-Rocky Mountain study area (Figure V-8), where only a few river basins are ranked higher than medium low. The Northern Great Plains (Figure V-7), on the other hand, has river basin rankings that indicate a diversity of availability of surface water flow.

These results are generally supported by the other studies cited previously. For example, in a recent assessment of the Upper Colorado River Basin, the Colorado DNR (1979) found that sufficient water could be made available in that region for major synfuels development if substantial capital investment, on the order of \$1 billion, was targeted for water development projects. The MRBC report for the Upper Missouri River Basin (1979) indicated that additional

Source: SRI Estimates

FIGURE V-5. RELATIVE EASE OF SITING BASED ON SURFACE WATER FLOW

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FIGURE V-6 RELATIVE EASE OF SITING BASED ON SURFACE WATER FLOW

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FIGURE V-7. RELATIVE EASE OF SITING BASED ON SURFACE WATER FLOW

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FIGURE V-8. RELATIVE EASE OF SITING BASED ON SURFACE WATER FLOW

reservoirs and aqueducts must be constructed to supply water and that severe institutional problems exist to hinder development of water for an energy industry. These considerations are discussed in the following section.

Limitations of Approach. The main limitation to our approach is that we have had to base our analysis on biased streamflow records. In other words, the historical streamflow records are imprinted with the effects of man's development and activities in the drainage basin. Because these activities have changed in intensity over time, the probabilities associated with the expected streamflows have also changed. However, the weight of the historical record does not allow the flow duration curves to change so rapidly. Ideally, flow duration curves should be reconstructed to reflect virgin flow conditions (i.e., conditions expected at the gage in the absence of any upstream diversions of water). This approach, which was used in the assessment conducted for the Upper Missouri River Basin (MRBC, 1979), is nevertheless extremely time-consuming and not particularly appropriate for assessing eastern river basins. With respect to our approach, long-term stream gage records do afford a better representation of expected precipitation variation and therefore make its other shortcomings less important.

Basing an analysis on probabilities means that we must accept the concept of risk. Our determination of a particular streamflow that must be allocated for maintenance of fish habitat effectively eliminated the potential for meeting demands in a river basin 100% of the time. The concept of risk, though not often discussed directly in studies of water availability, is definitely implied in much of the analysis, as discussed previously. However, we cannot predict the future accurately by relying on probabilities. If a particular streamflow has an 80% exceedance level, the streamflow should be equalled or exceeded 80% of the time. But 10 years may pass during which that streamflow never occurs more than 60% of the time. Statistically, however, its probability may still be at the 80% level over the long term.

Unallocated water in storage in reservoirs was not considered separately in this analysis. A reservoir is a part of the hydrologic cycle and does not create new water for later disbursement to users. Rather, a reservoir stores water during high flow years for later release during low flow years. The effect is that fluctuations in streamflow are reduced, a fact reflected in the flow duration curves by a reduction in the slope of the curve. Our flow duration curves downstream of reservoirs already reflect their hydrologic effects in reducing fluctuations in streamflow. An analysis of the hydrologic effects of specific reservoirs on a river basin is both time-consuming and costly. Furthermore, the data required for a consistent analysis of all reservoirs in the study areas (including data on location, maximum storage, normal storage, drainage area, inflow, and hydraulic head), though contained in the Corps of Engineers data base for the National Hydropower Study, are not available for general use. A brief discussion of marketing water from Bureau of Reclamation storage projects is presented in the following section.

B. Legal and Institutional Considerations

1. Introduction

Water availability, given the intricacy of federal and state laws and policies, could become a matter of profound importance in regard to where, or whether, a synfuel industry will be developed. For a successful national synfuel program, not only the hydrocarbon resources themselves, but water, must be available. Section A of this chapter indicates areas with adequate water and areas where water is in short supply. Some observers, in looking at gross river basin or gross regional flow figures have stated that sufficient water exists to support a given number of synfuel plants. Closer scouting of regional and state policies, however, reveals that energy companies seeking reliable water sources will encounter many problems in the East and West. As long as companies are required to find supplies of water in

the chaotic system that prevails, a feasible synfuels program will be hard pressed to flourish.

The allocation of water rights and the regulations that grant access to water are composed of federal and state laws that were shaped by piecemeal judicial decisions and that are overlaid with international treaty obligations and Indian rights (Dickson et al., 1976). Because these laws often conflict, the water-for-energy institutional problem could take 20 years or more to resolve. That issue, coupled with what the states will or will not do with their hydrocarbon resources, could result in serious federal-state confrontations. The West, where vast amounts of strippable coal are found and where water is often in short supply, will be the setting for the conflict, but Eastern coal states will not be exempt.

President Carter has called for increased development of domestic energy resources and has also declared that states have the primary authority for water management. At the same time, he has sought to de-emphasize water storage programs. These policies are mutually exclusive. The stage for conflict is set by the following:

(Water Resources Council) assessments indicate that water in excess of needs for other uses (including instream) could be made available for energy development; however, major investments in water development and management would be required. This investment...may reach \$500 million for water storage and transport facilities... A water program of this magnitude is major...^a

and

A supply of water for energy development may involve changes in present water uses; transfer of water rights and other legally binding actions may be required (Seinwill, 1979).

^aEmphasis added

In general, Congress has chosen to let the states manage water resources according to state laws and occasional court decisions. However, as indicated below, these state laws have serious shortcomings in regard to energy development--in part, because it is only in recent years that the Eastern and Western water supply systems have been subject to stresses of great magnitude that have in turn revealed legal flaws.

Indian water rights also constitute a matter of importance in the West. Depending on how these rights are resolved, a reliable source of water for energy development could result, or a substantial stumbling block to the provision of water under state allocation systems could be encountered.

The federal government will play a major role in allocating water: it is a property owner in the West; it approves of interstate compacts; it builds flood control projects in the East and reclamation dams in the West; it disburses irrigation water from its large reclamation projects; it is signatory to treaties with the Indians and with Canada and Mexico; and, it has a major interest in the development of domestic energy resources.

These elements,

- o State laws and policies
- o Indian water rights and Indian goals
- o Federal water rights and energy needs
- o International treaty obligations,

unfortunately conflict and their resolution is not in sight.

Thus, parallel attention should be paid to these legal problems when the water-for-energy problem is addressed.

2. State Systems: The West

The Western states follow the appropriation doctrine that awards water rights to the individual who diverts water from a stream for a beneficial use; if a water shortage occurs, the water right secured earliest prevails over the rights of more junior appropriators. For a long while these doctrines operated with little necessity for action by state governments and with few visits to local courthouses. As competition for water has increased over the years, however, permit systems and more sophisticated adjudication procedures have evolved. In the last 10 years, energy's demands for water have grown substantially, and state governments have taken an increasing interest in matters pertaining to water. In shaping water law systems to meet immediate needs, some states have virtually ignored the long term requirements of water for energy. Why states do so is understandable, but a federal synfuels program is thus left in an awkward situation.

Illustrative of the problem is action taken by the State of Montana. Pursuant to a constitutional change, Montana passed a sweeping new set of water laws in 1973. In 1974, a long-term moratorium was placed on the allocation of new water rights in the Yellowstone Basin while the Montana Department of Natural Resources and Conservation (DNRC) considered all aspects of the competition for Yellowstone River water. In December, 1978, DNRC announced its allocation prefacing its conclusions with the following reminder:

The ultimate responsibility (is) to the people of Montana in general, and to those in the Yellowstone Basin in particular.

The allocations that followed set forth specific municipal, instream, and irrigation uses, but no mention was made of water for industrial or energy uses. The implication is that water for energy development would come from the modest amounts of unreserved water that would exist only in high-flow years.^a

For energy companies seeking to obtain water from those who hold water rights in the western states, obstacles range from administrative resistance to statutory prohibition. Administrative resistance includes state inquiries (or court hearings) about whether the transfer would injure other holders of water rights. Such inquiries have taken years (W. R. Humm et al., 1979). The issue is more clear cut when state law decrees that a water right for a given use cannot be transferred by sale or other means to another use. This is the case in North Dakota, where an agricultural water right with a reliable, early priority date cannot be purchased by an energy developer for use in a synfuel plant. In South Dakota, water rights apply only to the land for which the original water right was granted. Thus, water rights are intrinsically connected with the land on which the water is used, thereby effectively precluding their transfer to energy development purposes, although the right might be usable if the synfuel plant were to be located on the parcel of land to which the water rights apply. In Arizona, transfer of water to a new place of use may be impeded by requirements for the approval of the transfer by irrigation districts or by water users' associations. In Wyoming, the State Engineer may disapprove a transfer if he determines that the proposed use is not in the "public interest"--a term that is not statutorily defined and that the Wyoming Supreme Court has had no occasion to interpret.

The concept of a "public interest" standard not only represents an increased sensitivity to water matters by state governments, it also may result in constraining energy development. It is not difficult to envision a state official or state agency finding a large synfuel plant not in the public interest, inasmuch as the "public" in this case means that state's public and not the nation as a whole. Similar problems are encountered when a state legislature is responsible for the final approval of large water appropriations--a category that would include water needed for a synfuel plant; South Dakota is such a

^aAt Billings there would be no such water in 3 years out of 10 and, at Miles City, there would be none 2 years out of 10.

state. By way of example, in 1977 the Montana legislature declared that the state's water could not be used to transport coal out of the state in a slurry pipeline because the legislature deemed this application of water not to be a beneficial use.

The prohibitions and inhibitions built into a state's statutes reflect a state's attitudes toward energy development. Additional indicators are found in the statements of public officials about water and energy. Contrast the following statements by two governors of the western region:

Governor Thomas Judge, Montana:

"We will determine at what pace development will proceed ... (and) how water will be allocated...." (Newsweek, September 17, 1979).

Governor Richard Lamm, Colorado:

"We are going to have to be a region with synfuel plants and wilderness side by side. Our streams must support fish and wildlife, agriculture and industry. It's going to require a good deal of creative planning to bring about that balance and harmony...." (Newsweek, September 17, 1979)

A 1977 study on state perspectives on water requirements for future energy development revealed that their receptiveness to the idea varied (Gertsch et al., 1977). Utah evidenced high receptiveness:

...Water should be available for those uses which offer the greatest promise of ... opportunities. In general, it is believed that this will accrue from municipal and industrial types of water uses;

and

Past experience indicates a general willingness of nonindustrial water users to sell their water rights to energy companies according to the market system.

Montana revealed low receptivity:

Construction of large-scale energy conversion facilities in Montana for export of energy products to other states will not be encouraged, unless no other alternatives exist;

and.

Only if such facilities are necessary to meet identified and defined Montana energy needs, will their construction be approved.^a

Attitudes and state statutes whose cumulative effect is negative would undoubtedly deter private investors seeking to establish a synfuel plant. Such uncertainty, which may delay construction plans, would then become a concern for the federal government and its energy program.

3. Indian Water Rights

Indian claims to water rights play a significant role in the West. These Indian rights, described by the U.S. Supreme Court in Winters v. United States (1908), provide water to the Indians. Subsequent court decisions further declared that these rights cannot be lost by abandonment or nonuse. Nor can the rights be altered by state law or by interstate compacts. In Arizona v. California (1963), the court established an irrigable acreage standard for determining the amount of water allocable to Indian reservations on the lower Colorado River. This resulted in almost 1,000,000 acre-feet of water for the Indians, or about 7% of the flow of the Colorado River.

In the Northern Great Plains, however, the "irrigable acreage" measure may be inappropriate.^a Strong arguments are set forth by the Crow and Northern Cheyenne Indians that the Indian rights should include the water necessary to support full development of the coal resources on Indian lands. Support for this nonirrigation use of Indian water is found in the recent supplemental decree to Arizona v. California; the court stated that the water rights shall be determined by an irrigable acreage test, but that the test "shall not constitute a restriction of

^aEmphasis added.

the usage of them to irrigation or other agricultural application (Supplemental Decree, Arizona v. California, 1979). This seems to indicate that the water to which the Indians on the Northern Great Plains reservations have rights to could be used to support coal development. (Although lacking further clarification by the court, the amount of water granted to these reservations would be based on irrigation needs.) Left unanswered is the question, whatever the measuring standard, of whether the Indians can sell or lease the water for industrial purposes off the reservation (e.g., for use in synfuel conversion plants at some distance from the reservation itself).

In the lower Colorado River area, the courts have ruled in favor of Indian tribes in that area; however, those same tribes are now dissatisfied and are seeking to increase the amount of water allocated to them. The Navajo tribes, whose rights have not been adjudicated, believe that they are entitled to at least 5,000,000 acre-feet of water from the Colorado River, or more than one-third of the river's flow. The Navajo have begun legal action to have their claims resolved (GAO, 1979). Water taken "off the top" of the river's flow to satisfy Indian demands has the highest legal priority (as high as federal reserved rights) on the river. This priority could prove a critical factor in determining whether water will be available for synfuel development from state allocation systems.

Resolving the Indian water rights issue is part of President Carter's call for a new, enlightened water policy at the federal level. The President has directed the Bureau of Indian Affairs to:

- o Develop and submit a plan for the review of Indian water claims to be conducted within the next 10 years
- o Develop technical criteria for classifying Indian lands that reflect and make allowance for water use associated with the maintenance of a permanent tribal homeland (Presidential Memorandum, 1978)

^aNote the presence of Indian reservations on important rivers and tributaries shown in Figure V-9.

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FIGURE V-9. INDIAN RESERVATIONS IN RELATION TO MAJOR RIVERS IN THE NORTHERN GREAT PLAINS

Moreover, he has directed all concerned agencies to formulate procedures to be used in evaluating projects for the development of Indian water resources and to increase Indian water development in conjunction with quantification of rights.

Some progress has been made by task forces acting on these issues (DOI, 1979). However, the Department of the Interior has not revealed its plans for quantification of Indian water rights while the matter is being discussed with the Indians. It is quite likely, however, that the amount the Indians think appropriate will be far greater than what the federal government thinks appropriate. Furthermore, Indians are divided among themselves about whether to have their water rights quantified. The position of the Joint Committee on Indian Water Rights states that:

Quantification of Indian Water Rights is neither necessary nor desirable at this time. A final determination, made at any given date, is inconsistent with the open-endedness of the right itself (Boyden, 1978).

Lawsuits involving Indian water rights are pending in federal and state courts in Wyoming and Montana. None, however, promises to resolve the underlying issues quickly because appeals will certainly follow and because courts traditionally decide cases as narrowly as possible, rather than on broad principle. Thus, many observers believe that the character and quantity of Indian water rights will best be resolved through good-faith negotiations on a basin-by-basin, reservation-by-reservation basis.

One such approach has been tried, with apparent success, in two areas. One is in Maricopa, Arizona, where in accord with a negotiated settlement, the Ak-Chin Indians accepted a quantity of water. The settlement was then acknowledged and confirmed by federal legislation (Lynch, 1979). Another negotiated settlement took place in Utah and involved the Ute Indian Tribe of the Uintah and Ouray Reservation. The agreement acknowledges the Ute's water rights and

assigns a priority date of 1861. The Ute Tribe agreed to defer use of its water right during the construction of the Central Utah Project, provided that the United States would develop storage facilities sufficient to allow the tribe to develop all of its lands. The Utah State Legislature and Congress approved this agreement (Boyden et al., 1978).

Indian communities are also divided about whether Indian resources, including coal, oil, gas, and uranium, in addition to water, should be developed. Indians are gravely concerned that economic development will irreparably harm their culture (McKee, 1979). A poll taken on the Crow Reservation illustrated the divided feeling (Crow Impact Study Office, 1977):

Question: Should Reservation land be disturbed or disrupted for coal mining?

	<u>Percent</u>
Yes	25
No	36
Undecided	39

Question: Should a power plant be built on the Reservation?

	<u>Percent</u>
Yes	16
No	48
Undecided	36

If Indian water rights are quantified and clarified, they can be marketed off the reservation, and a reliable source of water would become available for synfuel production. Alternatively, if the rights remain in legal limbo or if the Indians choose not to quantify them or market them, water allocation under state distribution systems will remain uncertain.^a

4. The Federal Role In The West

The complex federal involvement in western water matters was detailed in SRI's earlier study of synfuel development (Dickson et al., 1976). The U.S. government owns 50% of the land in western states. As a property owner, it can lay claim to waters flowing through it. In particular, it has a court-determined right to water that is necessary to support the purpose that the federal lands, which are reserved from public disposal, are intended for. Water runoff from federal lands constitutes 66% of the water in the Upper Missouri River Basin (including the Yellowstone) and 96% in the Upper Colorado River Basin. Article IV, Section 3, of the U.S. Constitution gives Congress "the power to dispose of and make all needful rules and regulations respecting the territory or the property belonging to the United States". Thus, in this regard, laws passed by the Congress supersede state laws, and the states cannot control "federal" water (Trelease, 1978).

Article I, Section 8, of the Constitution also gives the federal government power to regulate interstate commerce. The U.S. Supreme Court, in Gibbons v. Ogden, has interpreted this power to include control over the nation's navigable waters. Thus, even small tributaries come under the federal aegis, and state allocation of these waters must be carried on at the pleasure of the U.S. Congress (Trelease, 1978).

The federal government also disburses the water from those federally funded water storage areas that are part of the national reclamation and flood control program. The power of the U.S. government to sell stored Yellowstone River Basin water for industrial purposes has been affirmed at the U.S. District Court and Court of Appeals levels.

^aFor example, the Crow Indians claim the entire flow of the Bighorn River, and the Northern Cheyenne claim the entire flow of the Tongue River.

Finally, the federal government can enter into treaties with other sovereign states; in the past the government entered into treaties with Indian nations. Of interest here are the treaties between the United States and Indian tribes that reside in energy resource regions, and the treaty between the United States and Mexico regarding the waters of the Colorado River.

The water treaty with Mexico was entered into in 1944. It obligates the United States to provide 1,500,000 acre-feet of the Colorado's flow each year to Mexico.^a

Because the annual flows of the Colorado River have been well below 15,000,000 acre-feet, more than 10% of the river's water has been delivered to Mexico each year. Several points are to be made in regard to this obligation. First, because it is a treaty obligation, it has precedence over state law and interstate allocations. That is, the water obligated by treaty has to be delivered to Mexico before other allocations are considered. Second, it is extremely unlikely that the treaty will be abrogated for U.S. needs for water for energy. Mexico relies on this water to irrigate 450,000 acres in the Mexicali Valley. In addition, Congress has authorized the construction of a desalination facility near the U.S.-Mexican border so that the quality of the water that Mexico receives will be equal to or better than that found in the lower mainstem of the Colorado River (PL-93-320, 1974). Until the desalination plant is completed, the United States will release low-salinity water upstream to dilute the high-salinity water heading for the border. Because the water for dilution will come from the available water in the upper Colorado River Basin, the shortage of water for energy development will be exacerbated.

^aIn addition, "...in any year in which there shall exist in the river water in excess of that necessary to satisfy the requirements of the U.S. and the guaranteed quantity of 1,500,000 acre-feet...the U.S(will attempt) to supply additional quantities of water...up to a maximum of 1,700,000 acre-feet...."

Although federal powers over water distribution are indeed far-reaching, recent U.S. Supreme Court decisions have restricted federal water rights heretofore granted by statute and other court decisions. In California v. United States, (1978) the court found that Congress intended federal agencies, in this case the Bureau of Reclamation, to acquire water rights under state law; when such an acquisition involves conditions on those rights, the agency has to live with those conditions. In United States v. New Mexico, the court narrowed federal reserved rights strictly to their stated purposes--in this instance, to preserve timber and favorable water flows. The court rejected federal claims for aesthetic, environmental, recreational, stockwatering, and wildlife preservation purposes. In both cases, the court relied on Congress' intention, thereby implying that Congress could change the decision through legislation.

The federal government's attempted sale to industrial concerns of options on some 700,000 acre-feet of water in the Boysen and Yellowtail Reservoirs and the proposed sale of approximately 1,000,000 acre-feet of water from mainstem Missouri River dams have been unsuccessful. Even though such sales have survived legal challenge, options on the water have been allowed to expire. This has been attributed (1) to energy companies' concern that the federal government will not help construct the aqueducts and pipelines required to transport the water to where it will be needed and (2) to a concern that Yellowstone River Compact signatory states will not give the requisite unanimous approval for transporting water into the Gillette, Wyoming area for coal development there. (Article 10 of the Yellowstone River Compact prohibits the diversion of water out of the Yellowstone subbasin without the approval of the three signatory states--Wyoming, Montana, and North Dakota.)

In addition, controversy and tension between the states and the federal government is increasing over the "ownership" of the water stored in these reservoirs and over the true quantities available (i.e., water not yet allocated to other prior appropriators). For example,

when Montana set aside 80% of the Yellowstone flow for maintenance of instream values, the question was posed: Did that action reduce (or eliminate) reservoir water available for industrial marketing? The issue has not been resolved. The matter is further complicated because the federal government has chosen to allow the states concerned to market reservoir water in federally constructed impoundments.^a

The current status of industrial allocations and marketing from several Bureau of Reclamation reservoirs is shown in Table V-4. There are clearly large quantities of water potentially available for a synfuels industry if the conflicts discussed above can be resolved.

Congress is doing nothing about water for energy. Rather, it is letting the courts decide what they will about Congressional intent in dusty statutes of times past. Were Congress to chose to do so "there is little doubt that supremacy could be invoked and federal powers found to regulate and control the quantitative aspects of waters back to the smallest springs and tributaries and the deepest aquifers" (Trelease, 1978).

5. State Systems: The East

Until recently, the eastern United States has had sufficient water to satisfy all users. As a result, little recourse to common law riparian rights has been necessary in dealing with general issues of water for energy development and with specific issues of how to proceed if shortages cause a \$1.5 billion synfuel plant to face a shutdown. The issues were succinctly stated at a recent water resources conference:

^aNorth Dakota has chosen not to assume this function, leaving the federal government as the marketing agent of water in Lake Sakajawea (Garrison Dam).

Table V-4

STATUS OF SELECTED BUREAU OF RECLAMATION RESERVOIRS
LOCATED IN THE WESTERN STUDY AREAS

<u>Region</u>	<u>Reservoir</u>	<u>Industrial Allocation^a</u>	<u>Active Contracts^a</u>	<u>1978 Deliveries^a</u>
Upper Missouri	Boysen	135,000	35,000	0
	Yellowtail	697,000	200,000	0
Upper Colorado	Fontennelle	228,000	120,000	19,820
	Navajo	115,250	64,250	7,353
	Powell	142,000 ^b	142,000	17,943

^aAcre-feet per year.

^bCurrent or past contracts outstanding.

Source: U.S. Bureau of Reclamation.

...riparian law has certain inherent characteristics that make it unsuitable under conditions of intensive water use and conflict among competing interests (Bates, 1979).

The result is the bane of all high-cost projects: uncertainty.

The riparian doctrine and its shortcomings have been well-documented (Dickson et al., 1976). Riparian rights are incidental to lands bordering on streams; the water is generally limited to use on riparian lands. A user is not limited to a specified amount of water as is the case under the western appropriation system. Rather, the riparian user is entitled to a "reasonable use" of the water flowing by or through his land. In theory, when the stream flow is insufficient to satisfy all users because of low flow, the rule of "correlative rights" applies: all users must reduce their use equally. This system contrasts with the western appropriation system in which more recent appropriators are excluded from using water when shortages occur; senior users, on the other hand, continue to have the full amount of their water appropriation.

The limitations inherent in riparian uses and water rights restrict both interstate and interbasin transfers of water, thereby forcing energy facilities to locate on major waterways.

Because the concept of "reasonable use" is abstract and poorly defined in eastern water law, it leads to great uncertainty:

Since the right is not quantified, the user or potential user has difficulty establishing the magnitude of a particular right at a given time.... /The/ reasonableness criterion allows the magnitude of the water to change in time in response to exercise of previously unused rights or other changed conditions. In theory, a use considered reasonable at one point in time can even become unreasonable at some future time if conditions change sufficiently (Batie, 1979).

Except for a few efforts at codification, the riparian law is court-made--the product of piecemeal decisions made in the context of narrowly drawn lawsuits involving a limited number of parties. As a result, predicting the resolution of future conflicts entails much conjecture. Furthermore, the riparian doctrine involves private individuals, and state governments have participated minimally in the evolution of the doctrine. These aspects hamper management of water resources and make planning extremely difficult.

In the eastern coal states, only Kentucky and Maryland have enacted legislation that establishes an administrative permit system to deal with the shortcomings of the riparian doctrine. However, because of constitutional problems with existing property-like riparian rights, these systems supplement the riparian system rather than replace it. In addition, both states exclude agricultural and power-related uses of water from their statutory schemes. Nevertheless, some improvement has occurred, inasmuch as nonriparian users may be able to use water, and water can be allocated in times of shortage. However, because of the exclusions noted, and because of constitutional protections given to rights that might be cut back, it remains to be seen whether the systems will serve to equitably distribute water in times of shortages.

6. The Federal Role in the East

The role of the federal government in the eastern states is markedly different from that in the West. The government is not a major landholder in the eastern states and is therefore not a serious competitor for water supplies. Furthermore, water projects in the East have been constructed to keep flood waters from damaging lands in areas of high precipitation, rather than to provide water for semi-arid lands. Water retained for flood control and water from storage projects could be made available for synfuel projects. It is not clear who "owns" this water, however, or how its allocation would complement water allocated under the riparian doctrine.

Future federal flood control and water projects in the East will face the same environmental resistance as those in the West and will also encounter resistance at the Presidential level to structural alternatives for water planning. Thus it would seem unwise to plan a synfuel plant for a location where water storage opportunities are only hydrologic possibilities.

7. Concepts for Resolution of Water for Energy Needs

In seeking to resolve the problem of water for energy, it is most important to recognize that serious stress could be placed on federal-state relationships, especially in the West, if energy development and water matters are not dealt with carefully. It is also important to distinguish "water for energy development" from "water for industrial development" to allow the identification of federal water needs for a given amount of energy production. Specified amounts of water can thus be set aside, or "zoned," for energy production. Other industries seeking water would be required to obtain it under the state water allocation mechanisms that remain in effect. That is, federal "water for energy" would be similar to other federally reserved water in that it would be exempt from state control. Once the quantity required

was ascertained (on the basis of the number of conversion facilities desired), fixed amounts of the water would be appropriated by the federal government from unappropriated water in the states or it could be condemned, with compensation paid, in analogy to the acquisition of land for parks or military needs. Some water rights holders would be willing to sell their rights to the federal government for this water-for-energy "bank"--a situation that would present the least political tension. When this approach does not yield sufficient amounts of water, other water rights could possibly be condemned. Careful study would have to be made of which rights to condemn in this circumstance, because these water rights for energy use may only be needed for 50 years (or less) and some agricultural water is being put to use on marginal land.

Such a federally controlled "bank" of water could be leased to energy companies under strict conditions, including those that stipulated plant designs employing state-of-the-art technology to achieve minimum water use. Whether or not such leasing should be shared with the individual states, as is the marketing of reclamation water for industrial use now, is a subject for further analysis. Any of these actions would require new legislation in Congress (1) to establish the program, (2) to override conflicting state statutes, and (3) to provide money for purchasing the water rights and for compensating those whose rights are taken for this national purpose.

In riparian states, water could be marketed from federal storage and flood control sites (which is now done to some degree); the federal government could purchase riparian sites, with their concomitant water rights for lease to energy companies; the government could condemn riparian sites for lease, with compensation paid to the former owner; and the government could construct new water storage sites for water for energy, compensating those riparian rights damaged by taking water necessary for storage. In the riparian law states of the East, a \$1.5 billion synfuel plant could, without government intervention, incur unacceptable losses, by shutting down or curtailing operation during low stream flow periods.

In the Northern Great Plains, water for energy development might well be found on Indian reservations. If Indian rights are quantified and clarified for marketing off the reservation, reliable sources of water could be made available for synfuel production for areas near Indian reservations.

8. Map Presentations of Institutional Factors

Codifying the institutional constraints described in this section is difficult--especially so when several states must be compared. However, in an effort to provide an overview compatible with the other presentations of this report, we developed an institutional matrix for the western study areas (Table V-5) and one for the eastern study areas (Table V-6). Maps display the overall ratings and accompany the relevant tables as Figures V-10 and V-11, and V-12 and V-13, respectively.

In the West, Colorado, New Mexico, South Dakota, and Utah received the most favorable ratings, with Montana receiving the lowest rating. To illustrate, Colorado has a generally positive attitude toward developing its energy resources, including a willingness to contribute to meeting national needs. Moreover, Colorado's water laws will not particularly obstruct water use for energy needs. Transfers between basins and between uses are permitted, and have successfully taken place. Colorado does have some interstate compact problems, however, in that the state contributes 73% of the Colorado River's flow, but is allocated just 20% under the relevant compacts. Potential problems with Indian water rights may be encountered in downstream claims that the Navajo Tribes may make over and above those Indian rights already allocated by the U.S. Supreme Court in Arizona v. California. Federal reserved rights are also being adjudicated in Colorado, but these may not prove to be injurious amounts.

Table V-5

WESTERN STATES' WATER FOR ENERGY: INSTITUTIONAL FACTORS

	<u>State Policies^a</u>	<u>State Statutes^b</u>	<u>Interstate Compact Problems</u>	<u>Indian Water Issues</u>	<u>Federal Water Issues</u>	<u>Overall Rating</u>
Arizona	MH	MH	M	ML	MH	M
Colorado	MH	H	M	M	M	MH
Montana	L	L	L	L	MH	ML
New Mexico	MH	H	MH	ML	MH	MH
North Dakota	M	LM	H	M	MH	M
South Dakota	M	MH	H	M	MH	MH
Utah	H	H	MH	M	M	MH
Wyoming	MH	MH	L	L	MH	M

Key: High (H) Problems minimal
 Medium High (MH) Minor institutional problems
 Medium (M) Problems identified, reasonable solutions at hand
 Medium Low (ML) Serious problems, possible solutions available
 Low (L) Serious problems, no foreseeable solution

Source: ^aGould, 1979.
^bGertsch, 1977.

FIGURE V-10. RELATIVE EASE OF SITING BASED ON INSTITUTIONAL WATER CONSIDERATIONS

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FIGURE V-11. RELATIVE EASE OF SITING BASED ON INSTITUTIONAL WATER CONSIDERATIONS

Montana, by way of contrast, has indicated its resistance to having its water used for meeting national energy needs. Montana's statutes reflect this position. For example, the recent state allocations placed industrial and energy use far down the preferred list for Yellowstone River water. Montana is a signatory of the Yellowstone River Compact, which forbids transfers out of the Yellowstone River Basin without the consent of all the signatory states--a significant institutional constraint. Montana is also the site of Indian tribes that have made substantial claims to water flowing through the state, thus opening water rights allocated under state law to question. Nonetheless, Montana does have several large federal reservoirs that might provide water for energy development, provided that several key issues are resolved.

It is virtually impossible to compare the humid eastern states with the semiarid western states. The institutional factors found in the West arise because of the meager precipitation found there. Although the East has not heretofore been subject to problems that characterize western water, evolving eastern issues are now reaching a point where comparisons are possible. As illustrated in Table V-6, and in the accompanying maps, few distinctions can be made, except for a shift in water law to a permit system; these distinctions may be augmented by general state policies.

C. Water Quality

1. Background

Few studies have evaluated water quality effects of energy development in much detail. The assessment of the National Energy Plan by the national laboratories (Argonne National Laboratory, 1979) was the most comprehensive. Using the WRC subbasins for their geographic unit of comparison, they estimated the potential contamination given the projected development assuming only dilution of the pollutants. These mass balance calculations were made for total suspended solids, total dissolved solids, and trace elements for median and low flow conditions. We attempted to improve on

Table V-6

EASTERN STATES' WATER FOR ENERGY: INSTITUTIONAL FACTORS

	<u>Permit State^a</u>	<u>State Policies^b</u>	<u>Overall Rating</u>
Illinois	M	H	MH
Indiana	ML	MH	M
Kentucky	MH	H	MH
Maryland	MH	MH	MH
Ohio	ML	H	MH
Pennsylvania	ML	MH	M
Virginia	ML	MH	M
West Virginia	M	H	MH

Key: High (H) Problems minimal
 Medium High (MH) Minor institutional problems
 Medium (M) Problems identified, reasonable solutions at hand
 Medium Low (ML) Serious problems, possible solutions available
 Low (L) Serious problems, no foreseeable solution

^aIf the state has a permit system, a medium high rating is given; if not, a medium low rating is given. West Virginia moves from medium low to medium because it has a liberal water condemnation statute; Illinois moves up one step because nonriparian users can get water.

^bSource: Ross and Lewis, 1977.

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FIGURE V-12. RELATIVE EASE OF SITING BASED ON INSTITUTIONAL WATER CONSIDERATIONS

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FIGURE V-13. RELATIVE EASE OF SITING BASED ON INSTITUTIONAL WATER CONSIDERATIONS

this analysis by selecting smaller river basins as the basis for comparison and by determining how estimated contaminant levels in the streams compare with state standards for ambient water quality.

2. Description of Approach

We employed two basic assumptions in our assessment:

- o No discharge from synfuel facilities in the West.
- o Dilution effect in the receiving waters.

As most recent studies of water quality have done, we assumed that synfuel plants in the West will discharge no effluents. The cost of cleaning effluents sufficiently for discharge to receiving waters is much higher, given the limited nature of that resource in the West, than is extensive recycling of water with final discharge to evaporation ponds. Therefore, we have evaluated only the water quality effects of discharge from synfuel plants in the East.

We evaluated the effect on stream water quality by assuming that at least one synfuel plant was located in each river basin. We concentrated on evaluating the dilution effect of the discharge, and did not evaluate chemical kinetics in the receiving waters. (Such sophisticated analysis would be inappropriate, given the scope of our analysis.)

As discussed in an earlier chapter, we assumed that each synfuel plant would be required to meet NSPS established by the EPA that are similar to those established for refineries and steam electric power plants. On the basis of an analysis of those standards and assumptions about BAT for synfuel plants (see Appendix B), we estimated effluent rates for selected pollutants from a standard size plant as shown in Table V-7 (see Appendix E).

We needed to ascertain whether state standards would be violated by siting a synfuel plant in a particular river basin. Therefore, we restricted our analysis to pollutants for which state standards exist or for which some determination of acceptable water quality can be made.

Determining Ambient Water Quality. We obtained STORET data on ambient water quality from EPA. These data, when available, were obtained at the stream gages selected for the analysis of surface water flow. The data include all water quality parameters sampled, including temperature, streamflow, and concentrations of various organic and inorganic compounds.

Determining State Standards. We obtained state standards for all the river basins. In some cases, standards have been established for a particular stream, and in other cases general standards have been established that covered all streams in the state. For streams that cross state lines, we assumed that the strictest standard applied at the location of the stream gage.

Calculating Concentrations for Indicator Pollutants. We selected four indicator pollutants--total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), and phenols. Although no state standards exist at this time for TDS and TSS, both are considered to be important indicators of the water quality of a stream. We set limits of 1000 mg/l for TDS and 50 mg/l for TSS in our assessment. Standards for phenols were low--between 1 and 10 ppb--in the states evaluated, and as a result were of major influence in our water quality analysis.

Estimating Whether Standards Will be Violated. The final step in our assessment was to estimate whether limits set for the indicator pollutants were violated. The degree to which these standards could be met determined the basis for the ranking.

Table V-7

ESTIMATED EFFLUENT WATER QUALITY FOR 60,000 B/D
DIRECT COAL LIQUEFACTION PLANT

<u>Contaminant</u>	<u>Concentration (ppm)</u>	<u>Rate (lb/hr)^a</u>
Oil	5	20
Phenols	1	4
H ₂ S	1	4
NH ₃	10	35
BOD ₅	10	35
COD	50-100	175-350
TSS	10	35
TDS	3200	135 st/d

^aContaminant discharge for total plant effluent rate of 6,450 gpm, which includes discharge from on-site power generation.

3. Results

Relative Ease of Siting. Table V-8 lists the categories of ranking used in this assessment. The results are shown in Figures V-14 and V-15. Note that only the mainstem of the Ohio River is ranked high in Appalachia and that all other basins are ranked either medium or low. The Illinois region, on the other hand, has many basins that are ranked high. The phenol standard proved to be a major limiting factor in most river basins. TSS and TDS were only shown to be a problem where background concentrations were already high and the streams had low flow rates.

Table V-8

CATEGORIES OF RANKING FOR WATER QUALITY

High	All standards met.
Medium	No more than one standard violated.
Low	More than one standard violated.

Limitations of Approach. The broad assessment used here is no substitute for site-specific studies. Although our method is desirable for comparing relatively large river basins, it cannot be used to predict where actual water quality problems will occur. Rather, it identifies river basins with potential water quality problems. We have also based our assessment on assumed discharge rates. If actual standards are imposed that are significantly different from those assumed, our analysis could also change significantly. Finally, an energy facility could meet any standard and have no discharge of contaminants if it were willing to pay the cost. However, we cannot predict the future economics of water quality control for synfuel production. Nonetheless, our assessment does indicate the river basins

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FIGURE V-14. RELATIVE EASE OF SITING BASED ON WATER QUALITY

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Source: SRI Estimates

FIGURE V-15. RELATIVE EASE OF SITING BASED ON WATER QUALITY

in which water quality problems are likely to occur unless substantial capital over and above that mandated by regulations is invested to control discharges.

D. Overall Water Availability

As discussed in this chapter, the assessment of water availability is complex, involving a plethora of assumptions and nonquantifiable factors. We have evaluated the water resource from three perspectives--surface water flows, institutional factors, and water quality. The final step in the assessment is to develop a composite ranking that combines these three diverse analyses into one overall assessment of water availability. The results of this composite ranking are shown in Figures V-16 through V-19.

To arrive at this ranking, we used the same approach defined earlier for our overall ranking of the study areas (Chapter II). Simply stated, we took the maps showing the results for each part of the water analysis and overlaid them. We then determined how the rankings were affected by each other to arrive at the overall ranking. For example, in Western river basins, a ranking of "low" for surface water flows could be raised to an overall ranking of "medium," if the institutional factors were rated "high." On the other hand, a ranking of "medium" or "medium low," if institutional factors were ranked "low." Because institutional considerations are extremely important in the West, we weighted the rankings for institutional factors higher than those for surface water flows in the western regions. In the East, we allowed the lowest ranking for either water quality or quantity to be definitive so that, for example, if a basin was ranked medium for water quality, the overall ranking could be no higher than medium. Institutional factors were weighted lower in the East than in the West.

FIGURE V-16. RELATIVE EASE OF SITING BASED ON OVERALL WATER AVAILABILITY

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FIGURE V-17. RELATIVE EASE OF SITING BASED ON OVERALL WATER AVAILABILITY

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FIGURE V-18. RELATIVE EASE OF SITING BASED ON OVERALL WATER AVAILABILITY

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FIGURE V-19. RELATIVE EASE OF SITING BASED ON OVERALL WATER AVAILABILITY

Note first that much of the variation in rankings is eliminated and that most river basins move to a ranking of medium low, medium, or medium high. In the Northern Great Plains, some river basins formerly ranked as "high" have now been reduced to "medium high" or "medium" to reflect the negative influence of institutional factors in some states. In the Four Corners-Rocky Mountain study area, on the other hand, "low" rankings in the Upper Colorado River Basin have been raised to "medium low" as a result of the positive influence of institutional factors in Colorado. These overall rankings provide a useful way of comparing diverse regions of the country and for identifying areas in which the availability of water resources could place limitations on synfuel development.

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VI FEDERAL LAND MANAGEMENT

A. Introduction

In this chapter we examine the restrictions to mineral entry, prospecting, leasing, and development on federal lands in the western United States to determine how such restrictions may inhibit the development of a commercial synfuel industry that employs coal as a feedstock.

Federal lands contain a major portion of the demonstrated 200 billion ton reserve base of western coal, of which 16 billion tons is currently under federal lease, and another 10 billion tons is under preference right lease applications. About 60% of the known coal lands, or 68.3 million acres, are under federal control.

B. Federal Land Management Agencies

Management responsibilities for federal lands rest within several agencies of the Departments of Interior (DOI) and Agriculture (DOA). DOA's Forest Service (FS) manages 187 million acres in 173 separate units. Operated under the principles of multiple use and sustained yield, these forests are to provide lumber, recreation, wildlife habitat, livestock forage, water, and natural beauty.

DOI's National Park Service (NPS), Fish and Wildlife Service (FWS), and Bureau of Land Management (BLM) manage all other lands. The NPS's 300 parks, monuments, historic sites and recreation areas were created for the education and enjoyment of the public, for the protection of the natural environment, and for the preservation of historic areas. Acting under the Federal Land Policy and Management Act (FLPMA), BLM oversees

473 million acres in the West and Alaska. The Bureau is primarily involved in orderly resource development (e.g., oil and gas drilling, coal mining, grazing, recreation, and conservation). FWS, operating primarily as a conservator and environmental steward, manages 370 wildlife refugees on more than 30 million acres to assure the public the opportunity of benefitting from fish and wildlife.

C. Recent Legislation and Agency Actions

Aside from the basic enabling statutes, several critically important federal actions have been taken in recent years to regulate use of federal coal and to constrain mineral development on the lands described above. The Wilderness Act of 1964, the Multiple Use Sustained Yield Act (MUSYA), the FLPMA of 1976 and The Surface Mining Control and Reclamation Act of 1977 (SMCRA) have given rise to the agency regulations, programs, and actions analyzed below. Our analysis does not cover The National Environmental Protection Act of 1970 (NEPA), the environmental impact statement process, or the "normal" mineral entry, location and leasing system. Rather, we deal strictly with constraints to that process posed by the legislation described above.

1. Wilderness Act of 1964

This legislation formalized the wilderness preservation concept that had gradually been developed since 1924, when 574,000 acres of Gila National Forest in New Mexico were administratively classified as wilderness. The Wilderness Act set up a National Wilderness Preservation System (NWPS) and vested authority for additions to the NWPS solely with Congress. Wilderness is defined philosophically "as an area where the earth and its community are untrammelled by man, where man himself is a visitor who does not remain," and legally as undeveloped federal land without permanent improvements or habitation that (1) has been affected primarily by nature, (2) has outstanding opportunities for solitude or nonmechanized recreation, (3) is larger than 4,000 acres,

and (4) may be of ecological, geological, scientific, educational, scenic, or historic value. FS and NPS reviewed roadless areas of 5,000 acres or more and recommended their ultimate disposition. Subject to valid existing rights and mineral entry through 1983, roads, installations, commercial operations, use of motorized vehicle and aircraft are prohibited. Prospecting and mining may continue--the latter in the same manner and degree as conducted before passage of the act.

2. Multiple Use - Sustained Yield Act

This act empowers FS to enhance the availability of wood, water, wildlife, fish, forage, wilderness, and outdoor recreation through (1) zoning all lands for multiple uses (2) analyzing impacts before resource development occurs. Wilderness management was also established to leave such areas unimpaired for future use and enjoyment, with their wilderness characteristics preserved. The goal of mineral management is to integrate resource discovery and development with use and protection of other values.

3. Federal Land Policy and Management Act

FLPMA applies the concepts of the Wilderness Act and MUSYA to BLM lands. The law keeps public lands in federal ownership and requires consideration of all potential uses of each area before management decisions are made. Wilderness preservation was added to BLM's responsibilities, and an inventory and study process has been undertaken to recommend additions to the NWPS by 1991. Existing mining and leasing were grandfathered "in the manner and degree in which the same were being conducted on the date of approval of this Act." Other uses are permitted if they do not impair the suitability of an area as wilderness, and all uses may be regulated to prevent undue or unnecessary degradation and to protect the environment.

4. Surface Mining Control and Reclamation Act

SMCRA is primarily intended to establish performance standards to regulate coal mining, but it also places land use controls on mining on federal (and nonfederal) lands. Mining in national parks, monuments, and wildlife refuges is prohibited (subject to valid existing rights and with the exclusion of some units outside our study area). Alluvial valley floors and prime farm lands are recognized as lands deserving special protection, and mining is only permitted in such areas under stringent controls. In addition, a process for administratively determining "lands unsuitable for surface coal mining" was created under which the public may petition to have certain specific areas protected from mining, if they meet certain criteria.

5. Roadless Area Review and Evaluation (RARE II)

FS established the Roadless Area Review and Evaluation (RARE) process to execute its responsibilities under the Wilderness Act. All roadless tracts within national forests were to be inventoried and their suitability and quality for wilderness preservation determined. The initial RARE covered 1449 tracts and 56 million acres but is considered to have had major shortcomings. In 1977, RARE II was established to make recommendations to Congress for allocation of all roadless areas into three categories - wilderness, nonwilderness and further planning - with Congress making final determinations by legislation. About 3,000 tracts encompassing 62 million acres, were reviewed and the final recommendations were:

<u>Classification</u>	<u>Size (Acres)</u>	<u>Number of Tracts</u>
Wilderness 15,088,838	624	
Nonwilderness 36,151,588	1981	
Further planning 10,796,508	314	

The final programmatic policy was to balance two goals: emphasis on high resource output, with consideration of high wilderness attributes, and emphasis on preserving areas with highest wilderness attributes, with secondary consideration given to high resource production potential.

FS recommendations were modified by the current Administration and are now before Congress.

6. BLM Wilderness Program

A long-term land inventory and classification project is now in its initial stages at BLM. All roadless areas greater than 5,000 acres are to be reviewed for wilderness characteristics, and recommendations to the President are to be made by 1991. The criteria of the Wilderness Act are to be applied, thus making this program the BLM analog of RARE II. The review is broken up into three elements:

- (1) Inventory--identifying wilderness study areas (WSAs) meeting wilderness criteria
- (2) Study--considering all values and resources, making allocations
- (3) Reporting--sending results to the President and Congress for action and addition to NWPS.

In addition, provisions have been made for study by July 1980 of areas that BLM has designated as natural or primitive and for interim management of WSAs to protect their values.

D. Restrictions on Coal Exploration, Leasing, and Mining on Federal Lands

Complex and often confusing overlapping regulations have been enacted to control access to minerals on federal lands. The Mining Laws of 1892 and 1920 regulate exploration, location, and leasing, and the statutes discussed above also place additional restrictions on these activities for lands in special categories of lands are closed to mineral exploration or development: national parks, monuments, wildlife refuges, and NWPS. This prohibition is subject to valid rights existing at the time of designation. Because NWPS lands undergo recurrent mineral surveys, Congress could presumably redesignate certain areas. The lands are also subject to mineral exploration and leasing until 1984, and existing mining and prospecting can continue "to the same manner and degree" as they have been conducted.

Non-wilderness RARE II lands will be open to coal exploration and subsequent mining. Further planning areas will be surveyed for minerals and exploratory drilling, and prospecting will be allowed to the extent that wilderness characteristics are not impaired.

Lands administered by BLM are subject to restrictions during the wilderness inventory and study. BLM has developed a draft interim management policy to govern those that have been identified by the inventory process as WSAs. The interim management program has three objectives: to prevent impairment of wilderness values; to allow existing mining and grazing to continue in the same manner and to the degree in effect on October 21, 1976, while at the same time preventing undue or unnecessary degradation and protecting the environment; and to disrupt resource use as little as possible during the wilderness review.

New mineral activities are permitted in WSAs if they have only temporary impacts. In any case, however, no new roads, structures, or installations are permitted. Existing structures may be maintained but not improved. If an area has not been inventoried, an accelerated inventory must take place concurrently with the NEPA process normally required for a major resource proposal. If the area is unsuitable for wilderness, the normal BLM land management process continues. If it is

classified as a WSA, no surface coal mine leasing can occur. Existing preference right leases may be granted if the operation does not unduly or unnecessarily degrade the environment. Coal exploration may occur, subject to environmental analysis and stipulation.

E. Analytical Approach

We examined legislative and administrative actions that restrict coal mining to determine how much they might constrain synfuel development. The constraint levels were determined on the basis of the general qualitative level of the analysis and the degree to which exploration, mining, and coal conversion plant siting would be prevented. Only primary and secondary counties previously identified were analyzed.

On the basis of those considerations and on the availability of suitable data, we developed four general constraint categories in which 10 federal land management units were placed (See Table VI-1). Then, we determined the existence of such units and their locations within the primary and secondary coal counties, and we mapped them. The results are displayed graphically in Figures VI-1 and VI-2. These categories also attempt to recognize political realities in terms of citizen acceptance of various uses.

Note that these are relative constraint levels: For example, land use controls on mining in national forests are moderate in relationship to similar controls that pertain to national parks. In addition, the BLM wilderness inventory is in such a preliminary state that consistent, accurate maps are not yet available. Nonetheless, all BLM lands have been identified although it must be understood that further restrictions

^aSingly hatched green areas of these maps indicate BLM land and national forests that are in scattered ownership patterns (e.g., alternating sections).

Table VI-1

FEDERAL LAND MANAGEMENT CONSTRAINTS TO MINING
AND SYN FUEL PLANT SITING

<u>Constraint</u>	<u>Relative Ease Of Siting</u>	<u>Land Classification</u>
Absolute	Low	National parks
		National monuments
		National Wildlife Refugees
		National wilderness preservation system
Severe	Medium Low	RARE II wilderness
		Administration endorsed wilderness
Moderate	Medium	RARE II further planning
		National forests and BLM lands
Minor	Medium High	National forests and BLM lands with scattered ownership patterns

may be imposed. The analysis presented here should thus not be construed as a substitute for site-specific or even county-specific analyses.

F. Results

Inspection of Figures VI-1 and VI-2 show that federal land use controls will not seriously constrain siting of coal mines or synfuel plants within the western study areas. In only three counties

(Hinsdale, Pitkin, and San Juan, Colorado) do absolute constraints exceed 25% of the total acreage, but in no county does the area so controlled exceed 50%. Two Colorado counties reach the 25-50% level of severely constrained land. Neither are coal resource counties. Several coal resource counties have more than 25% of their land in national forests (Sheridan, Wyoming; Billings and McKenzie, North Dakota; Garfield, Utah; and Gunnison and Routt, Colorado). The only coal resource county with more than 50% of its area under federal control is Gunnison, Colorado, whereas nine non-resource counties have a majority of their surfaces in Federal ownership. The Four Corners area of Colorado and Utah is the only area where significant conflicts are likely to occur; the Northern Great Plains are relatively free of federal lands.

FIGURE VI-1. FEDERAL LAND MANAGEMENT IN NORTHERN GREAT PLAINS AREA

VII SOCIOECONOMIC CAPACITY

A. Introduction

Full-scale commercial synfuel production has potential for causing major social and economic impacts in the areas surrounding the conversion plants. This section outlines the first step in a strategy designed to minimize such impacts. The impacts result from a combination of the rapid buildup of a large construction work force followed by a sharp decline to a much smaller operating work force, and from the location of the coal and oil shale resources in largely unpopulated rural areas. In some cases, these factors may combine to cause a "boomtown" phenomenon on a scale even more massive than happened in recent energy boomtowns in the West. On the other hand, when a siting opportunity exists in an area with (or with access to) substantial urban resources, the potential for severe dislocation is greatly lessened. We have developed a method for ranking each study area's potential to absorb socioeconomic impacts induced by synfuel development. When combined with the results of other siting analyses, these results will identify candidate areas for further consideration and more site-specific analysis.

B. Socioeconomic Impacts of Synfuel Facilities

1. Industrial Growth Impacts

The most dramatic socioeconomic impacts of synfuel plants will result from the associated population increase in the areas around the plants. The community growth induced by synfuel or other kinds of basic industrial development is diagrammed in Figure VII-1. A detailed

FIGURE VII-1. SCHEMATIC OF COMMUNITY GROWTH INDUCED BY INDUSTRIAL DEVELOPMENT

discussion of this process can be found in Dickson et al. (1976 and 1977). An abbreviated explanation of the process follows.

The construction and operation of the plant will result in new jobs in the region. The plant will generate increased business for supplying and supporting industries (e.g., construction materials, transportation facilities), and this activity will also generate increased employment. Depending on whether the increased employment opportunities are filled by local residents or by newcomers, the plant activities can cause a population influx in the community. The increased income generated by the plant and increased population will result in heightened demand for publicly and privately provided goods and services such as schools, shopping, housing, water, and sewage treatment. Provision of these goods and services will again result in employment opportunities, some of which will be filled by current residents and some by in-migrants.

Many of the socioeconomic impacts of synfuels development depend on the extent and rate at which the new employment triggers population growth in the areas surrounding the plant. If most of the primary and secondary jobs are filled by local residents, in-migration will be minimal. If, on the other hand, most jobs are filled by in-migrants, the effects of the population change could be quite severe, especially in sparsely populated areas.

Rapid population growth can result in a higher demand for publicly and privately provided goods, infrastructure, and services. It can also result in higher local income; higher prices; and a change in the fabric and quality of life. The impacts of growth can be both positive and negative, depending on (a) the ability of local human and urban resources to meet higher levels of demand, (b) the size of the population influx relative to the existing population, (c) the quality of local management of the growth process, and (d) the willingness of the community to undergo major social changes.

When growth is too rapid, local resources cannot respond in a timely and efficient manner and a boomtown may result. Boomtown phenomena have been described in detail elsewhere (Dickson et al., 1976 and 1977). They include deficiencies in local facilities and services, housing problems, social disruption, and abandonment problems (Gilmore, 1979). On the other hand, an urban community with excess capacity in public and private infrastructure may experience only moderate impacts from growth. Likewise, impacts can be modified by planning, cooperation between resource developers and public officials, and timely and adequate provision of capital for private and public sector expansion (Pierce, 1979), even in smaller communities.

The settlement patterns of in-migrant workers will affect the level of impact caused by industrial development. Workers in a synfuels plant located in a County will choose between housing from residential areas both in and outside the county. A number of factors affect the worker's locational choice, including commute distance, price and quality of available housing, and the availability of publicly and privately provided goods and services. If a plant is located near a number of attractive communities, the population inflow may be spread over a wide enough area to minimize (or at least partially alleviate) the impacts. On the other hand, when a plant is located in an isolated rural area, the population inflow is likely to be concentrated in a few communities, and the resulting impacts will be much greater.

2. Synfuels Growth Impacts

The various coal conversion and oil shale technologies have different work force requirements (see Figure VII-2). The Fischer-Tropsch coal liquefaction technology has the most demanding employment schedule, with construction jobs increasing from nothing to 2,500 in the first year, reaching a peak of about 10,000 in slightly more than 3 years, and then dropping to a permanent operating work force of 1,000 by the fifth year. For the Paraho oil shale process, the contrast between the peak and permanent work forces is similar, although less dramatic,

Source: SRI

FIGURE VII-2. WORK FORCE REQUIREMENTS FOR OIL SHALE VS. COAL LIQUIFICATION

largely because mining and processing activities occur at the same site and cannot be separated. (We have not considered mining impacts for coal liquefaction.) In addition, the oil shale extraction process does not entail the short, intense construction period followed by capital- as opposed to labor-intensive operation period, as does coal liquefaction (see Chapter III, Technology Characterization). However, the ratio between peak and permanent employment is still nearly 2 to 1. This ratio has major consequences, as indicated below.

For most of the study areas under consideration, the vast majority of the plant's construction and operating labor force will have to be recruited from outside the region. Many coal counties in the West are not within commuting distances of an adequate labor pool with relevant construction and manufacturing skills. In addition, it is quite probable that a fully developed industry will result in a highly trained group of synfuels construction workers who travel from plant to plant, much like power plant and nuclear plant construction workers. Such a pool of workers would make it quite unlikely that companies would set up expensive and time-consuming training programs for local workers for the relatively short construction phase. In these areas, then, synfuels plant construction will result in substantial in-migration of workers and their families. Hiring and training of local workers is more likely to occur in the permanent operating phase of a synfuels facility.

Some coal counties are within commuting distance of a large pool of potential workers. These counties, largely found in the East or near the small number of medium-sized cities in the West (e.g., Billings and Minot), are more likely to be able to fulfill hiring requirements from within the region. Of course, the presence of construction and manufacturing workers does not guarantee that these workers have the skills necessary for the synfuel construction process or that they can be lured away from their current jobs. However, these counties do have greater potential for more local hiring (see Section VII-D, Method), and thus less population growth.

To consider the potential population impacts of synfuel development, simple employment multipliers have been estimated for the Northern Great Plains and Appalachian regions for both construction and operating phases. To arrive at the total population increase, these multipliers estimate the basic and secondary employment generated by each synfuel job and the number of family members associated with each new job (see Table VII-1). (For a discussion of how population multipliers are derived, see Dickson et al. (1976 and 1977). The elements (important ratios) of this population multiplier are summarized below.

$$\text{Population Multiplier (P)} = \left[\frac{\text{In-migrant Basic worker}}{\text{Basic Job (B)}} + \left(\frac{\text{New Secondary Job (S)}}{\text{New Basic Job}} \times \frac{\text{In-migrant Secondary Workers}}{\text{New Secondary Job}} \right) \right] \times \frac{\text{Total Family size}}{\text{New Worker}} \quad (F)$$

(I_B) (I_S)

This conservative multiplier assumes that the new plant activity is the only additional basic job, whereas in actuality increased activity in other basic sectors such as mining or transportation is likely. The number of secondary jobs per basic job (S) is derived from the ratio between these employment categories in the present local economy. Again, this estimate is quite conservative because this ratio is likely to increase in areas where the total population growth is large compared to the current population. Total family size (F) is derived from one of two sources: survey data of the actual demographic characteristics of local resource workers (e.g., the Construction Worker Profile) or the ratio of total population to labor force.

If all workers are hired from outside the region, then I_B = 1 and I_S = S. The population multiplier so derived represents a high estimated population growth from synfuels development. The only available estimate for construction (i.e., short-term) multipliers is 4.6 (see Table VII-1), considerably less than most operating phase estimates. The low multiplier estimate for Wise County is consistent with the region's low level of economic development. In this case, leakages of

Table VII-1

SAMPLE POPULATION MULTIPLIERS

<u>County</u>	<u>Type of Multiplier^a</u>	<u>Multiplier (P)^b</u>	<u>S</u>	<u>F</u>
Wise, Virginia ^c	Operating	4.6	1.86	2.5 ^d
Dickenson, Virginia ^c	Operating	5.3	1.86	2.86
Mercer, North Dakota ^e	Operating	6.3	1.69	3.74
Rosebud, Montana ^e	Operating	5.1	1.96	2.36
Rosebud, Montana ^e	Construction	4.6	1.96	2.62
Western counties ^e	Construction	4.6	2.0 ^f	2.28
Western counties ^e	Operating	6.6	2.56	2.58

^aThe impacts of construction and operating period multipliers differ because of the difference between temporary construction jobs and permanent operating jobs. Construction workers are younger and less likely to have families who move with them than operating workers. Permanent operating employment will stimulate more secondary employment than temporary construction employment.

^bBecause $I_B = 1$ and $I_S = S$, $P = (S) \times (F)$.

^c"Analysis of Public Sector Capital Markets in Wise and Dickenson Counties, VA." (1978)

Source: Denver Research Institute

^dFor Appalachian counties, $F = 1/(\text{labor force participation rate})$.

^eMountain West Research, Construction Worker Profile (1976)

^fFor western county summary, S is derived by assuming that the number of new jobs generated in each sector locally is proportional to the amount of income generated in each sector locally. This is likely to underestimate the growth in secondary employment because (a) smaller economies are often more labor- versus capital-intensive, and (b) new basic jobs are generally higher-wage than new secondary jobs.

generated economic activity to neighboring trade areas are greater than for the Western counties considered.

As an example of the population impacts of synfuel development, estimates of potential population growth for three different sized counties were made using the multipliers developed above, (see Table VII-2, Sample Population Inflow Estimates). These estimates are illustrative of the magnitude of the potential impact of a single synfuel plant sited within particular counties. To the extent that local labor is used and that excess capacity in the provision of private and public goods and services exists, a county may have far smaller population inflows. However, the potential inflow is quite large, especially when compared to recent population levels. In the smaller counties, a boom phenomenon is likely.

The dramatic decrease in work force in the operating phase points out another area of potential impact. Because the tremendous initial population inflow is temporary, the local private and public sectors will have little incentive to provide large sums of money for meeting the needs of the construction phase population. If work force requirements could be made more constant by stretching the construction period or by building several plants in the same area in sequence, the alleviation of the spectre of imminent bust would provide more incentive to supply the services required by the boom.

C. Overall Approach

We developed a method to stratify study areas on the basis of their potential capacity to absorb the socioeconomic impacts of synfuel-induced growth. A county level of analysis was selected for study for three reasons: (1) maximum consistency with other sections of this study; (2) compatibility with available data sources; and (3) the need to keep the scope of the task to a manageable size. Using counties as

Table VII-2

SAMPLE POPULATION INFLOW ESTIMATES^a
FOR A SINGLE FISCHER-TROPSCH FACILITY

<u>County</u>	<u>Construction Population Inflow^b</u>	<u>Operating Population Inflow^c</u>	<u>1975 Population</u>
Rosebud, Montana	46,000	5,130	9,700
Wise, Virginia	46,000 ^d	4,600	40,900
Yellowstone, Montana	46,000	6,600	97,220

^aPopulation inflow = $P \times$ number of construction or operating jobs.
Assumes all workers hired from outside the county and that all workers live in the same county as the plant is located.

^bAssuming work force requirements for Fischer-Tropsch coal liquefaction, construction work force requirements of 10,000 measured at the peak, or 3 years into the construction period.

^cFischer-Tropsch operating work force of 1,000 measured at Year 5.

^dEstimate based on P calculated for operating phase. This estimate is likely to err on the high side.

Sources: SRI calculations; U.S. Census; Table VII-1.

the basic unit of measurement presents one problem, however: Geopolitical boundaries are often inconsistent with the social and economic activities that should be measured. For instance, urban resources within commuting distance from a county's border may not be within commuting distance from a plant located in the far corner of that county. Ultimately, site-specific analysis will be needed to refine these estimates of capacity.

Several approaches to measuring absorptive capacity for the 324 study counties were considered. To predict synfuel plants' impacts with complete accuracy, however, an analysis would have to incorporate a full understanding of each study county's baseline conditions and projected changes in the absence of synfuel development in order to estimate the unique impact of the plant on each county. Although that extensive analysis is important to the understanding of the socioeconomic issues involved, it is clearly beyond the scope of this effort. Therefore, we chose an approach that separates counties into broad categories by their potential for successfully absorbing the impacts.

For each county, we considered indicators of potential capacity, choosing those indicators for which data were available, those whose relationship to major areas of socioeconomic impact was known, and those that allowed us to distinguish between the ability of different areas to absorb those impacts. For each indicator used, we defined a region of influence around each study county. Our approach thus considers a county and its supporting region.

The analysis is static in that it compares study counties on the basis of existing socioeconomic characteristics to establish those counties that have higher potential capacity. For a discussion of the limitations of this approach, see Section F. The approach results in the stratification of study counties into broad groupings of probable capacity levels.

D. Method for Ranking Counties

We employed a two-step method for separating counties into groupings of high, medium high, medium low, and low.

1. Initial Screening

In the first step, we developed a way to identify counties with very high or very low potential absorptive capacity. These areas were removed from further study because they clearly differed from most of the counties in the study regions. We chose population as the indicator for this initial screening because it is the strongest proxy for the available infrastructure in a county. The larger the county, the greater the likelihood of it being able to meet the employment needs of the facility and the infrastructure demands of increased population. In recognition of the limitations of using a single variable to make this judgment, we relied on extremely conservative measures.

To be ranked in the "high" category, a county had to have a population of 250,000 or more. A county of this size would have extensive human and urban resources, and would be more likely to be able to satisfy a large portion of demands of synfuel siting, including supplying a significant fraction of the construction and operating labor force (see Figure VII-2) from within those resources. We chose to consider only county, not regional, population for county inclusion in the high category—a conservative decision.

On the other hand, if a plant were to be located in a sparsely populated, isolated county, potential socioeconomic impacts would be maximized. Such a county would not be expected to be able to satisfy synfuel demands from local resources, and most of the work force would be in-migrants. High worker in-migration would result in population inflows nearly as large as the sample maximum inflow estimates in Table VII-2. In a region of 40,000 or less, a plant siting could result in more than doubling the population in 3 years, followed by a traumatic

population decline in the operating phase. A boomtown phenomenon would surely develop. Thus, if the population of a county and its proximate areas was 40,000 or less, we judged its potential absorption capacity to be low.

To properly account for the support population upon which a developing county will draw, a region around each study county (except counties ranked "high") was defined. Experience with western energy boomtowns has shown that people are willing to travel long distances for housing, shopping, and other services (Dickson et al., 1977). The ability of a nearby area to provide resources to meet synfuels-induced demand depends on the attractiveness of that area to synfuels workers. Assuming that people will venture further to seek the resources of a larger area than a smaller one, we have defined attractiveness in terms of distance and size. For example, a small area (population 20,000) at a great distance (more than 40 miles) is not so attractive a resource base as a larger city (e.g., 60,000) at an even greater distance (e.g., 60 miles). Rules for inclusion of proximate areas in each study county's regional population base are displayed in Table VII-3.

Table VII-3

REGIONAL PROXIMATE POPULATION FOR STUDY COUNTIES

<u>Population Included</u>	<u>Maximum Distance Away</u>
10,000 to 20,000	10 miles
20,000 to 60,000	40 miles
60,000 to 100,000	60 miles
100,000(+)	100 miles

Distances were measured from study county border to area border along existing major roads to assure that proximate areas were actually accessible. In the West, proximate areas were defined as cities and towns. In the East, whole counties were used. This distinction was made because western counties have sparser populations and larger

geographic areas than do the more densely populated, smaller eastern counties.

The counties that ranked either high or low were not treated in the second step, although data on them were collected. The majority of the study counties fell into neither category and were ranked medium high or medium low in the second step.

2. County Stratification

Counties that fell into the medium category were ranked on the basis of five indicators. Each indicator, its relationship to synfuels socioeconomic impacts, and how it was measured is discussed below. A schematic of the relationship of indicators to a study county is shown in Figure VII-3.

Population Centers. This indicator is designed to represent the urban resources (i.e., public and private infrastructure) available to each study county. It is a measure that considers the concentration of population, as opposed to the mere number of people in the region. Proximity and size of population centers is important in assessing capacity. A single population center of 15,000 is likely to have a higher level of urban resources than three centers of 5,000 each. Note the distinction between this measure and the one used in the first step. In that step, we asked how many people reside in the region; in this step, we ask how that population is distributed.

The measurement of this indicator is shown in Table VII-4. U.S. Census population estimates were used. Distances are in road miles. Proximate areas were defined as cities in the West and counties in the East.

Historical Growth Rate. This indicator was used to reflect an area's potential capacity to accommodate future growth on the basis of its recent growth history. A county with a history of long-term, moderately high growth could be expected to have developed mechanisms and

FIGURE VII-3. SCHEMATIC OF RANKING METHODOLOGY

Table VII-4

RATING OF PROXIMATE POPULATION CENTERS

<u>Rank</u>	<u>Characteristics</u>
High	60,000+ population within 50 miles
Medium	100,000+ population between 60 and 100 miles, or 60,000+ population between 50 and 60 miles, or 20,000-60,000 population within 40 miles
Low	All others.

resources to cope with future growth. On the other hand, an area with recent history of high, short-term growth may have already exceeded its capacity to cope with another large influx. All other cases were considered ambiguous and therefore given a neutral, medium rating. This indicator was measured for a region comprising the study county and all proximate areas as defined in the first step.

Table VII-5

HISTORICAL GROWTH RATE

<u>Rank</u>	<u>Compound Average Growth Rate</u>
High	1960-1975 growth rate between 1% and 3%
Low	1970-1975 growth rate of 5% or more
Medium	All others.

Available Labor Force. This indicator is a rough measure of the in-migration that may be required to satisfy employment generated by the plant. The availability of secondary-sector labor is not considered. Construction and manufacturing employees were measured because the plant's construction labor force will be drawn from these skill groups.

As previously stated, the mere presence of manufacturing and construction workers in a region is no guarantee that plant labor needs can be satisfied locally. However, many areas have far fewer employees in these broad categories than the plant requires (some have virtually none), and it is a safe assumption that these areas will have higher worker in-migration than an area with many times more workers in these fields.

A construction labor supply support region for each study county was defined. In the West, a commute distance of 75 road-miles (measured from county border to county border) was used to define the region, whereas in the East 50 road-miles were used. This reflects the history of tolerance of longer commutes in the West (Dickson et al., 1977).

For this indicator, the counties were compared to each other and ranked high, medium, and low. One-third of the counties were placed into each category.

Table VII-6

LABOR FORCE AVAILABILITY

<u>Rank</u>	<u>Size of Construction/ Manufacturing Labor Force</u>
High	Top one-third
Medium	Middle one-third
Low	Bottom one-third

For this measure, the larger this sector of the labor force, the higher the potential for local hiring and lesser in-migration. No attempt has been made to establish the relationship between labor force size and local versus in-migrant hiring. Recent experience with western power

plant projects has shown a greater tendency to invest in job training for local residents and to fill permanent jobs operating the plant from the community (Kroll, 1979).

Percent of Income from Agriculture. This indicator measures the dominance of agriculture in the local economy. Introduction of a major new industrial activity in a predominantly agricultural community will disrupt that area more than it would in an area without this potential conflict. Of course, there is potential for economic disruption of other activities (e.g., a steel mill might suddenly be in competition for industrial workers with a synfuel plant). However, disruption of agricultural activities usually entail a major change in the quality of life for farmers and ranchers. In areas dominated by agriculture less economic diversity exists, indicating that the facilities and services needed to support nonagricultural ventures may not be in place. In addition, a high level of agriculture activity indicates that potential conflict over water and land use may occur, as well as between agrarian and "newcomer" lifestyles.

Table VII-7 shows how counties were rated on this measure. Income for 1974, 1975, and 1976 was averaged to account for fluctuations in agricultural production. Counties were compared to each other and ranked from lowest percentage of income from agriculture (high ranking) to highest percentage (low ranking). This measure considers the study county only.

Table VII-7

DOMINANCE OF AGRICULTURE

<u>Rank</u>	<u>Percent of Income from Agriculture</u>
High	Bottom one-third
Medium	Middle one-third
Low	Top one-third

Median Age. The potential for conflict between "newcomers" and "old timers" is, in part, indicated by the differences in the age profiles of the two groups. The construction work force, in particular, tends to be young and mobile. The average age of construction workers in representative rural energy construction projects is 22.5. (Mountain West Research, 1975). The older the resident population, the more likely that the construction activities will be disruptive. Older individuals are more likely to be on fixed incomes and to suffer from the increased cost of living caused by large-scale energy development. Older individuals are also less likely to be receptive to the change that a synfuel plant will bring. Furthermore, a young work force has different needs for services and facilities (e.g., recreation and schools) than an older population. Median age is measured for the study county only.

Table VII-8

MEDIAN AGE

<u>Rank</u>	<u>Years</u>
High	Younger than 24.5
Medium	24.6 to 28.5
Low	Older than 28.6

3. Scoring

Table VII-9 shows how the various indicators were scored. Note that infrastructure indicators were assigned heavier weights than social disruption indicators. The scores for each indicator were summed to give a total score for each county in the "medium" category. We analyzed 999 study and proximate counties; data manipulation was done by computer.

Table VII-9

SCORING

Indicator Ranking	Infrastructure			Social Disruption	
	Population Center	Growth Rate	Labor Force	Dominance of Agriculture	Median Age
High	6	5	4	3	3
Medium	4	4	4	2	2
Low	2	2	2	1	1

E. Results

Table VII-10 shows how county rankings are distributed by using the method described above. Only seven counties, or approximately 2%, had large enough populations to be classified as having high potential for absorbing synfuel-induced growth impacts. The Appalachian and Four-Corners/Rocky Mountain study areas each have two counties with 250,000 or more residents, and the Illinois Basin has three such counties.

Approximately 22%, or 68 counties, had fewer than 40,000 residents in the county and its supporting region and were therefore classified as having low absorption potential. Of these 68 counties, 47 are located in the Northern Great Plains region, representing nearly 64% of that region's total. The remaining 21 "low" counties were located in the Four Corners/ Rocky Mountain study area. There were no "low" counties in the Illinois Basin or Appalachia study areas. However, the method of identifying proximate areas in these regions has introduced a probable bias to these results, which could boost the rankings of these regions. By using counties rather than cities and towns to measure regional populations in the East, nonurban populations were counted that would not have been accounted for in the West. However, we have two reasons to believe that this interregional bias should not unduly discriminate against the West. First, significant numbers of persons live in unincorporated areas in Illinois and Appalachian regions. Second, the counties in the East are much smaller geographically, and often measure

Table VII-10

RESULT OF COUNTY RANKING

County Ranking	All Regions		Northern Great Plains		Four Corners		Illinois		Appalachia	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
High	7	2.2	0	0	2	4.1	3	2.6	2	2.4
Medium high	217	27.0	6	8.1	17	34.7	113	97.4	81	95.2
Medium low	32	9.9	21	28.4	9	18.4	0	0.0	2	2.4
Low	68	21.0	47	63.5	21	42.9	0	0.0	0	0.0
TOTAL ^a	324	100	74	100	79	100	116	100	85	100

^aTotals may not add to 100% due to rounding

less than 10 miles by 10 miles, as compared to Western counties, which may be as large as 85 by 40 miles. Given the small size and the more even population dispersion, it is a reasonable simplifying assumption to consider whole proximate counties when computing each county's regional population in the East.

Nearly 77%, or 249 counties, fell in the medium category, having fewer than 250,000 persons in the county but more than 40,000 people in the region (see Table VII-10). The counties in this category received total scores ranging from 12 to 23, based on the criteria of population centers, growth rate, labor force, median age, and agricultural dominance. The division between medium high and medium low was somewhat arbitrary. The cutoff was chosen after scoring was completed to reflect the clustering of the data. Counties receiving scores of 17 and above (87.1% of this group) were classified as medium high, whereas counties with scores of 16 and below (12.9% of this group) were classified as medium low.

In the Northern Great Plains study area, 77.7% of the medium counties were classified as medium low, and these counties' scores were clustered at the lower end of the range. In the Northern Great Plains counties, medium high counties are characterized by their proximity to larger population centers (e.g., Billings, Montana, or Minot, North Dakota) and relatively low percentage of total income from agriculture. "Medium-low" counties, on the other hand, were farther from population centers, derived a larger proportion of personal income from agriculture, and tended to have older populations.

Of all Four Corners/Rocky Mountain counties in the medium range, 70% were classified as medium high. This reflects the influence of the larger cities in or proximate to this region (Albuquerque, New Mexico; Salt Lake City, Utah; and Denver, Colorado). "Medium high" counties are located near these population centers, tended to have a large construction and manufacturing labor force, and tended to have a moderately low median age. The "medium low" counties in this region generally had a smaller labor force and higher median age.

All the Illinois Basin counties rated medium high or above, reflecting the relatively greater supply of urban and human resources available in the region. In Appalachia, the two "medium low" counties had small construction and manufacturing labor forces, whereas nearly 95% of the counties rated medium high.

The results of the socioeconomic ranking procedure are illustrated in Figures VII-4 through VII-7.

F. Limitations of this Analysis

We have stressed that this approach has, by necessity, considered only indicators of growth absorptive capacity instead of measuring actual capacity. It is important to understand both the utility and limitations of applying such an approach to a highly complex question.

1. The Meaning of High, Medium, and Low Rankings

The strategy we employed was not designed to identify unambiguously counties that will or will not be able to accommodate a synfuel plant. Rather, it establishes a basis for comparing counties to each other in order to determine those that are most or least likely to accommodate synfuel-induced growth. Therefore, it cannot be assumed that the small number of counties in the "high" category will have tolerable growth impacts, only that the impacts will be less than those in a medium low or low county. (Because some medium-high counties are contiguous with these large population centers, they may be just as able to accommodate growth impacts.)

Although chances are very good that a low county will not be able to respond to the demands of growth in an adequate or timely manner, it cannot be assumed that a synfuel plant absolutely cannot be located in a "low" ranked county. However, with judicious planning,

FIGURE VII-4. RELATIVE EASE OF SITING BASED ON SOCIOECONOMIC CAPACITY

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FIGURE VII-5. RELATIVE EASE OF SITING BASED ON SOCIOECONOMIC CAPACITY

FIGURE VII-6. RELATIVE EASE OF SITING BASED ON SOCIOECONOMIC CAPACITY

DRAFT

FIGURE VII-7. RELATIVE EASE OF SITING BASED ON SOCIOECONOMIC CAPACITY

with full cooperation between the community and the synfuel plant operator, with adequate lead time, and with sizable amounts of financial assistance, a small rural, isolated community that is receptive to growth may be able to accommodate a plant siting.

The distinction between rankings should best be considered as an indication of the ease at which siting could be accommodated and the relative amount of resources required to do so. The choice between areas for siting then becomes a question of public policy: How high a "price" (in terms of both socioeconomic impacts and the cost of mitigating them) are we willing to pay for synfuel production? Our analysis suggests a starting point for minimizing that price.

2. Potential Biases of this Approach

This approach has two major limitations that could affect the results of this analysis. Both limitations would tend to bias the results upward, leading to inclusion of too many counties in the higher ranking categories. Therefore, this bias can be rectified by performing site-specific analyses of counties identified as having good siting potential in regard to socioeconomic as well as air, water, and other criteria.

The first problem is that cumulative effects are not considered. Because the analysis features support regions defined around each study county, the regions overlap and human and urban resources may be counted more than once. For example, several study counties are within commuting distance of St. Louis. Because of the abundance of resources in this area, the potential absorptive capacity of any one county could be quite high. But if plants were located in all or even several of these counties, the capacity of the region would quickly be exhausted. An actual estimate of absorptive capacity on a limited site-specific basis could resolve this multiple-counting problem.

Another problem is the fact that coal mining impacts are not considered for coal liquefaction, because we have assumed that conversion plants are not necessarily co-located with mines. However, because of this constraint, the location and magnitude of mining impacts are not considered. (Recall, however, that oil shale work force estimates do include extraction workers.) The impacts of mining would be especially important when mining occurs in a different county than the plant siting. If a plant sited in an urban county was fed by mines located in rural or undeveloped counties, boomtowns could result in the mining counties. These possible boomtown effects are not considered in this report, and therefore the full socioeconomic "price" of synfuels development has not been considered. Again, detailed site-specific analysis would allow these effects to be included.

3. Limitations of Only Considering Capacity

Considering only potential levels of impact in selecting potential sites could neglect two important features of the socioeconomic impacts of synfuel development. First, impact mitigation strategies can relieve or prevent some of the urban distress caused by synfuels siting. With careful planning, and an adequate injection of development funds, moderate infrastructure impacts can be reduced (see Appendix M, Impact Mitigation). Planning and assistance will be less able to minimize social disruption impacts. However, some communities are more receptive to growth and will tolerate greater changes in the quality of life (see Appendix N, Receptivity). These two factors, either separately or in combination, may make an area for which a high probability of impacts exists a good candidate for a synfuels plant. However, making this determination will only be possible after the kind of thorough, site-specific examination that was beyond the scope of this study.

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VIII ECOLOGICAL SENSITIVITY

A. Introduction

We have analyzed the relative ecological sensitivities of regions within the four study areas defined in Chapter II. We have used quantitative information when it was available and appropriate, although our investigation has not been designed to be rigorously quantitative. We have sought to gain an informed overview of the ecosystems involved and their susceptibility to changes anticipated from implementing synfuel programs. This analysis provides general ecological guidance in defining relative ease of siting synfuel facilities within the four study areas.

A "low" ranking based on ecological criteria does not represent a "no-go" situation. Rather, it indicates that siting synfuel plants, mines, and associated developments in this region will require substantial mitigation measures to maintain a level of ecosystem quality similar to that which existed prior to the development of the facilities. A "medium" or "high" ranking based on ecological criteria indicates that an area has relatively fewer potential ecological problems associated with synfuel development compared to those of surrounding areas within that region.

Although certain of the ecological components that we analyzed are more highly regulated than others by existing laws (e.g., endangered species by the Endangered Species Act of 1973, PL 93-205) the scope of the study did not generally include a separate analysis of the legal and institutional considerations that affect ecological management of an area. Rather, the study was carried out recognizing the national policy protecting natural resources and ecological systems set forth in the National Environmental Policy Act of 1976 (PL 91-190). This act states,

in part, that "it is the continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate federal plans, functions, programs, and resources to the end that the Nation may ...attain the widest range of beneficial uses of the environment without degradation...; preserve important ... natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity, and variety of individual choice," and "enhance the quality of renewable resources...."

Recently, the Office of Surface Mining Reclamation and Enforcement has published rules to implement a nationwide program for the regulation of coal mining operations by the States and the Federal Government as required by the Surface Mining Control and Reclamation Act of 1977 (PL 95-890). These rules cover a wide range of biophysical environmental features including reclamation programs, agricultural activities, acid drainage, areas unsuitable for mining, endangered species, fish, wildlife, forestry, natural hazard lands, soils, vegetation and revegetation, water resources and watersheds.

B. Problem Definition

The ecological sensitivity of an area may be defined in terms of a ratio between the quality of the ecological resources before synfuel development and that likely to exist after development. The term "ecological resources" includes both aquatic and terrestrial habitats in natural ecosystems, as well as agricultural ecosystems.

Although the terrestrial ecological impacts of synfuel operations may be the most apparent (e.g., land disturbed by mining or attendant urbanization in an area), aquatic ecosystems may also be significantly affected. Direct physical impacts include channelization and rerouting of existing streams, impoundment and reduction of stream flows, reduction of streamside and watershed vegetation cover, and disruption

of underwater aquifers that supply year-round water to surface streams. Sediments resulting from surface disturbance and erosion may also increase, as may the toxicity potential from plant effluents, from settling ponds and from solid wastes.

We have measured agricultural lands within ecological resources because those lands, as highly managed and productive ecosystems, form a functional whole with their environments, just as natural ecosystems do.

We have defined the ecological sensitivity of an ecosystem in terms of three interrelated factors:

- (1) Ecosystem Quality--The inherent quality of natural habitats and agricultural lands (measured by such factors as productivity, diversity, and uniqueness) that may be directly or indirectly preempted or altered by synfuel development. The higher the ecosystem quality of an area, the more ecologically sensitive it is and the lower its relative ease of siting has been rated.
- (2) Disturbance Susceptibility--The likely duration, extent, and degree of indirect habitat preemption or deterioration resulting from the human population increases anticipated to accompany synfuel development; the amount of land and the extent of waterways already highly disturbed or polluted; and the physical resiliency of an ecosystem to land form alterations. We emphasized the demographic approach to defining disturbance susceptibility instead of defining this factor by an ecosystem's ability to withstand changes that directly result from synfuel emissions and effluents. The major reasons for this emphasis were:
 - o The importance of indirect urbanization impacts on ecological resources, compared to direct disturbances caused by energy development. Although a large strip mine will ultimately disturb thousands of acres, at any one time mining operations are restricted to a relatively small area. For example, during the year's time, a moderately large coal stripping operation might mine 500 acres; under ideal conditions, the mined area would remain disturbed for only a year (O'Neill, 1977). Yet the overall magnitude of habitat preemption, an important part of which is attributable to urbanization, is accelerating rapidly.

- o Availability of recent human population density data, and the suitability of those data for extrapolation over defined geographical units, unlike site-specific ecosystem pollutant susceptibility information.
- o The overall ecological protection provided by environmental laws and regulations that limit mining emissions and effluents, compared to the low level of protection for direct habitat preservation.^a For example, the recent federal strip mining rules (DOI, Office of Surface Mining, 1979) set forth regulations on mine pollutants. Similarly, to develop oil shale on federal tracts in Colorado, more than 100 federal, state, and local permits (Hoffman, 1979), most of which relate to individual environmental components, must be obtained.

The greater the disturbance susceptibility of an area the higher we rate its ecological sensitivity and the lower its relative ease of siting. On the other hand, if an area had already been greatly disturbed, its ecological sensitivity is lower and therefore its siting capability is evaluated more highly.

- (3) Rehabilitation Potential--The capacity of man to rehabilitate natural habitats and agricultural lands to ecologically stable, productive, and useful conditions after such areas have been altered by synfuel development operations. We limited the aspects we analyzed to revegetation potential and to watershed management potential of an ecosystem.

Even though significant progress has been made in mined land reclamation over the past decade (see Appendix O) successfully rehabilitating disturbed land depends on the specific ecosystem and land use plan involved. Thus, the rehabilitation potential of an area is useful in differentiating the potential ecological impacts of the synfuel operations within a region. It is often difficult, however, to define generally accepted future uses of the land, particularly in the East. An area with high rehabilitation potential is rated as having low ecological sensitivity and more developmental potential.

^aOne issue raised in connection with the combustion of synfuels is the carbon dioxide (CO₂) greenhouse effect in an area not covered by environmental regulations. However, unless regions' assimilative capacities differ significantly, CO₂ impacts appear more a world-wide climatic concern, than one that geographically varies and thus has siting value. We have not addressed the acid rains associated with massive combustion of hydrocarbons. Acid rains could have significantly more impact in the East than in the mountains and intermountain regions of the West.

C. Methodology

To obtain an overview of the ecological sensitivities of areas within the four regions selected for synfuel development within a short time, we have relied heavily on:

- o Readily available quantitative ecological data that deal with large geographical regions
- o Information derived from interviews with scientists knowledgeable in the art of natural resource management
- o Our qualitative professional judgments
- o Field trips to mining sites for reconnaissance.

Many important ecological siting criteria are site-specific and are thus more appropriately applied at the county or state level, rather than at the regional one that has been the concern of this study. Progress is being made in coordinating ecological data at a national level; nonetheless, many ecological data bases remain largely uncoordinated with one another over large geographical regions and are thus difficult to compare. Often they have been developed by using different measuring techniques, have no means for being updated, are subject to a broad range of interpretations, and rarely cover more than one state. Detailed, but largely unanalyzed data, are available for many resources (e.g., game species), whereas data gaps exist for others (e.g., critical habitats of most endangered species). Although several nationwide inventories are in progress, including the U.S. Fish and Wildlife Service's wetlands inventory, the Soil Conservation Service's (SCS) inventory of prime agricultural lands, and the Nature Conservancy's inventory of natural areas, most of the data from these inventories are currently unavailable. Nonetheless, ecological data coordination has progressed to the point that allows preliminary ecosensitivity analyses within regions of the country.

We consulted mapped and tabulated data sources (Table VIII-1) to evaluate the four major ecological sensitivity factors. We ranked areas

Table VIII-1

MAPPED OR TABULATED ECOLOGICAL DATA SOURCES BY STUDY AREA

	<u>Northern Great Plains</u>	<u>Four Corners/Rocky Mountain</u>	<u>Illinois Basin</u>	<u>Appalachia</u>
<u>Ecosystem Quality</u>				
Natural Ecosystem				
Wildlife habitat	DOI, 1978b, 1978c, 1978e	DOI, 1978a, 1978d, 1978e	--	Heritage, 1979
Aquatic habitat	DOI, 1978f, 1978g, 1978i	DOI, 1978h, 1978i, 1979	Bayha, 1979	Bayha, 1979
Endangered species	Calef and Nagy, 1979	Calef and Nagy, 1979	Calef and Nagy, 1979	Calef and Nagy, 1979
Natural areas	NGPRP, 1974	--	Evers, 1953 Nature Conservancy, n.d.	Heritage, 1979; WPNC, 1979; Herrick, 1975; ORBC, 1974 1975, 1976, 1977a, 1977b, 1978a, 1978b, 1979a, 1979b
Agricultural Ecosystems				
Cropland Density	DOC, 1978	DOC, 1978	DOC, 1978	DOC, 1978
Prime Farmland	USGS, 1970	USGS, 1970 University of Illinois, 1977	USGS, 1970	USGS, 1979
<u>Disturbance Susceptibility</u>				
Existing Disturbance				
Human Population density	DOC, 1978	DOC, 1978	DOC, 1976	DOC, 1978
Lands/waterways disturbed or polluted	--	--	Haynes and Klimstra, 1975a, 1975b	ORBC, 1975, 1977, 1978
Future disturbance land surface forms	USGS, 1970a	USGS, 1970a	USGS, 1970a	USGS, 1970a

Table VIII-1 (Continued)

MAPPED OR TABULATED ECOLOGICAL DATA SOURCES BY STUDY AREA

	<u>Northern Great Plains</u>	<u>Four Corners/Rocky Mountain</u>	<u>Illinois Basin</u>	<u>Appalachia</u>
<u>Rehabilitation Potential</u>				
<u>Revegetation Potential</u>				
Existing vegetation; past vegetation success	Packer, 1976, 1977, Packer et al (in press) Evans et al., 1979	Packer, 1976, 1977; Packer et al (in press) Evans et al., 1979	USGS, 1970	USGS, 1970
Annual precipitation	Packer et al., (in press)	Packer et al., (in press)	--	--
Soil Suitability	NGPRP, 1974	SCS, 1975	--	--
<u>Watershed management potential</u>				
Soil salinity	SCS, 1975a	SCS, 1975a	--	--
Treatment/management potential	SCS, 1975b	SCS, 1975b	--	--

as having an overall high, medium, or low ecological sensitivity on the basis of our subjective evaluation of their composite ratings for the various components analyzed. If an area received a high ecological sensitivity rating (and thus a low rating for relative ease of siting), it rated high in a majority of the components analyzed; if an area received a low rating, it rated low in a majority of the components analyzed. Medium rated areas fell somewhere between. For each component, high, medium, and low values were defined in relation to other values within a particular region. A brief description of the major mapped and tabulated data sources used in our ecological sensitivity analysis follows.

1. Ecosystem Quality Data: Natural Ecosystems

When data were available, we evaluated four components of natural ecosystems: (1) wildlife habitat, (2) aquatic habitat, (3) endangered species, and (4) natural ecosystems.

For wildlife habitat evaluations in Colorado, Montana, North Dakota, Utah, and Wyoming, we reviewed the ranking data for terrestrial habitats in federal lands developed by the state fish and game departments in cooperation with the U.S. Fish and Wildlife Service. These ranked wildlife habitats of species with state or federal endangered and threatened status and species of high economic and social importance on a section basis (640 acres) according to four wildlife value classifications, ranging from critical wildlife values to limited wildlife values (see Table VIII-2). The agencies present the wildlife information in highly detailed atlases mapped at large scale (0.25 to 0.5 inch = 1 mile; DOI: 1978a, 1978b, 1978c, 1978d).

Similar kinds of wildlife atlases do not exist for the East because eastern coal areas, unlike western areas, are largely on private lands. Although species data bases are being developed at the state level for many of the eastern states, they appear largely unanalyzed with respect to overall terrestrial wildlife habitat in the eastern

Table VIII-2

U.S. FISH AND WILDLIFE SERVICE CLASSIFICATION OF WILDLIFE HABITAT

Habitat Value Classification

<u>Criteria</u>	<u>I. Critical</u>	<u>II. High Priority</u>	<u>III. Substantial</u>	<u>IV. Limited</u>	<u>Comments</u>
1. Status of endangered state and/or federal species	Present or past (documented)	Possible presence (undocumented)	Absent	Absent	List endangered species
2. Status of threatened state and/or federal species	Present (documented)	Past (documented)	Possible (undocumented)	Absent	List threatened species
3. Importance for species of high interest to the state	Sensitive area: o Marginal population of unique species--Bighorn sheep o Sage grouse strutting ground o Sharp-tailed grouse dancing ground	Intensive use areas: o Big game winter range o Class I bird area o High species diversity	Existence areas: o Overall distribution for white-tailed deer and antelope; high security area for mule deer o Class II bird area	Occasional or Absent o Low security area for mule deer o Class III bird area	State which species considered and/or if a unique or scenic area
4. Restoration/ ¹ Reclamation/Mitigation Potential	Intolerant: No restoration potential; no acceptable mitigation	Highly sensitive: Low restoration potential; limited mitigation possible	Moderate sensitivity: Moderate restoration/reclamation potential; mitigation possible	Tolerant: Restoration/reclamation possible to achieve equal or greater values; mitigation possible	Briefly state reason for selection

¹No classification is made on criterion (4) alone because not all states used that criterion.

Source: Based on DOI (1978a, 1978b, 1978c, 1978d)

regions. However, wildlife habitat considerations are taken into account in West Virginia, where the Department of Natural Resource's Heritage Trust Program (1979) provided an overlay map of the state on which the locations of animals of special interest were plotted.

For aquatic habitat evaluation in the West, we used the U.S. Fish and Wildlife Service's Stream Evaluation Maps (DOI: 1978e, 1978f, 1978g, and 1979), which were available for North and South Dakota, Wyoming, Colorado, and Utah. These maps result from cooperation between the U.S. Fish and Wildlife Service and various state fish and wildlife departments, which used standard rating systems to evaluate the fishery habitats of the waterways in each state. The criteria the state fish and game departments used were primarily based on the occurrence of endangered and threatened species and of species of "high interest" to the state.^a (e.g., species of high yield or unique aesthetic, scientific, economic, educational, or recreational value). We measured the number of miles of each stream type class for each county and calculated the stream value density for each county. Stream evaluation maps are not yet available for Montana and New Mexico. High priority streams were determined on the basis of the U.S. Water Resources Council map of streams of national significance (Bayha, 1977). Lower priority streams were determined from the appropriate coal base maps (USGS, 1976a, and b) by using stream size as a classification guide. Streams less than 16 miles in length were not included on the coal base maps and were, therefore, not assigned a classification.

In the Eastern states of the study, we determined the aquatic ecosystem quality by measuring the lengths of nationally significant streams of fish and wildlife that the U.S. Water Resources Council (WRC) mapped (Bayha, 1977). In using the WRC map, we lost a considerable amount of detail but gained wide geographical coverage.

^aOnly in a few instances was habitat restoration, reclamation, or mitigation potential used to upgrade or downgrade the habitat evaluation.

One natural ecosystem data source that was available in all regions was was federally listed endangered species information of the Brookhaven National Laboratory's Endangered Species Project (Calef and Nagy, 1979). For areas of the study region for which overall terrestrial wildlife or aquatic habitat ranking values were unavailable, we used endangered species information.

We obtained a listing, based on recent U.S. Fish and Wildlife data, from Brookhaven of all groups of federally listed endangered, threatened, proposed, review, candidate, delisted, and rejected species for each county in the four study regions. We did not employ the plant species data, however, because they are still too incomplete for differentiating ecological sensitivities among areas.^a

We classified the animals listed as either terrestrial or aquatic species, and we analyzed data for these groups separately. The level of ecological sensitivity assigned to a county primarily depended on the number of endangered and threatened species, and secondarily on the number of proposed, review, or candidate species.

For the fourth component used in measuring natural ecosystem quality, we evaluated the extent of natural areas. We obtained information about wild lands in the Northern Great Plains from a map produced by the Northern Great Plains Resources Program (NGPRP, 1974). Natural area information was derived for the Appalachian Region from several sources, including the Heritage Trust Program of West Virginia (1979), the Western Pennsylvania Nature Conservancy (1979), and publications of the Ohio River Basin Commission (ORBC) (1974, 1975, 1976, 1977a, 1979b, 1978a, 1978b, 1979a, 1979b) and the Ohio Biological

^aA recommended improvement in this analysis is to use the U.S. Fish and Wildlife Service's Plant Information Network (PIN), a computer-based data bank on more than 4,000 plant species in the states of Colorado, Montana, and Wyoming (Vories and Sims, 1977). PIN can aid in identifying such features as probable habitats of rare and endangered plants and the revegetation potential and wildlife value of plant species in a given area.

Survey (Herrick, 1975). No easily retrievable natural area data bases were found for the Four Corners/Rocky Mountain Region. Two maps of natural areas in Illinois were found, however, neither is complete (Evers, 1963; The Nature Conservancy, no date).

Areas that have a large amount of land in a largely undeveloped state receive a high ecological sensitivity rating; conversely, areas with few or no natural areas received a low rating.

2. Ecosystem Quality Data: Agricultural Ecosystems

We used two components to evaluate agricultural ecosystems: cropland density and prime farmland information. Cropland density information was calculated for each county on the basis of data obtained in the County and City Data Book (Department of Commerce, 1978). The amount of cultivated land was calculated as a percent of the total land area of each county--the more cropland in an area, the greater that area's ecological sensitivity and the lower its rating for relative ease of siting.

A map indicating prime farmland information was obtained for Illinois from the University of Illinois Agricultural Experiment Station (1977). Prime farmland maps, per se, were not found for the other states. Various economic classes of farms have been mapped for all the regions in the National Atlas, however (USGS, 1970). The location and density of Class I farms (those which have gross annual sales exceeding \$40,000) were determined. The more land classified as prime farm land, or as Class I farms the higher the ecological sensitivity rating assigned to an area.

3. Disturbance Susceptibility Data

Disturbance susceptibility was evaluated from two different standpoints: (1) the amount of existing disturbance and (2) the natural resiliency of an ecosystem.

The factors used in measuring existing disturbance were: human population density, the extent of polluted waterways, and the amount of highly disturbed land.

Population density data were obtained for each county in the four study regions from the County and City Data Book (Department of Commerce, 1978). We assumed that the denser the existing population of an area was, the higher the level of existing disturbance would be, and that if the population was already dense, significant additional increases would be less likely to occur and substantially affect ecosystems.

Mapped data on the extent of mine-polluted waterways and the amount of highly disturbed land were found for the Appalachian Region (ORBC, 1975; 1977a; 1977b) and for Illinois (Haynes and Klimstra, 1975a; 1975b). The larger the existing pollution levels, the lower we rated the ecological sensitivity of an area.

The component we used to measure the natural resiliency of an ecosystem was the land-surface form class mapped by USGS (1970a) for the conterminous United States. Hilly and mountainous areas were rated as having a higher ecological sensitivity than gently sloping ones such as plains.

4. Rehabilitation Potential Data

These data comprised general survey information (see Appendix 0), revegetation potential information, and watershed management evaluations.

We briefly surveyed disturbed land rehabilitation practices to enable us to evaluate the revegetation potential component of ecological sensitivity. Land reclamation has rapidly advanced since our description of that potential for various U.S. regions in SRI's earlier work, "Synthetic Liquid Fuels Development: Assessment of Critical

Factors" (Dickson et al., 1976). We obtained information about revegetation practices through a literature review, personal interviews, and field trips to the following areas:

- o Colorado
 - U.S. Geological Survey (USGS) Area Oil Shale Office, Grand Junction
 - Union Oil Revegetation plots, Parachute Creek, Piceance Basin
 - Colony Development Operation revegetation plots, Parachute Creek, Piceance Basin
 - Oil Shale Tract C-a and C-b, Piceance Basin
- o Montana
 - Rosebud Mine, Western Energy Company, Colstrip
 - Decker Mine, Peter Kiewit and Sons, Col. Decker
- o Wyoming
 - Big Horn Mine, Peter Kiewit and Sons Co., Sheridan
 - Wyodak Mine, Black Hills Power and Light Co., Gillette
 - Belle Ayr Mine, AMAX Coal Co., Gillette

For the western regions, we also consulted maps that are currently being published by Packer et al., that allow us to predict the revegetation potential on surface-mined lands. These maps, jointly financed by the Environmental Protection Agency, U.S. Fish and Wildlife Service, and the U.S. Forest's SEAM project, depict annual precipitation, growing season lengths, natural vegetation types, and soil association data. Although site-specific determinations can be made, depending on the revegetation treatment selected, generalized conclusions about the revegetation potential of large geographical areas cannot be derived from the maps without considerable data analysis. The maps were useful, nonetheless, for their indication of natural vegetation and annual precipitation data from which we roughly estimated the relative potential for revegetation success.^a We also referred to the Mine Facts Sheets of the 28 coal surface mines in the West that

^aWe note that the most significant moisture criteria are the amount of water available to plants and the time of its availability. Thus, for precise determinations such factors as evaporation and seasonality of the precipitation must be considered. This level of analysis was not generally possible in this study.

Packer et al., visited in their reclamation potential study in order to determine past revegetation success (1976, 1977). For the Northern Great Plains Region, we also consulted the map entitled "Suitability of Dominant Soils for Rehabilitation," (NGPRP, 1974). For the Four Corners/Rocky Mountain region, we used a generalized soil map prepared by USDA, (SCS, 1975b). In addition, we consulted the Atlas of Western Surface-Mined Lands (Evans et al., 1978) to determine premining vegetation and postmining reclamation conditions of mines in both western regions. This atlas consolidated information about coal, uranium, and phosphate surface mines that exceeded 10 acres and that were in operation before 1976 in the 11 contiguous western states, plus North and South Dakota.

Revegetation potential evaluations for eastern areas have largely been based on a literature survey and on our experience and knowledge of the rehabilitation practices in the Illinois Basin and in Appalachia, and by examination of the current major land uses of these areas as shown in the National Atlas (USGS, 1970).

Watershed management potential data were found only in the western regions. Two SCS maps were analyzed: an interpretive saline soil map (SCS, 1975a) which indicates the degree of salinity in various layers of the solid profile, and a watershed treatment and management map (SCS, 1975c). Referring to the salinity map, we rated the areas with the greatest extent of saline soils as ecologically sensitive areas; areas with none or very little saline soils were rated as least ecologically sensitive.

Referring to the watershed treatment and land management map, we rated those areas as the most ecologically sensitive that SCS has indicated cannot be managed or treated because of economic, physical, or policy reasons. Management measures include proper uses of land and related resources, whereas treatment usually refers to physical processes for holding the soil in place. We rated those areas that have the greatest potential for intensive management and related land treatment as the least ecologically sensitive.

D. Ecological Sensitivity Results

The areas within the four study areas were ranked as having high, medium, or low ecological sensitivity, relative to other areas within a given region. These rankings were then translated into low, medium, or high ease of siting, respectively, and are indicated on the maps shown in Figures VIII-1, through VIII-4 below. The meaning of these rankings is also explained below for each region. Examples of environmental features ranked as having high ecological sensitivity in the four study areas are summarized in Table VIII-3.

We do not present general ecological descriptions of "baseline conditions" and the likely impacts of resource development in the four regions; however, these can be found in several references (e.g., Hittman Associates, Inc., 1975; Dickson et al., 1976). In addition, Moore and Mills (1977) present regional ecological information about the effects of surface mining in the western United States on fish and wildlife reserves and recommendations for ways to mitigate these effects. Major land rehabilitation techniques and habitat requirements of important wildlife species in the West have been summarized by the Institute for Land Rehabilitation (1978).

1. Western Regions

In general, the western regions are sensitive to resource development. The overall ecological sensitivity of areas within the Northern Great Plains and Four Corners/Rocky Mountain areas were either high or medium. Regions within these study areas were given high ecosystem quality rankings, largely because of their varied and often numerous native wildlife, good aquatic habitats, and large areas of undeveloped or unimproved land. Although many of the western rangelands have been overgrazed, these areas nevertheless contain diverse native habitats. Unlike the natural ecosystem rankings, the agricultural ecosystem rankings were generally fairly low. However, the disturbance susceptibility rankings were fairly consistently high, largely because

the human population densities in the western areas are low. For example, only 6 counties in the 2 western regions had population densities exceeding 25 people per square mile and more than 100 counties (more than 80% of the counties comprising the two regions) had population densities of less than 10 per square mile. The ecological sensitivity of the land forms varied considerably, ranging from high in mountainous terrain to low in the plains. Likewise, the rehabilitation potential of areas varied substantially.

Significant advances are being made in western rehabilitation practices, including improving techniques of increasing the available moisture for plants. Reestablishing the major hydrological features of an area to pre-mining conditions remains challenging (see Appendix O for a discussion of the status of disturbed land rehabilitation).

Northern Great Plains. Using ecological sensitivity criteria, we assigned an overall ease of siting of low or medium to all areas within the Northern Great Plains Region, although individual criteria received high, medium, and low rankings (Figure VIII-1).

Examples of habitats that were assigned high ecological sensitivity rankings with respect to natural ecosystems include:

- (1) Natural areas, including relatively undisturbed woody draws that provide critical habitat for many wildlife species in the Northern Great Plains (Bjugstad, 1978) and unique riparian ecosystems along the Missouri River breaks, such as those found at the Charles M. Russell National Wildlife Range in Montana (FEA, 1975).
- (2) Prime wildlife habitat, including migration corridors, breeding grounds, are critical wintering areas for antelope, mule deer, white tailed deer, elk, and moose; strutting grounds for sage grouse and sharp-tailed grouse, along with golden eagle and prairie falcon nesting areas; as well as parts of the pothole country of northwest North Dakota and northeastern Montana, which are important parts of the North American "duck factory."

FIGURE VIII-1. RELATIVE EASE OF SITING BASED ON ECOLOGICAL SENSITIVITY

- (3) Streams with valuable resources, including sections of the Missouri and Little Missouri rivers in western North Dakota.
- (4) Habitats containing potential or known habitats of such endangered or threatened species as the black-footed ferret, swift fox, grizzly bear, or whooping crane.

Some of the areas that we rated medium to low with respect to natural ecosystem quality because of their lack of prime wildlife habitat ranked high with respect to agricultural ecosystem quality on the basis of their cropland density. These latter areas included several counties in the North Dakota and Sheridan and Daniels counties in Montana.

Most areas in the Northern Great Plains also ranked high with respect to the disturbance susceptibility criteria. Only three counties, Yellowstone, Montana and Burleigh and Ward, North Dakota, have population densities of greater than 14 people per square mile (with the maximum 37 people per square mile) and more than 85% of the counties had population densities of 6 or fewer people per square mile. The land in the Northern Great Plains is used for raising cattle, and to a lesser degree, sheep, and is cultivated for dryland cropping--especially wheat and barley. Secondary land uses include wildlife habitat and recreation (Power et al., 1978). Because the region depends on agriculture and lacks an industrial labor market, considerable immigration into the area (with resulting habitat preemptions and ecological changes) would be required to support a large synfuel industry (see Chapter VII).

Although overgrazing, herbicidal spraying, and agricultural practices have considerably altered the original plant species of the Northern Great Plains, leaving little pristine sagebrush-grassland, changes such as the construction of stock ponds have served to increase the wildlife habitat value. More important, the level of disturbance has not been sufficient to produce derelict lands or highly polluted streams, although agricultural runoff has already adversely affected certain river basins.

Natural resiliency usually received a low ecological sensitivity ranking because most of the area is composed of rolling hills and open prairie. Exceptions include the badlands of North Dakota and Montana (see NGPRP, Surface Resource Work Group, 1974) and the flood plains scattered throughout the region; both types of areas are much more sensitive to surface disturbance than are grassland plains.

Rehabilitation potential varied from low to high with respect to ecological sensitivity. Many surface-mined areas in the Northern Great Plains have been successfully reclaimed--in that they are generally more productive than undisturbed areas (Barth, 1977). Although aridity is a major concern, xeric environments can be easier to revegetate than areas with heavy rainfall. For example, because most spoils in the Northern Great Plains are relatively dry at time of mining, the use of heavy machinery during land reclamation seldom causes severe compaction (Power et al., 1978). Erosion and sedimentation can also be more easily minimized than in areas receiving heavier rainfall.

Successfully reclaimed areas that received low ecological sensitivity ranking include those with fertile, nontoxic soils and adequate moisture available for vegetation establishment. In addition, the watershed management potential of these areas, including the existing soil salinity levels, are relatively low. Areas given high rehabilitation potential rankings, include lands in west central North Dakota, lands near Gillette and Sheridan, Wyoming, and areas near Colstrip, Montana. Since 1967, considerable reclamation has been carried out in these areas by groups that include the Montana Agricultural Experiment Station (Hodder, 1977); the Natural Resources Ecology Laboratory of Colorado State University, who developed a preliminary reclamation simulation model for the Colstrip area (Ellis, 1977); the South Dakota School of Mines and Technology of North Dakota State University; the University of Wyoming; SEAM (Aldon and Springfield, 1977); the Argonne National Laboratory (ANL); and most of the major mining companies, such as Western Energy Company (Cull and DePait, in press; Murray, 1979), AMAX, Peter Kiewit and Sons, and Peabody Coal (Grandt, 1977).

Of special note are the surface water quality studies that ANL is conducting at the Big Horn Mine north of Sheridan, Wyoming. Two permanent streams, Goose Creek and the Tongue River, which is a major tributary to the Yellowstone River, cross the line. The mine has been operated for more than 20 years by Peter Kiewit and Sons Mining Company and is one of several large mining operations in the Powder River Basin. Both of the rivers that cross the mine site have been diverted through final cuts of past stripping operations; spoil materials, as well as highwall areas, form banks for the diverted streams. Preliminary results indicate that the present Big Horn Mine operation has no analytically detectable effects on the water quality of the Tongue River (Dettman and Olsen, 1978). However, ANL cautions that the addition of several new large-scale mining operations in the watershed could adversely affect the river quality. The apparent absence of present impact has been attributed to the high flow rate of the Tongue River watershed upstream from the mining activities where intensive (but not extensive) agricultural activity exists.

Areas given a low to medium rehabilitation potential ranking include lands where ponderosa pine forests grow (e.g., areas in southern Montana). Western Energy Company has succeeded in using a tree spade to transplant trees (Murray, 1979), and dryland techniques for woody plant reestablishment have been moderately successful in northeast Wyoming (Bjustad, 1978). Nonetheless, tree establishment procedures, (particularly for the native species) for the most part remain expensive and the establishment success rate is uncertain in the Northern Great Plains. Other areas receiving low to medium rehabilitation potential rankings include saline and alkaline areas in the Williston Basin; areas receiving less than 10 inches of rainfall (Big Horn, Washakie, and Natrona counties in Wyoming); and areas marked by high species diversity (e.g., natural mixed-grass prairies). Although the productivity of vegetative resources can frequently be improved, no technology as yet exists for reproducing the species diversity of the native mixed prairies of the Northern Great Plains (Power et al., 1978). It has been

estimated that although it may only take 3 to 5 years to establish a good grassland cover in this region, the reestablishment of the original vegetation diversity may require 40 years or more (USGS, 1979).

Four Corners/Rocky Mountains. A larger percentage (more than 85%) of this region's areas were ranked as highly ecologically significant than those in any other region. The reasons for these overall high ecological sensitivity rankings and, thus, the low ease of siting (see Figure VIII-2), are as varied as the region itself. The region is represented by a great diversity of topographic, climatic, and soil conditions, as well as biotic communities. Included are southwestern Wyoming's and Utah's cold shrub deserts (e.g., sagebrush, saltbrush, and greasewood) that extend into Colorado; the pinyon-juniper-oak woodlands and pine-douglas fir forests and alpine meadows at upper elevations; and the desert grasslands of New Mexico. The vegetation types are an index of the drought, temperature extremes, and saline/alkaline soils that characterize the region.

High natural ecosystem rankings were given to much of western Colorado, largely because of the widespread occurrence of exceptionally valuable wildlife and aquatic habitats. The wildlife and fish resources of this area are known throughout the United States, and attract millions of sportsmen annually. Large mammals range throughout the areas and include the largest migratory mule deer herd in North America. (Upper Colorado Region, 1979; USDA, 1973.) Potential conflicts that a large-scale synfuel operation might cause in western Colorado include disturbance of the following areas: the critical wintering range, breeding grounds, and the migration corridors of mule deer, pronghorn antelope, elk, and moose; the hunting areas of the black bear, the winter range and breeding grounds of the mountain lion; the summer range of the bison; the winter range of the bighorn sheep; concentration areas of cougar, beaver, marmot, Merriam's turkey, and morning dove; wintering ranges and production areas of the sage grouse, sharp-tailed grouse, and blue grouse; the breeding area of Wilson's

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FIGURE VIII-2. RELATIVE EASE OF SITING BASED ON ECOLOGICAL SENSITIVITY

snipe; and the feeding and nesting areas of the great blue heron. In addition, wild horses roam throughout certain parts of Colorado.^a

Given the number and types of wildlife habitats available, southern Utah receives low to medium ecological sensitivity rankings for this criterion, and northern Utah and southwestern Wyoming receive medium to high rankings.

In addition to rich and diverse wildlife, western Colorado has a high density of high priority fishing streams, and thus receives a high ecological sensitivity ranking for aquatic habitats. The other areas in the region have much lower stream densities and thus receive medium or low ecological sensitivity rankings.

In general, compared with the other areas, western Colorado also supports slightly more endangered or rare species, including the grizzly bear, the black-footed ferret, and several fish species. Although information about the location of rare plants is still fragmentary, a number of endangered and threatened plants are known to occur in western Colorado, as well as in eastern Utah (for rare plants, Utah, see Welsh, 1978).

We did not evaluate natural area information per se for the area because no comprehensive data base exists. References were found, however, that indicated one of the large box canyons in the southern portion of the Piceance Creek Basin in western Colorado should be maintained as a native reserve (Stoecker, 1974) and that a green belt area along the section of the bluffs adjacent to the Colorado River, which are highly valued for their natural characteristics be preserved (Knutson and Boardman, 1973).

^aWild horses are protected under the Wild Horses and Burros Protection Act of 1971 (PL 92-194).

Unlike the natural ecosystem rankings, the ecological sensitivities of most of the area in the Four Corners/Rocky Mountain area were ranked low with respect to agricultural ecosystems. Only 5 of the 50 counties in the region had cropland densities of 10% or greater; the highest density found (in Dolores County, Colorado) is less than 14% of the total land in the county. Most agriculture in the region is characterized by irrigated cropland, hay fields along river bottoms, or small dry land grain farms (Moore and Mills, 1977).

Most of these areas have high ecological sensitivity rankings with respect to disturbance susceptibility. The lands in the region are primarily used for livestock grazing, wildlife habitat, recreation, and watershed. The human population of most areas is small, and industry is not extensive; as a result, in many areas the air and water quality has not been unduly influenced by human activities. Consequently, the potential habitat preemption and deterioration that would result from urbanization of these areas is great. Only 6 counties in the region have population densities greater than 14 people per square mile, although two (Salt Lake, Utah, and Bernalillo, New Mexico, which includes Albuquerque) have urban centers with population densities exceeding 100 people per square mile. Nonetheless, about 80% of the counties have population densities of 6 people or less.

Extensive disturbances have occurred in the past, resulting in significant terrestrial habitat alterations. Among the most important of these disturbances are heavy grazing by domestic livestock, past mining activities, and removing pinyon-juniper trees to convert certain areas of limited grazing potential to areas with much higher forage production.

The introduction of species from other ranges, agricultural diversions, riparian alterations, and mining activities have also led to substantial deterioration of water quality in certain streams; for example, the Piceance Basin in western Colorado (Gray and Ward, 1978) and at the Edna Coal Mine in Routt County, Colorado (McWhorter et al., 1976). Nonetheless, considerable high quality fishery and wildlife

habitat remains, particularly in western Colorado, which is largely undeveloped. In addition, the mid- and upper-elevation mountain zones that occur in western Colorado are easily disturbed. Many of the upper elevation zones are deep snowpack areas, which produce much of the West's water. In addition, several of these areas provide important summer ranges for wildlife and domestic stock. Canyons and steep escarpments that occur in western Colorado, Utah, and New Mexico are also easily susceptible to disturbance. Strip mining, on the other hand, appears to produce permanent impact on water quality in very arid areas in the Southwest if the disturbed lands are rehabilitated and effective vegetation cover is established (Verma, 1977; Halpenny, 1977).

Ecological sensitivity rankings based on rehabilitation potential varies from low to high in the region. Areas receiving high rankings include:

- (1) High alpine and subalpine ecosystems, characterized by extremely rigorous climatic conditions, (e.g., low temperature, strong winds, shallow soils, high radiation loads, and very short growing seasons), and the commercial unavailability for revegetation of plant materials adapted to these areas. Several of these areas also have steep slopes conducive to erosion, thus causing sedimentation problems (Bay, 1976). These areas occur in west central and southwestern Colorado. Moreover, these ecosystems have undergone relatively little rehabilitation research (Willart et al., 1971; Berg et al., 1974; Thilenius, 1975; Bay, 1976; Brown, 1976; Brown et al., 1978).
- (2) Extremely xeric sites caused by low and erratic precipitation; high evapotranspiration rates, and low moisture retention capacity of soils (Evans et al., 1978). These areas are found mostly in eastern Utah and the New Mexico portion of the study region. For example, the Navaho Mine in northwestern New Mexico receives an annual yearly precipitation of 6-7 inches. Even with the advances in rehabilitation practices, irrigation is still considered necessary today in the arid West if the annual precipitation is less than 8 inches (Aldon and Springfield, 1977). In certain areas dependable rainfall, high evapotranspiration, or other problems reduce the moisture available to plants (e.g., low soil water storage capacity) or reduce the water use

efficiency of plants (e.g., infertile or toxic soils). In those areas, irrigation might be required even if precipitation exceeds 30 inches per year (DeRemer and Bach, 1977). Water efficient methods of irrigation have been developed (e.g., drip or trickle irrigation), but they remain expensive to develop and operate. It appears that although extremely xeric sites can be successfully revegetated, doing so will be difficult and costly, largely because of uncertainties rather than spoil material toxicity (Aldon et al., 1977). Nonetheless, it is encouraging that even in these arid areas of the Southwest where the plant-growing medium is particularly toxic, excellent stands of grass can be grown through proper irrigation and fertilization (Ludeke, 1977).

- (3) Areas with poorly developed soils that are easily erodible by wind and water and areas with highly alkaline or saline soils that inhibit revegetation. These areas were found in parts of western Colorado and eastern Utah.
- (4) Areas containing watershed that are difficult to manage or treat because of economic, physical, or policy reasons. These areas were found largely in Utah's Garfield, Emery and Grand Counties.
- (5) Areas in which past reclamation efforts have been only moderately successful or largely unsuccessful; for example, in Wyoming's Sweetwater and Carbon counties (Evans, et al., 1978; BLM, 1979), or areas where research on mine spoil reclamation is relatively young. For example, in New Mexico, most reclamation research did not begin until 1972, the year the state passed a coal surface mining act (Aldon and Springfield, 1977). By comparison, in central Routt county of northern Colorado, several large mines were treated in the mid-1960's by grading ridge crests and by aerial seeding. Relatively stable vegetation covers were achieved but much of the area has to be retreated under the requirements of the recent state reclamation act. However, according to Evans et al., (1978), success of the new treatments cannot yet be determined.

Areas that received medium to low ecological sensitivity rankings for rehabilitation potential included those with adequate moisture, well-developed soils, low topographical relief, a wide variety of commercially available plant materials for use in revegetation, and a history of successful reclamation. These areas included plain and plateau areas of western Colorado, including some areas within the oil shale counties of Rio Blanco and Garfield.

2. Eastern Regions

The ecological sensitivity rankings of the eastern regions ranged from low to high, with most of the low rankings in the Appalachian study area and many of the high ones in the Illinois Basin study area. Much of the land in the latter region is privately owned and has been cultivated. Thus, it received low natural ecosystem rankings but high agricultural ecosystem rankings, particularly because much of the land is prime agricultural land. Both regions, however, contain a number of endangered and rare species, and sections of Appalachia have quite a few remaining undeveloped natural areas.

The disturbance susceptibility of the eastern regions is generally low because the population is relatively dense (No county had a population density of less than 19 people per square mile) and because the level of existing disturbance is high, especially in Appalachia where abandoned surface and deep mines have created acid mine drainage, problems that have persisted for many years. The ecological sensitivity of the land surface varied from low in the Illinois Basin plains to medium to high in the Appalachian hills and mountains.

The rehabilitation potential of areas in the Illinois Basin Region varied from low to high. Adequate moisture and excellent soils are present in many areas of the plains, but rehabilitating these areas to their previous high fertility rates would be very expensive. However, the findings of decades of research on rehabilitating eastern mined lands are available, and reclamation laws date back to the 1940's.^a Nonetheless, strict land reclamation laws have been passed only fairly recently, and most comprehensive environmental control programs such as that for mined lands at Argonne National Laboratory (ANL, 1976) did not begin until the 1970's.

^aArgonne National Laboratory (ANL) has recently prepared a selective bibliography on surface coal mining and reclamation literature for the Eastern Coal Province (Weiss et al., 1977).

Illinois Basin

Figure VIII-3 sets forth the siting-potential rankings based on ecological sensitivity. In contrast to the western study regions, a number of areas receive a "high" ranking (i.e., low ecological sensitivity). The eastern region has had a long history of surface mining. The first commercial surface mine in the United States opened near Danville, Illinois, in 1866. Since then the area has been heavily employed for mining, as well as for agriculture and industry.

Most of the natural ecosystem rankings for these areas were fairly low, except for regions with a relatively high number of rare or endangered species or a high density of waterways of national significance for fish and wildlife. Counties with many endangered or rare species included Knox, Indiana; Crawford, Franklin, Gallatin, Hamilton, and Williamson, Illinois. Some of the rare species whose potential habitats are in these counties include the Indiana bat, the gray bat, several clam species, and the ivory-billed woodpecker. Very few areas had high aquatic habitat rankings, with the major exception of those regions adjacent to the Mississippi and Ohio rivers. Scattered remnant natural prairie areas and relatively undisturbed oak hickory forests occur throughout the area, but most all are of limited extent.

On the other hand, the ecological sensitivity of the agricultural ecosystems in large parts of the region was high. Approximately one-fourth of the counties have more than 75% of their land in cropland. Dewitt, Douglas, Ford and Piatt counties located in central Illinois have more than 90% of their land in cropland. Except for regions adjacent to the Illinois River, much of the land in north and central Illinois is classified as prime farmland.

Largely on the basis of existing human population density, we have ranked most of the counties as having medium disturbance susceptibility. Most of the counties have population densities ranging from 30 to 70 people per square mile. Only Schuyler and Hamilton

FIGURE VIII-3. RELATIVE EASE OF SITING BASED ON ECOLOGICAL SENSITIVITY

counties in Illinois have 20 or fewer people per square mile, and 12 counties in the region have population densities greater than 100 people per square mile. The two most populated counties are St. Claire, Illinois (417 people per square mile, near St. Louis, Missouri) and Vanderburgh, Indiana (676 people per square mile) where Evansville is situated. Counties in the region with relatively large amounts of land already severely disturbed by past mining activities include Fulton, Will, La Salle and Grundy in north-central Illinois, and Perry, Randolph, St. Claire, and Jackson counties in southern Illinois (Haynes and Klimstra, 1975). Except for hill areas in Kentucky, the entire region, which is comprised of plains and tablelands, received a low ecological sensitivity rating.

The restoration of the lands in the Illinois Basin to productive pasture land seems quite feasible (see Appendix O). Thousands of acres have been successfully reclaimed for grasslands and legumes. The thin coal seams and the thick overburdens encountered in much of the Midwest help make the task of land reshaping fairly easy (O'Neil, 1977). Row cropland, on the other hand, although it has been restored, requires substantial money and time (Kennedy, 1977). With the new Illinois grading requirements, returning land to row cropland has been particularly challenging because the soil sometimes becomes compacted and thus is unable to produce high yields of field crops such as corn and soybeans. Neutralization of acid spoils, which can cause water quality deterioration if unchecked, can also be expensive (Kennedy, 1979).

Kennedy (1977) has suggested that until methods of saving and restoring topsoil during mining become economical, prime row cropland should be mined only after poorer quality land has been mined. The mining industry has questioned the soundness of returning cropland to that use, citing the high amounts of energy required to grow an acre of corn today (Reiss, 1977). For our analysis, however, we have noted the current Illinois law that requires productive fertile soils to be returned to cropland and have thus assigned prime farmland a low

rehabilitation ranking. Farmland other than prime has been given high rehabilitation ranking. Forested areas and hilly areas are given medium rankings. Most of the areas in Kentucky, where the reclamation laws are not as strict as those in Illinois, but are becoming more stringent, are given high rehabilitation potential rankings, as are the farmland areas in Indiana.

Appalachia

More areas in the Appalachian study area receive low overall ecological sensitivity (high siting potential) rankings than in any other region (see Figure VIII-4). Nonetheless, about one-fourth of the areas receive high sensitivity rankings. The low rankings primarily result from the high levels of existing disturbance. However, disturbance had to be balanced against the difficulty of reclaiming certain areas, and the natural ecosystem rankings.

Most areas received a medium or high sensitivity ranking for their natural ecosystem value and a low sensitivity ranking for their agricultural ecosystem value. The areas receiving high natural ecosystem values include: those with a relatively large number of endangered species (e.g., counties in southeastern West Virginia and southwestern Virginia have endangered bat and clam species); counties with a substantial amount of land of natural significance, (e.g., Washington and Jackson counties in southeastern Ohio; mountainous regions in West Virginia such as Preston, Randolph, and Greenbrier counties; and Fayette and Somerset counties in Pennsylvania); and areas with a high density of naturally significant waterways (e.g., southeastern Ohio).

The highest cropland density in the 109 counties in the region was merely 31%. Only 7 counties--6 in central and eastern Ohio, and 1 in western Pennsylvania (Beaver)--had cropland densities greater than 25%. Much of the land in the region is not intensively cultivated or is in woodland.

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FIGURE VIII-4. RELATIVE EASE OF SITING BASED ON ECOLOGICAL SENSITIVITY

Human population densities are fairly high, and thus received low ecological sensitivity rankings. Most of the counties have between 50 and 150 people per square mile. Only two counties (Wirt and Webster in West Virginia) have population densities of less than 19 people per square mile, whereas 10 have population densities greater than 300. The three counties with the greatest population are Allegheny County in Pennsylvania, where Pittsburgh is located (2085 people per square mile), and Mahoning and Stark counties in eastern Ohio (741 and 653 people per square mile, respectively) where Canton and Youngstown are located.

Mining activities in Appalachia have drastically disturbed the land and water. By 1969, coal mining was blamed for the pollution of more than 10,500 miles of streams in this region, 5,700 of which were seriously polluted by acid drainage. More than 70% of this acid pollution originated in underground mines (Curtis, 1979). Abandoned surface and deep mines are widespread throughout West Virginia and southwestern Pennsylvania--the same areas where many of the streams are continuously affected by mine drainage.

Except for the tablelands in the northeastern Ohio part of the study region, most of the area consists of high hills or low mountains. Thus, the ecological sensitivity ranking for natural resiliency for most areas is high, somewhat countering the low sensitivity ranking the area received on the basis of existing disturbance.

On the basis of information in Appendix O, the ecological sensitivity rankings for the revegetation potential of areas within the Appalachian Region range from high in north and central Ohio to medium and low in almost all other parts of the region.

Table VIII-3

**EXAMPLES OF ENVIRONMENTAL FEATURES RANKED AS HAVING HIGH ECOLOGICAL SENSITIVITY
(Low Ease of Siting)**

<u>Criterion</u>	<u>Study Area</u>			
	<u>Northern Great Plains</u>	<u>Four Corners/ Rocky Mountain</u>	<u>Illinois Basin</u>	<u>Appalachia</u>
<u>Ecosystem Quality</u>				
Natural Ecosystems	Undisturbed woody draws, unique riparian migration corridors, breeding grounds and critical wintering areas for large game mammals and game birds; critical habitat for migratory waterfowl and endangered/threatened species	Migration corridors, breeding grounds and critical wintering areas of large game mammals and game birds; heavy concentration areas of game species; high priority fishing streams; critical habitats for endangered/threatened species	Areas with high number of endangered, threatened species or nationally significant waterways	Areas with high number endangered, threatened species or nationally significant waterways
Agricultural Ecosystems	Areas with high cropland densities	None	Undisturbed forests/prairies	Undisturbed mountainous areas
<u>Disturbance Susceptibility</u>				
Existing Disturbance	Areas with low population densities	Areas with low population densities	Areas with low population densities	Areas with low population densities
Future disturbance	Flood plains; badlands	Canyons, steep escarpments deep snow-pack areas	Steep hills, river bluffs	Steep mountainous areas
<u>Rehabilitation Potential</u>				
Revegetation Potential	Forested areas; alkaline areas; arid areas	Alpine subalpine areas; arid areas; areas with infertile/alkaline soils	Prime row cropland	Steep mountainous areas with high rainfall; acid forming soils
Watershed Management	Watersheds not feasible to manage or treat; watersheds with highly saline soil	Watersheds not feasible to manage or treat; watersheds with highly saline soil	No data	No data

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IX ENVIRONMENTAL HEALTH

A. General Principles

Assessing potential health risks^a for a full-scale synfuel industry is complicated, as are the assessments of other impacts, by the lack of data from any commercial conversion facilities or even commercial-scale demonstration plants. Compounding the problem in regard to health risks are the two following difficulties:

- o First, the nature and quantities of toxic pollutants discharged to air and water or existing in the workplace or products must be estimated from fragmentary evidence.
- o Second, the levels of pollutants must be related to the number and severity of health effects through highly speculative models and sparse data from experiments whose relevance is questionable.

Nevertheless, available evidence suggests that health impacts are possible, perhaps likely, from a synfuel industry. Effects may result from the following types of exposures to chemicals:

- o In the occupational environment, from waste streams as well as from intermediate and final product streams.
- o In final products, manifested as exposures to the consumers of the products.
- o In the general environment, as ambient concentrations in air and water from direct and fugitive air emissions, direct discharges, and leachate from waste piles and mines.

^aWe do not address safety of workers with respect to physical hazards such as explosions, hot surfaces, or moving machinery. These problems may be serious in the synfuel industry, but should be relatively independent of plant location.

Among many possible health-affecting constituents and contaminants of oil shale and coal conversion processes and their liquid products are:^a

- o Polycyclic aromatic hydrocarbons
- o Aromatic amines and other nitrogenous compounds
- o Trace metals, especially heavy metals
- o Radioactive nuclides.

^aPotential health effects related to criteria pollutants like SO_x in air and total dissolved solids in water are covered by the analyses in Chapters IV and V.

The presence of these compounds in the process streams of commercial synfuel plants is inferred from pilot-scale measurements as well as theoretical treatments (Sexton, 1960; Pollard et al., 1978; Lee, 1977).

The likelihood of consequent health effects is based on:

- o Epidemiological evidence of questionable relevance from such industries as the turn-of-the-century shale oil used for cutting oils and lubricants and early coal conversion facilities, including gasworks, many of which were outside the United States (Kanreich, 1976).
- o Tests in animals of total streams and stream fractions from pilot-scale plants, with extrapolation to man.
- o Reasoning from levels of exposure to specific chemicals and either animal or human evidence of toxicity from those chemicals in other situations (Enviro Control Inc., 1978).

For example, an as yet unpublished study by Battelle Pacific Northwest Laboratories appears to have identified beta naphthylamine in SRC-II boiler fuel (Air/Water Pollution Report, July 30, 1979). Beta naphthylamine is an aromatic amine unambiguously associated with bladder cancer and no longer used in commercial quantities by U.S. industry.

The list of possible effects from synfuel generation includes (The Mitre Corporation, 1978):^a

- o Cancer
 - Skin
 - Lung
 - Bladder
 - Leukemias
 - Liver
- o Central nervous system effects
- o Liver Damage
- o Mutagenic effects

The effects of coal and shale mining such as pneumoconiosis (black lung disease) are associated with expanded fossil fuel development, but not uniquely with synthetic fuel plants.

^aMany researchers have assumed that coal gasification and liquid syn-fuel operations will have many health effects in common. Whether or not this is true remains to be seen.

B. Method for Determining Siting Significance

Given the preceding speculative background on health risks, we were faced with finding some simple, yet logical indicators of the influence of the siting decision on the likely magnitude of those effects. We considered giving considerable weight to the availability of medical services by arguing that where physicians were less available, detection and treatment of disease would be delayed and thereby the impact of serious illness or death would be increased. Similarly, unionization or

other location-dependent influences on industrial hygiene programs could make a difference. However, we decided that such variations were adequately covered by the socioeconomic indicators of available services treated in Chapter VII.

Accordingly, we decided to concentrate not on the treatment of synfuel-related diseases, but on their occurrence. For this report, we define occurrence as the annual number of new cases leading to a specified end point; occurrence then depends on the incidence rates in a population (a measure of an individual's risk) and on the number of people at risk. The number of occurrences of disease in a population exposed to pollutants from synfuels is given by the mathematical expression:

$$N_o = P_o(E) N$$

where

N_o = Number of new cases of the disease per year
 $P_o(E)$ = Probability of incurring the disease in a year,
 given an exposure E
 N = Number of people exposed to level E.

We then looked for information that could indicate how N and $P_o(E)$ might vary with location.

1. Number of People Exposed

The simpler argument applies to N . Within limits, the number of people associated with a plant (workers and their families, and the induced population) is not a function of plant location. Nor do we have reason to suspect that the distribution of residence location or mobility patterns would be location-dependent, except under pronounced site-specific conditions. Thus, it is the preplant population variation that significantly affects N . Again, apart from extremely site-specific reasons, the distribution of the latter population has no predictable

location dependence. The remaining location-dependent variable is population density, which is available at the county level or even at finer levels (enumeration districts or 1 km squares) (U.S. Bureau of Census, 1973). The county level was chosen as being consistent with our other levels of analysis, including (as shall be seen) our occurrence information. The most easily available county level data derived from the 1970 census. Although it would be preferable to have projections for, say, 1990 (without a synfuel industry), the extra effort to generate such a data base is not justified in view of our inability to project the occurrence data to that time.

Population density for the candidate counties was mapped using the following ranges:

<u>Range</u>	<u>People/mi²</u>
1	More than 100
2	10-100
3	Fewer than 10

If we assume equal total chemical exposures to individuals at various distances from the plant, the number of people exposed and thus the number of cases of disease would be about 10 times higher for counties in range 2 than for those in range 3, to pick an example.

2. Probability of Occurrence

Our reasoning for the locational dependence of the probability of occurrence, as measured by P(E), is more complicated and much more speculative. Again, we assume that pollutant discharges will generally not vary much with plant location. (An obvious counterexample is dependence on coal composition.) Because we are not examining differences in such influences as air dispersion or aquifer transport, we also assume that the profiles of ambient concentrations of synfuel pollutants are not predictably related to location. How, then, can we predict differences in disease occurrence? First, we look for effects

that can occur in the general population at relatively low pollutant exposures. Of the effects cited above, cancer^b is the most likely to be manifested at low exposures and is also probably the most serious type of effect, although its incidence may be so low that it is not the most important effect. Cancer is also known to be a disease that often has multiple causes. For example, it is well known that exposure to asbestos and cigarette smoke is much more likely to cause lung cancer than exposure to either substance alone. Similar relations have been found between exposure to alcohol and liver carcinogens such as chlorinated hydrocarbons, and between other risk factors and the corresponding carcinogens.

Synergistic carcinogenesis produces more cancer occurrence for the sum of two exposures than the sum of the occurrences for the two exposures separately. The probability of a cancer given two exposures is given by the expression:

$$P(E_1 + E_2) > P(E_1) + P(E_2).$$

Although a carcinogen antagonism in which the inequality is reversed may occur, that is much less likely. Therefore, if a mixed exposure to synfuel carcinogens and other carcinogens causing the same kinds of cancer takes place,

$$P(E_1 + E_2) > P(E_1) + P(E_2)$$

where E_1 denotes synfuel exposures and E_2 denotes other exposures. Because we have assumed that E_1 is not strongly influenced by location, it follows that $P(E_1 + E_2) - P(E_1)$ --defined as the excess cancer rate--is correlated with $P(E_2)$, the cancer rate without the synfuel plant.

^bThis choice of an effect by no means suggests that we believe cancer to be a necessary consequence of synfuel development

Although synergism between two carcinogens is only considered proved in the case of asbestos and smoking, a higher risk factor for one carcinogen could also increase the risk for another similar carcinogen.

We therefore decided to use the preexisting occurrence of cancers as an indication of the excess cancer rate (over the location-independent $P(E_1)$). The pre-existing cancer rates of interest are those that are likely to be associated with synfuels. On the basis of limited evidence, we think the cancers most likely to be so associated, if any prove to be—are skin cancer (polycyclic aromatics), bladder cancer (aromatic amines), and lung cancers (polycyclics, others).

The only readily accessible data base for cancer rates by county is the Atlas of Cancer Mortality for U.S. Counties 1950-1969. The atlas presents maps of counties to indicate those counties where cancer mortality rates are significantly higher or lower than the U.S. average. Maps are presented for white males and females, for various cancer sites (organs in which the cancers occur). Some maps, such as for skin cancer, are by State Economic Area (SEA) instead of by county to improve the ability to make a statistically significant observation.

We scrutinized these maps, looking for counties or SEAs that were:

- o Significantly high by being in the highest decile; or significantly high, although not in the highest decile (high)
- o Significantly lower than the U.S. average (low).

The high category is considered to be relatively less favorable for a synfuel plant location, with more weight given if more than one cancer site or sites are represented. The second category is considered to be relatively more favorable to synfuel plant location.

We quickly point out that these data are weak for the purpose because:

- o The data for mortality are for the two decades beginning in 1950, and are representative of chemical exposures and other etiological factors occurring as much as 20 or 30 years earlier. We would ideally want exposure information projected to 1990.
- o There are significantly etiological factors (such as sunlight for skin cancer) that may not be synergistic with, or risk factors for, synfuel carcinogens.
- o The significance of the data themselves for etiological factors is clouded; as the Atlas states, "It is important to recognize that the associations suggested by the maps are not proof of causation. Even if demographic or environmental characteristics of counties correlate well with the distribution of cancer mortality, the relationships are not necessarily etiologic." (Maron, 1975).
- o The locational dependence of exposures, susceptibility, and other factors is not separated. However, high susceptibility would be as strong an argument against synfuel plant siting as would high exposures. Furthermore, it is irrelevant where the nonsynfuel exposure is incurred: the synfuel exposure still adds to the risk of the population in the county of siting, because the synergism or risk factor occurs in the individual, not in the environment.
- o Finally, the specific location of the synfuel plant and its pollutant footprint may not overlap the part of the county contributing the high or low cancer rates. This problem of geographic aggregation is common to many of the siting constraint indicators.

C. Results

The county-level data on population density and cancer incidence by body site (skin, lung, and bladder) were combined to arrive at an overall assessment of the relative health risk posed by siting synfuel plants. Table IX-1 shows the combinations of factors that result in various overall ratings and that are consistent with the format used throughout this report (e.g., relative ease of siting, ranging from low through high). Those results were mapped onto the four study areas, and are displayed in Figures IX-1 through IX-4.

Table IX-1

COMPONENTS OF OVERALL HEALTH RISK RATING--RESULTS
EXPRESSED AS RELATIVE EASE OF SITING

<u>Cancer Rate</u>	<u>Population Density</u>		
	<u>More than 100/sq. mi.</u>	<u>10-100 Sq. mi.</u>	<u>Less than 10/sq. mi.</u>
One or More High Rates	Low	Medium Low	Medium High
All Rates are U.S. Average	Low	Medium Low	Medium High
One or Two Low Rates	Medium Low	Medium High	High
Three or More Low Rates	Medium Low	Medium High	High

FIGURE IX-1. RELATIVE EASE OF SITING BASED ON ENVIRONMENTAL HEALTH

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FIGURE IX-2. RELATIVE EASE OF SITING BASED ON ENVIRONMENTAL HEALTH

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FIGURE IX-3. RELATIVE EASE OF SITING BASED ON ENVIRONMENTAL HEALTH

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FIGURE IX-4. RELATIVE EASE OF SITING BASED ON ENVIRONMENTAL HEALTH

In the Northern Great Plains and Four Corners/Rocky Mountain study areas, it seems clear that health risk considerations have relatively little effect on synfuel plant siting. Only one county in the Northern Great Plains study area and three in the Four Corners/Rocky Mountain Area received ratings as low as "medium low," and those were due primarily to high population densities.

In the East, the situation differs substantially. None of the counties in the Illinois Basin and Appalachia received "high" ratings, and some counties in both areas received "low" ratings. The "low" ratings are usually in counties that have high cancer rates, as well as high population densities. The absence of "high" ratings is generally due to the uniformly higher population density in the East as compared with the West.

The overall rarity of low ratings in the health area reflects our judgment that the methodology for health assessment is of relatively low discrimination and is based on less than ideal data. Our purpose here is to suggest that when both population densities and pre-existing cancer rates (or, in fact, other rates of disease that relate to synfuels) are high, more care is justified in selecting the specific site and assuring the lowest feasible levels of population exposure.

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X SUMMARY AND CONCLUSIONS

Chapters IV through IX presented analyses of the important environmental considerations for siting synfuel plants for each of six constraining factors. The analyses were formulated in a way that allowed mapping of the relative ease of siting plants using a semiquantitative rating scale. Although each set of maps is useful in its own right, it is worthwhile to consider how the combination of some or all the constraining factors would affect the opportunities for synfuel plant siting in each of the four study areas.

We have combined the individual maps of constraining factors into composite maps according to the plan laid out in Chapter II. That is, we first combined the maps for those factors that are perceived to be the most constraining because of strong regulatory support or physical resource requirements. These factors are air quality, water availability, and federal land management. We then separately combined the factors that represent important social and environmental concerns, but which are perceived to be less constraining because of the absence of regulatory requirements. Finally, we combined all the factors in composite maps that represent the total effect environmental constraints to synfuel plant siting.

In examining the composite maps presented in the following sections, recall the combining rules set forth in Chapter II. The important points to recall are that: (1) an area that has a "low" rating for any single factor receives a composite rating of "medium low;" (2) an area that has two or more "low" ratings receives a composite "low" rating; (3) other composite ratings are approximate averages of individual ratings. Although this combining rules emphasizes the low end of the scale, it serves a very useful purpose in that it highlights those areas in which there are more major barriers to plant siting.

A. Northern Great Plains

The composite maps for the Northern Great Plains study area are shown in Figures X-1 through X-3. As seen in Figure X-1, the combined effects of air quality, water availability and federal land management are constraining at only localized geographic levels. Away from the Class I PSD areas and the river basins with very low flows, there are few environmental constraints to synfuel development. Most of the region is rated "medium high." The area defined by the upper Missouri River basin in North Dakota rates "high" overall, reflecting ample water, few PSD restrictions, and absence of federal land ownership.

It is useful at this point to examine why a composite map such as Figure X-1 reflects so much uniformity when the individual maps that comprise it present a more complicated mosaic. It is simply that a certain amount of averaging takes place when maps are combined, and different combinations of ratings can result in the same overall rating. The large extent of "medium high" ratings in Figure X-1 reflects the fact that individual factors with lower ratings did not often overlap spatially.

Figure X-2 presents a somewhat different picture. The "low" ratings for socioeconomic capacity and ecological sensitivity often overlapped, yielding extensive areas with composite "low" ratings. Where they did not overlap, many areas received a composite "medium-low" rating because of the combining rule discussed earlier. Figure X-2 reflects both the relatively non-urbanized nature of the Northern Great Plains, and the relatively pristine, highly ecologically sensitive nature of the environment. Environmental health considerations did not contribute strongly to the composite ratings.

Figure X-3 clearly shows the dominance of the "low" ratings in socioeconomic capacity and ecological sensitivity, which tend to mask the effect of the other factors. Only in those areas rated "medium" or "medium high" is there any difference from Figure X-2 (except for the

FIGURE X-1. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON AIR QUALITY, WATER AVAILABILITY AND FEDERAL LAND MANAGEMENT

FIGURE X-2. RELATIVE EASE OF SITING: COMPCSITE RATING BASED ON ECOLOGICAL SENSITIVITY, SOCIOECONOMIC CAPACITY AND ENVIRONMENTAL HEALTH

FIGURE X-3. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON ALL FACTORS

few "low" rated areas from Figure X-1). However, it is within these areas that, all factors considered, siting opportunities will occur that require the least extensive mitigation measures, and the lease difficult permit acquisition, and will result in the least environmental and social disruption.

B. Four Corners/Rocky Mountains

The composite maps for the Four Corners/Rocky Mountain study area (Figures X-4 through X-6) show patterns generally similar to those of the Northern Great Plains. Overall, they tend to show greater constraints to plant siting due to (1) more Class I areas, more federally owned land, and less available water, and (2) somewhat greater extent and overlap of ecologically sensitive areas and non-urbanized areas.

Figure X-6 shows the dominance of ecological and socioeconomic factors in a manner similar to Figure X-3. Areas around the major urban centers (e.g., Salt Lake City, Albuquerque) that tended to receive higher socioeconomic and ecological ratings did not have higher composite ratings because of generally lower air quality ratings (i.e., violation of one or more NAAQS) and lower environmental health ratings.

As in the Northern Great Plains, only a few areas appear to be good candidates for synfuel development on environmental grounds--that is, developable without extensive mitigation measures.

C. Illinois Basin

The composite rating maps for the Illinois Basin study area (Figures X-7 through X-9) appear much different from those of the western study areas. First of all, there tend to be many "high" rated areas based on water availability and air quality (federal land

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FIGURE X-4. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON AIR QUALITY, WATER AVAILABILITY AND FEDERAL LAND MANAGEMENT

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FIGURE X-5. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON ECOLOGICAL SENSITIVITY, SOCIOECONOMIC CAPACITY AND ENVIRONMENTAL HEALTH

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FIGURE X-6. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON ALL FACTORS

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FIGURE X-7. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON AIR QUALITY AND WATER AVAILABILITY

FIGURE X-8. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON ECOLOGICAL SENSITIVITY, SOCIOECONOMIC CAPACITY AND ENVIRONMENTAL HEALTH

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FIGURE X-9. RELATIVE EASE OF SITING: COMPOSITE RATING
BASED ON ALL FACTORS

management was not a factor here). Second, because of the absence of "low" ratings for socioeconomic capacity, and only a few "low" ratings for environmental health, there are no composite "low" ratings in Figure X-8.

The result is that Figure X-9 shows a more even distribution than Figures X-3 and X-6, with a few "low" areas and even a few "high" areas. Overall, the Illinois Basin displays ample opportunity for synfuels plant siting without the extensive mitigation requirements needed in the west. The most restrictive areas are those with water quality problems, air quality problems due to existing industrial and urban development, and a high density of prime cropland.

D. Appalachia

The composite maps for the Appalachian study area (Figures X-10 through X-12) show a generally similar pattern to those of the Illinois Basin, except that air quality problems are much more dominant in Appalachia, as reflected in Figure X-10, and ecological sensitivity somewhat less dominant, as reflected in Figure X-11. The combined effect is that there is about the same degree of higher rated areas (Figure X-12) in Appalachia as in the Illinois Basin, except that no areas rated "high" overall.

Although, on a composite basis, ample siting opportunities appear to exist throughout the Appalachian study area, one must not underestimate the difficulties imposed by air quality problems in the industrialized areas of Ohio and Pennsylvania, and in the steep valley terrain of Kentucky and West Virginia. These could likely be the major constraints to development in these areas.

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FIGURE X-10. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON AIR QUALITY AND WATER AVAILABILITY

FIGURE X-11. RELATIVE EASE OF SITING: COMPOSITE RATING BASED ON ECOLOGICAL SENSITIVITY, SOCIOECONOMIC CAPACITY AND ENVIRONMENTAL HEALTH

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FIGURE X-12. RELATIVE EASE OF SITING: COMPOSITE RATING
BASED ON ALL FACTORS

E. Implications of the Results

Although we have not carried out a quantitative assessment of synfuels development capacity in the four study areas, the question naturally arises as to the level of development that could be supported within the environmental constraints we have identified and mapped. Any attempt to address this question must be preceded by some major qualifications. First, no study, including this one, can hope to address all the factors that can conceivably constrain synfuel plant siting, or even all the environmental factors. Second, the ability to successfully deploy a synfuels industry will depend to a large extent on the timing and spatial distribution of the development, factors which we have not considered here. Finally, each individual plant must deal with a host of site-specific conditions and permitting requirements that will vary widely, even within some of the geographic units we have analyzed. With these caveats in mind, it is possible to draw some general conclusions about the overall size of an industry that could be deployed with minimal environmental conflicts.

We will begin with the Illinois Basin study area because it appears to offer the most siting opportunities. Examination of Figure X-9 indicates a number of distinct areas rated "high" or "medium high." If we attempt to enumerate areas in these categories that do not impinge on one another in terms of competition for the same air, water, social and ecological resources, there appear to be 10 to 15 such areas. If we assume that there is at least one plant siting opportunity in each area, then we may conclude that 10 to 15 plants of the size we have considered (40,000 to 60,000 eob/d) could be sited in the Illinois Basin without major environmental conflicts.

In the Appalachian study area (Figure X-12) a similar number of distinct, non-impinging areas appear with a "medium high" ranking. However, because of the air quality problems noted earlier, this is probably an optimistic upper limit, and we (somewhat arbitrarily) reduce the number of minimum-conflict siting opportunities by half, to 6 or 7.

In the western study areas, the picture is generally bleaker. Few distinct areas receive composite ratings higher than "medium." However, minimum-conflict siting opportunities do exist. In the Northern Great Plains, we can define 6 or 7 areas that received "medium high" rankings. In the Four Corners/Rocky Mountain area, this number drops to 3 or 4.

If we total the number of potential minimum-conflict siting opportunities found across the country, we find 25 to 33 such possibilities, representing a total industry size on the order of 1.5 million oeb/d. We emphasize that this is a very rough figure and that it does not represent either an upper or lower limit, on environmental grounds, to the size of an industry that could be deployed.

As an example, consider oil shale which we have not included in our discussion above. Although the oil shale areas in western Colorado and eastern Utah ranked "low" or "medium low" in our composite ratings, there are firm plans for an industry of about 400,000 b/d, and tentative plans for an even greater level of production. Yet much opposition exists to oil shale development on environmental grounds, and its potential socioeconomic and environmental problems have been well documented. The industry has begun to take steps to resolve these conflicts, knowing that their resolution will require substantial investments of time and money. The success of several companies in obtaining water rights and in securing air quality permits indicates the potential for meeting institutional requirements. The extent to which social and environmental conflicts can be resolved remains to be seen. The level of expected difficulty is certainly reflected in our maps of the oil shale region.

In conclusion, we may state that the best chance for deploying a synfuels industry over the next 10 to 15 years with a minimum of environmental difficulties lies in choosing sites in areas such as we have identified, that result in the fewest conflicts. Other areas are not precluded, of course. Rather, the investment of time and money

required to overcome conflicts and mitigate impacts will be greater. Tradeoffs will become apparent between costs of mitigation and, for example, costs of shipping coal to environmentally more suitable sites. The best sites will, of course, be those with both few environmental conflicts and favorable economics.

We believe that the progress that we have made here in identifying broad areas that minimize environmental conflicts should naturally lead to more site-specific analyses to determine if our general conclusions hold up when examined at a smaller scale.

Appendix A

COAL AVAILABILITY

As a feedstock for synfuel plants, economically accessible coal includes that

- (1) Controlled or acquirable by a mining company
- (2) Not committed for another use.

Factors affecting the availability of coal for synfuel production include government policies and regulations, deposit geology, mineral and surface ownership patterns, and market conditions. Coal transportation may be a problem in Appalachia for large nonmine mouth plants (i.e., those consuming more than 2 million tons per year).

1. Federal Coal Leasing and Management Program

Approximately 75% of the nation's coal resources is in the West, and 80% of those resources is owned or controlled by the federal government. At present, about 20% of the nation's coal production comes from the western coal provinces in the Northern Great Plain and Rocky

Mountain Regions and by 1995 this proportion should rise to about 60%. About 75% of western production comes from federal coal leases. The majority of western output through the year 2000 will probably come from federal leases; however, the future proportion will depend on the federal coal leasing program.

The current moratorium on federal coal leasing could reduce coal availability for synfuel plants beginning operation before 1995 - especially in the Northern Great Plains province.

Before the Mineral Leasing Act of 1920 was passed, surface and coal rights on federal land were granted to individuals for as many as 160 acres, to groups of four or more people for as much as 1 square mile; and to railroads for odd numbered sections within 10 to 20 miles of the track. With the 1920 act, a policy of leasing rather than selling the coal was instituted. Leases of known coal-bearing areas were auctioned by BLM. In areas with no known coal deposits, the Secretary of the Interior issued prospecting permits and preference right leases (PRLs); if the permittee provided that economically minable deposits were present in the prospect area, he could be granted PRLs.

In 1970, BLM estimated that the area of federal coal under lease in the seven-state study region totaled 788,000 acres of which only 10% was supporting production. These computations resulted in a moratorium on granting leases in 1971. In 1973 a new coal leasing policy suspended the issuance of new prospecting permits and imposed an almost total

moratorium on new federal leasing. (Only those prospective leasees who could prove their need for coal to fulfill an existing contract and could begin production within 3 years would be issued leases.) In 1975, The Department of the Interior (DOI) issued a draft statement concerned with instituting a new coal leasing system, EMARS I.^a In 1975, DOI issued a modified version, EMARS II, that incorporated industry views and market considerations, EMARS II should have resulted in the reinstitution of leasing; however, the resumption was delayed by other statutes and by litigation. In October 1976, the Federal Land Policy and Management Act (FLPMA) required BLM to propose leasing procedures, and to manage and coordinate leasing activities.

In July 1979, Secretary Andrus indicated that leasing would be resumed in 1981, when about 1.5 billion tons of federal coal will be released by the approved preference right leases and by auction sales.

Present and future mining of federally owned coal will occur in parts of coal basins termed "Known Recoverable Coal Resource Areas" (KRCRA), which are now being delineated by USGS. We estimate that the KRCRAs will amount to about 39,000 square miles and that approximately half of this area will have high to medium development potential.

^aEnergy Mineral Allocation Recommendations System

2. Illinois Basin and Appalachia

Total conventional strippable reserves in the Illinois Basin amount to some 8 billion tons, most of which is committed. Similarly, surface minable reserves in Appalachia are largely committed. Consequently, only limited quantities of surface coal will be available in both the Illinois Basin and Appalachia regions as feedstock for synfuel plants until at least 1995.

Mineral and surface ownership is particularly complex in Appalachia - individual seams are often separately owned, and clear title has frequently not been established. These complexities of ownership, in addition to the geologic complexity of the area, limit the capacity of most (80%) Appalachian underground mines to less than 1,000,000 tons per year. The ownership complexities typical of Appalachia also constrains development by entailing prolonged acquisition periods. Conversely, Illinois Basin geology is much more favorable for underground mining, and reserve acquisition is relatively straightforward. The main constraint to obtaining Illinois Basin coal is competition for reserves from utilities and industries that use coal as boiler fuel.

3. Gulf Province

Of the estimated resources and reserves of the Gulf Province, 95% are in Texas; in this discussion of Gulf lignite availability only Texas lignites are considered.

The Gulf Province has the lowest reserve/committed production ratio. The amount of reserves committed to existing and announced power plants in Texas is 2.2 billion tons - 73% of the demonstrated reserves in Texas estimated by USGS (or 32% of the Texas reserves estimated by the Texas Geologic Survey).

This relatively adverse committed reserve/total reserve relationship means that Texas reserves available for synfuel production will very likely be the least attractive to mine and will certainly be much less economical than those currently being exploited.

4. Northern Great Plains

Approximately 10 billion tons of surface minable coal is recoverable from existing federal leases in the Northern Great Plains (North Dakota and Powder River Basin). Based on estimates of demand and announced mine openings and expansions, capacity may exceed demand by 200 million tons per year by 1985. However, if DOI estimates of production and demand are employed, almost all of the 10 billion tons in the federal leases will be committed by 1985 for steam generation.

If DOI estimates prove nearest to reality and if the leasing moratorium is not lifted before 1985, the only coal available for synfuels in 1990 in the Northern Great Plains will be from Indian reservation leases in Montana and North Dakota, and from private holdings in North Dakota.

State severance taxes and state regulation regarding mining and end use may also slow coal development. Montana's severance taxes are currently the highest in the nation (30% of net) and Wyoming's rate of 10.5% may be increased. Mining regulations have been prepared for Montana that require the extraction in a property of all seams that the state determine to be economically minable. Furthermore, Montana's pollution limits are more stringent than EPA's.

5. Summary

Table A-1 summarizes the current status of coal availability in the major coal producing regions, expressed as constraints to expanded production of coal for synfuel feedstocks.

Table A-1

REGIONAL COAL AVAILABILITY FOR SYNFUEL FEEDSTOCKS

<u>Region</u>	<u>Principal Constraints</u>
Appalachia (Underground Coal)	Small size of the feasible mine units (1 million t/y capacity) Long lead times required for lease acquisition.
Illinois (Underground Coal)	Competition for commitment of available coal reserves from utilities and industrial users.
Gulf Province	Unfavorable reserve/committed production ratio, with utilities and industrial users competing for commitment of remaining reserves. Relatively unfavorable mining economics.
Northern Great Plains	Continuation through 1985 of moratorium on leasing of federal coal would affect 1990 mine openings because of western mine lead time requirements Possible future imposition of high state severance taxes.

Appendix B

HYPOTHETICAL ENVIRONMENTAL REGULATIONS FOR SYNTHETIC LIQUID FUELS PLANTS

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1. Introduction

Emissions regulations pertaining specifically to coal liquefaction or oil shale processing facilities do not now exist at either the federal or state levels. To complete engineering designs of commercial synfuel plants, a set of reasonably achievable environmental goals must thus be defined. Many of the processes involved in commercial coal liquefaction plants appear to be quite similar to those of conventional petroleum refineries. The technologies for other process units, coal driers, and utility steam boilers, are also well-established.

Air and water pollutant emission regulations were surveyed, as were solid waste disposal criteria for coal synfuel plants, on the basis of regulations from analogous industries. Federal New Source Performance Standards (NSPS) for air and water were specified when applicable. Wherever federal standards for a particular emission source or pollutant did not exist, yet appeared necessary, appropriate standards were specified on the basis of state regulations. States consulted were those identified in the DOE report, "Environmental Analysis of Synthetic Liquid Fuels," as having the greatest potential for synfuel plant siting.

The following sections contain estimates of emission and effluent standards that may be applicable to coal liquefaction facilities.

Emission standards are provided for coal driers, boilers, process combustion, and Claus sulfur plants. Effluent standards are provided for process, boiler, and miscellaneous waste streams. Sources of solid wastes from coal liquefaction and proposed disposal regulations for hazardous wastes are also described. Because of uncertainty in both commercial coal liquefaction plant designs and future regulatory action, caution should be exercised in using these estimates.

2. Estimating Air Pollutant Emission Standards for Coal Liquefaction

Coal Driers

For thermal drier gases the particulate matter emissions are limited to 0.070 g/dscm (0.031 gr/dscf); for pneumatic cleaning equipment, emissions for particulate matter are limited to 0.040 g/dscm (0.018 gr/dscf).

These standards do not apply to the conversion plant, but will affect emissions at the mine and coal cleaning facility (Env. Reporter August 4, 1978).

Utility Boilers

The burning in utility boilers of a gas or liquid that is derived from a solid fuel is subject only to the emission limits placed on the original fuel. Therefore, as a conservative (i.e., worst case) estimate, it should be assumed that the coal-fired boiler standards applies. Conversations with staff members of the Office of Air Quality Planning and Standards (OAQPS) revealed that at this time EPA is considering extending the revised utility boiler NSPS to large industrial boilers (25×10^6 Btu/hr), relaxing these standards slightly, and applying them to boilers in the $100\text{--}250 \times 10^6$ Btu/hr

^aD. G. Streets and T. A. Speciner, "Issues Relating to New Source Performance Standards for Industrial Steam Generators," ANL/EES-TM-54, (June 1979).

range.^a As such, it appears most advantageous to apply the revised utility boiler NSPS to the to the liquefaction plant steam boiler (Federal Register, June 11, 1979).

The standard for SO₂ is that for any solid fuel or solid-derived fuel (i.e., low-Btu gas, filter residues, etc.) There are to be no emissions in excess of 1.2 lb/10⁶ Btu heat input and 90% reduction in the potential emissions or 70% reduction when emissions are less than 0.6 lb/10⁶ Btu heat input. Compliance with this standard is determined for a 30-day period. There is no lower limit or "floor" on allowable emissions. Percentage reduction must always be at least 70%.

Example: Determine allowable SO₂ emission rate.

The average uncontrolled SO₂ emission rate based on input coal characteristics equals 3.0 lb/10⁶ Btu

1. Apply 90% reduction. Emission rate = 3.0 (1.0-0.9) = 0.3 lb/10⁶ Btu. This is less than the 0.6 lb/10⁶ Btu limit; therefore, the full 90% scrubbing is not needed.
2. Apply 70% reduction. Emission rate = 3.0 (1.0-0.7) = 0.9 lb/10⁶ Btu. This is more than the 0.6 lb/10⁶ Btu limit. Because greater than 70% reduction is required to meet this limit, the allowable emission is 0.6 lb/10⁶ Btu.

Sulfur removal through gasification and liquefaction can be considered to be fuel pretreatment. According to Appendix A (Section 2.3, p. 33620) in the proposed NSPS, the percent of SO₂ reduction due to fuel pretreatment is calculated according to the following equation:

$$\%R_f = 100 \left(1 - \frac{\% S_o / GCV_o}{\% S_i / GCV_i} \right)$$

Where:

- $\% R_f =$ SO_2 removal efficiency due to pretreatment; percent
- $\% S_o =$ Sulfur content of the product fuel on a dry basis; percent
- $\% S_i =$ Sulfur content of the inlet fuel on a dry basis; percent
- $GCV_o =$ Gross calorific value of the outlet fuel on a dry basis; kJ/kg (Btu/lb)
- $GCV_i =$ Gross calorific value of the inlet fuel on a dry basis; kJ/kg (Btu/lb).

The standard for NO_x allows the following emissions for the utility boiler:

- (a) 20 ng/J (0.5 lb/ 10^6 Btu) heat input from the combustion of subbituminous coal, shale oil, or any solid, liquid, or gaseous fuel derived from coal;
- (b) 260 ng/J (0.6 lb/ 10^6 Btu) heat input from the combustion of any other solid fuel (i.e., bituminous coal).

When a combination of bituminous coal and coal-derived gases is burned as fuel in the boiler, the allowable emission rate will be determined by a ratio of the heat inputs of the respective fuels. Heat input is considered to be that input to the boiler.

For Particulates the allowable emission rate is 13 ng/J (0.03 lb 10^6 Btu)

Process Combustion

NSPS for petroleum refineries regulate the combustion of refinery waste gases in process heaters. (Basis: Federal Standards of Performance For Stationary Sources, Subpart J: Petroleum Refineries).

SO₂ emissions are limited according to the H₂S content of the refinery gases. Emissions are based on the combustion of fuel gas containing less than 230 mg/dscm (0.10 gr/dscf) of H₂S. This fuel limitation is waived if a spot combustion treatment system is employed to provide an emission rate equivalent to the 230 mg/dscm limit. (Basis: Sec. 60.104 (a)(1)).

For Particulates 1 lb/1000 lb of coke burnoff is allowed from a fluid catalytic cracking unit (Basis: Sec. 60.102 (a)(1)). Combustion of additional fuels in waste heat boilers, etc., limits particulate emissions to 43.0 g/MJ (0.1 lb/10⁶ Btu) of fuel input. (Basis: Sec. 60.102 (b)).

No federal regulations limit CO emissions from combustion sources in refineries. A survey of pertinent state regulations was conducted; of the eight states indicated in the DOE, only Illinois has an applicable standard for CO from combustion. Emissions of CO are not to exceed 200 vppm at 50% excess air in flue gases for combustors having actual heat input greater than 10×10^6 Btu/hr.

Claus Plants

Emissions of SO₂ from Claus sulfur plants are covered under the petroleum refinery standards of performance, Section 60.104 (a)(2). Emissions may not be in excess of 250 ppmv of SO₂ at 0% oxygen on a dry basis if emissions are controlled by an oxidation control system or by a reduction control system followed by incineration.

3. Estimating Water Pollutant Effluent Standards for Coal Liquefaction

Development of effluent guidelines for coal liquefaction by EPA's Effluent Guidelines Division is under way. Several factors, including uncertainty regarding the economic feasibility of coal liquefaction, those liquefaction techniques most likely to reach commercial status, and the higher priority of developing and revising guidelines for existing industries, have delayed guideline development.

Estimation of effluent standards that may be applicable to coal liquefaction may be made by extrapolation from standards set for industries with processes and waste streams similar to those of coal liquefaction, and by considering those pollutants declared toxic under Section 307(a)(1) of PL 92-500 as amended by Section 53(a) of the Clean Water Act (CWA) of 1977 (PL 95-217).

Coal liquefaction requires the use of large quantities of steam. Boilers that generate this steam will be similar in size and waste streams to those that provide steam for electric power generation. Under some operating conditions, feedstocks and resulting waste streams for liquefaction and electricity boilers may vary. Liquefaction boilers may utilize process gases and such nonmarketable products as boiler feedstocks. Those fuels have fewer combustion related liquid wastes than coal. The use of standards applicable to coal-use provides an estimate of a high level of waste, a "worst case" condition. Effluent guidelines have been set for the steam electric power industry.^a These guidelines are undergoing revision to include those pollutants classified as toxic under CWA. Effluent limitations are based on boiler size and age. For this assessment it was assumed that coal liquefaction boilers will be of a size comparable to those used in electricity generation facilities with a capacity of 25 MW or greater, and that best available treatment (BAT) standards will apply to effluent steams.

^aDevelopment Document for Effluent Limitation Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category, USEPA (1974).

Process waste streams from coal liquefaction will be similar in many respects to those from petroleum refineries. Both technologies subject fossil fuels to varying degrees of temperature and pressure to upgrade and separate feedstock components. Effluent guidelines have been developed for the petroleum refinery industry.^a These guidelines are also undergoing revision to account for toxic substances defined under the CWA. The amount of allowable wastes vary according amount of process feedstock. For this assessment it was assumed that a commercial coal liquefaction facility would produce approximately 60,000 b/d of liquid product from approximately 24,000 t/d of coal feedstock (4.8×10^{11} Btu). This amount of feedstock is comparable to that used by small petroleum refineries. Petroleum refining processes assumed applicable to liquefaction include: topping, cracking, catalytic reforming, and petrochemical operations.

Table B-1 lists the primary process and boiler-related waste streams generated by coal liquefaction. The table also shows equivalent streams resulting from petroleum refining and coal-fired steam electricity generation.

For each waste stream identified, Table B-2 presents the 1-day maximum and 30-day average allowable pollutant loadings under BAT. The range in values for process streams reflect the uncertainty of commercial

^aDevelopment Document for Effluent Limitation Guidelines and New Source Performance Standards for the Petroleum Refining Point Source Category, USEPA, EPA-440/1-74-014a (1974).

designs. Values were obtained from petroleum refining standards,^a based on Btu values of feedstock and facility size. Boiler waste stream limits are based on steam electric power generation standards.^b Caution must be exerted in accepting these estimates because of inherent differences in process effluents and revisions in the standards that are currently underway.

The standards that values in Table B-2 are based on are currently under revision. Included in the revision will be those substances designated as toxic under CWA Section 307(a)(1).^c

4. Estimating of Hazardous and Solid Waste Criteria for Coal Liquefaction

The December 18, 1978, Federal Register set forth proposed guidelines and regulations for hazardous wastes, as well as proposing methods for their identification and listing. Although a number of issues remain unresolved, certain statements can be made by relying on published RCRA criteria for hazardous wastes.

The Act defines "hazardous waste" in Section 1004(5) as: "As solid waste or combination of solid wastes, which because of their quantity, concentration, or physical, chemical or infectious characteristics may -

- (a) cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness; or

^aEPA, "Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Petroleum Refining Point Source Category" (1974).

^bFederal Register, 39 (196): 36186-37207

^cFederal Register, p. 4108 (January 31, 1978)

Table B-1

PRIMARY WASTE STREAMS

<u>Liquefaction Waste Steam</u>	<u>Petroleum Refining or Steam Electric Equivalent</u>
<u>Process Waste Streams</u>	
Sour water - from hydrogenation, gas quenching, and condensing	Sour water - fractionation, catalyst regeneration, cracking
Quench wastes - scrubbing oil products, condensates from gas cooling	Oily water - sour water stripping, caustic recovery
<u>Boiler Waste Streams</u>	
Steam boiler blowdown, cooling tower blowdown	Steam boiler blowdown, cooling water blowdown
Miscellaneous water - cleaning, low volume, floor drains	Miscellaneous water - cleaning, low volume, floor drains
Coal pile runoff, storm runoff	Coal pile runoff, storm runoff

Table B-2

ESTIMATED EFFLUENT GUIDELINES

<u>Waste Stream</u>	<u>Pollutant</u>	<u>1-day Maximum^a</u>	<u>30-day Average^a</u>
Process			
<u>Waste Streams</u>			
Sour water	BOD ₅	0.86 - 1.69	0.46 - 0.89
Quench wastes	TSS	0.52 - 1.00	0.29 - 0.58
	COD	6.15 - 11.96	3.12 - 6.21
	Oil-grease	0.25 - 0.52	0.14 - 0.27
	Phenolics	0.006- 0.012	0.005- 0.02
	Ammonia	0.95 - 0.98	0.43 - 0.45
	Sulfide	0.005- 0.010	0.017- 0.005
	Chromium	--	--
	Total	0.012-0.025	0.003-0.014
	Hexavalent	0.0002-0.0005	0.00001-0.0002
	pH	within range 6-9	

^aAll values in lb 10¹² Btu input, except pH.

	<u>Pollutant</u>	<u>1-day Maximum^b</u>	<u>30-day Average^b</u>
Boiler			
<u>Waste Streams</u>			
Boiler blowdown, Cooling tower blowdown	TSS	100	30
Miscellaneous waste streams	Oil-grease	20	15
	Copper total	1.0	1.0
	Iron total	1.0	1.0
	Free available chlorine	0.5	0.5
	Corrosion inhibi- tors (e.g., zinc phosphorous)	None	None

^bAll values in mg/l, except pH; quantity of pollutants discharged shall not exceed the quantity determined by multiplying waste stream flow times BAT concentration.

Table B-2 (Continued)

ESTIMATED EFFLUENT GUIDELINES

<u>Pollutant</u>		<u>1-day Maximum^c</u>	<u>30-day Average^c</u>
Coal pile, storm runoff	BOD ₅	0.40	0.21
	TSS	0.24	0.14
	COD	3.1	1.6
	Oil-grease	0.126	0.067
	pH	within range 6-9	

^cAll values lb/10³ gal flow

- (b) pose a substantial present or potential hazard to human health or the environment when improperly stored, treated, transported, or disposed of or otherwise managed."

To assist in defining hazardous wastes, eight categories of characteristics have been developed and set forth by the EPA:

- (1) Ignitability
- (2) Corrosivity
- (3) Reactivity
- (4) Toxicity
- (5) Radioactivity
- (6) Infectiousness
- (7) Phytotoxicity
- (8) Teratogenicity or mutagenicity.

Tests that determine these characteristics have been proposed for the categories (1) through (4). Many of the wastes associated with coal liquefaction technologies may be determined to be hazardous. It should be assumed that at some point EPA will either perform its own tests or require DOE-related contractors to perform tests according to these criteria (or whatever criteria are accepted as final) in order to determine if specific wastes are hazardous. Some of the waste species are already regulated under the Safe Drinking Water Act (PL 93-523) or CWA (PL 95-217) as priority pollutants. In these contexts, wastes will need to be managed in such a manner as to prevent their entrance to the environment by way of leaching to the ground water or as runoff to surface waters. These waste species are listed below:

Inorganics^a

Antimony
 Arsenic
 Beryllium
 Cadmium
 Chromium
 Copper
 Lead
 Mercury
 Nickel
 Selenium
 Silver
 Thallium
 Zinc

Organics^a

Acenaphthene
 Fluoranthene
 Naphthalene
 Phenol
 Benizidine
 Chrysenes
 Benzantracenes
 Benzopyrenes
 Benzene

Note that a number of the organics are polycyclic aromatic hydrocarbons about which considerable concern has been expressed.

Even without testing for the above hazardous criteria, it is possible that these wastes may be considered hazardous wastes simply on a generic process level. In the Federal Register of December 18, 1978, hazardous waste lists have been developed on a generic process basis. Thus, if the waste results from a process that is characteristic under a given SIC code and it is on the list, the burden of proof is on the industry to show that the waste is not hazardous. Processes currently generating hazardous wastes include (Section 250.14(b)(2)) SIC 2911 Petroleum refining:

- o High octane production neutralization HF alkylation sludge
- o DAF sludge
- o Kerosene filter cake
- o Lub oil filtration clays
- o Slop oil emission solids
- o Exchange bundle cleaning solvent
- o API separator sludge.

Although it may be inappropriate to make strong analogies at this juncture, the listing of petroleum refining wastes and the production of similar products by liquefaction technologies should be taken into

^aFederal Register, p. 4108 (January 31, 1978).

account. In addition, because coal liquids in general contain more fused aromatics than petroleum liquids, liquefaction solid wastes may be defined more readily as hazardous.

5. Guidelines for Solid Waste Disposal

Section 1008(a)(1) of RCRA requires the publication of suggested guidelines that provide a technical and economic description of the level of performance that can be attained by various available solid waste disposal techniques. The Federal Register for March 26, 1979, set forth proposed guidelines for preferred designs and operation of solid waste disposal facilities for which landfilling was required. Standards of treatment, storage, and disposal of hazardous wastes under Section 3004 of RCRA have not been promulgated. However, because it appears that the large volumes of ash and sludge generated by a coal liquefaction plant will most likely be disposed of by landfilling, the following criteria proposed in the March 1979 Federal Register will need to be met as a minimum requirement.

Site Selection

Environmentally sensitive areas, including wetlands, 100-year floodplains, permafrost areas, critical habitats of endangered species, and recharge zones of sole source aquifers should be avoided or receive lowest priority as potential locations for landfill disposal sites. Locations of landfills in such areas are possible through the use of proper, and sometimes innovative, engineering practices and if no suitable alternative site exists.

Design

The principal objective of the disposal techniques outlined by EPA is to protect ground and surface waters from contamination by

leachate from the solid wastes. Thus, it is necessary to isolate the wastes from the ground water and minimize leachate formation.

- (1) The bottom of the disposal pond should be substantially above the high groundwater table (at least 1.5 m or more).
- (2) Surface runoff diversion; structures should divert all water runoff from the 10-year, 24-hour precipitation event.
- (3) Leachate at the bottom of the landfill should be collected and disposed of separately.
- (4) When natural hydrogeologic conditions cannot prevent flow of leachate to the ground waters, low permeability (1×10^{-7} cm/s or less) liners must be used. This includes the use of natural barriers such as a minimum of 30 cm of clay soils or artificial materials such as asphaltic materials and polymeric membranes.
- (5) Monitoring of surrounding ground waters is necessary to detect possible contamination.

Appendix C

SITING CHARACTERISTICS OF A REPRESENTATIVE FISCHER-TROPSCH BASELINE PLANT

1. Plant Description

General Plant Data

Facility name:	Fischer-Tropsch process
Prime input:	Coal, water
Prime output:	Liquid and gaseous fuels
Day/yr of normal operation:	336
Overall thermal efficiency:	58% (HHV)
Assumed site for baseline plant:	Wyoming

List of Process Unit Operations

The following process units comprise the facility:

- Gasification (Lurgi dry ash, fixed-bed pressure gasification)
- Raw gas shift
- Raw gas cooling
- Shifted gas cooling
- Gas purification (Rectisol)
- Sulfur recovery (Stretford)
- Gas liquor separation
- Phenol recovery (Phenosolvan)
- Ammonia recovery (Chemie Linz/Lurgi)
- Hydrocarbon recovery (heptane wash)
- H₂ recovery (pressure swing)
- Methanation

CO₂ removal (MEA wash)
SNG drying (TEG wash) and compression
F-T synthesis
Naphtha hydrotreating
F-T product fractionation
F-T product hydrotreating
Hydrotreated product fractionation
Catalytic reforming
C₅/C₆ isomerization
Catalytic polymerization
HF alkylation
Poly gasoline hydrogenation
Light ends recovery
H₂ purification
Alcohol recovery
Oxygen production (air separation)
Boiler
Main superheater
Superheater
Coal handling
Ash handling
BFW preparation (deaerator and demineralizer)
CW makeup preparation
CW towers
Electric power generation
Gasoline blending
F-T catalyst preparation.

List of Pollution Control Units

The following pollution control units and/or environmental design standards apply to the plant waste streams:

- o Electrostatic stack gas precipitator (ESP)
- o Stackgas cleanup
- o Waste water treatment (biological)

The plant complex has been designed to meet local and federal environmental regulations in force as of July 1977, for liquid and gaseous effluents.

Boiler stack gas cleanup facilities for SO_2 removal are provided to reduce the SO_2 emissions to $0.2 \text{ lb}/10^6 \text{ Btu}$ of fired heat. In addition, an electrostatic precipitator is included to reduce particulate matter to $0.03 \text{ lb}/10^6 \text{ Btu}$ of fired heat duty.

The sulfur emission target specification is the design limit for the latest proposed commercial Wyoming SNG plant (Panhandle Project). Note: when calculating the "boiler" fired duty, the main superheater duty is included, and LHV is the basis.

Sulfur emissions from the process units are reduced by treating all sulfur-containing offgases in sulfur recovery (Stretford) units. The tail gas stream containing 10 ppm H_2S from this unit is incinerated in the boiler to eliminate the hydrocarbons and to convert the COS and H_2S to SO_2 for removal in the stack gas cleanup facility.

The wet ash and solid wastes (e.g., from stack gas cleanup and water treating) are disposed of in a controlled landfill.

Water System Design

The following cooling system units and/or design philosophies apply to the plant water requirements.

The quality of the untreated fresh water assumed is the western location water quality. TDS equals 496 ppm, and hardness is 232 ppm CaCO_3 . We have assumed that the water is available at the plant gate.

All aqueous effluents are treated and recycled. Blowdown water is used for ash slurring, dust control, and similar activities.

2. Resource UseFeedstock

Quantity consumed by process direct:	22,816 st/d
Quantity consumed for on-site heat and power:	<u>4,976 st/d</u>
Total:	27,792 st/d
Nominal identification:	Wyoming sub-bituminous
Important physical properties:	See Table C-1
Important chemical properties:	See Table C-1
Feedstock preparation requirements:	Sizing

Water

Quantity consumed by process directly:	Total 6,600 gpm (extensive reuse)
Quantity consumed by cooling systems:	
Nominal sources:	River
Assumed quality/pretreatment:	496 ppm TDS; 232 ppm CaCO ₃

Chemicals and Catalysts:

F-T Catalyst:	2,500 lb/hr
Others:	Less than 1 t/d

Energy

On site production using feedstock:	See above
On-site production using by-products:	All organic wastes incin- erated.

Table C-1

STUDY COAL PROPERTIES
(Wyoming subbituminous coal)

<u>Proximate Analysis (wt.%)</u>	<u>As Received</u>	<u>Dry and Ash-Free</u>
Moisture	28.0	--
Ash	5.1	--
Fixed carbon	33.8	50.5
Volatile matter	33.1	49.5
<u>Ultimate Analysis (wt.%)</u>		
Carbon		74.45
Hydrogen		5.10
Oxygen		19.25
Nitrogen		0.75
Sulfur		0.45
		100.00
<u>Calorific Value (Btu/lb)</u>		
HHV	8,509	12,720
LHV	7,893	12,236
<u>Fusion Properties of Ash (°F)</u>		
	<u>Atmosphere</u>	
	<u>Oxidizing</u>	<u>Reducing</u>
Softening point	2,335	2,335
Melting point	2,360	2,360
Flow point	2,440	2,430
<u>Mineral Analysis of Ash (wt.%)</u>		
SiO ₂	19.0	
Al ₂ O ₃	14.0	
Fe ₂ O ₃	6.0	
MgO	7.8	
CaO	36.0	
Na ₂ O	2.7	
K ₂ O	0.2	
SO ₃	7.0	
BaO	0.2	
TiO ₂	1.0	
P ₂ O ₅	1.8	
Undetermined	4.3	
	100.00	

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FIGURE C-1. LABOR PROFILES FOR FISCHER-TROPSCH BASELINE PLANT

3. Land and Labor

Land requirements: Total acres, 650

Labor requirements

See Figure C-1.

4. Product OutputPrimary Products

	<u>Quantity</u>	<u>Energy Content (HHV) (10⁹ Btu/d)</u>
Gasoline b/d	13,580	72
SNG, 10 ⁶ scf/d	173.3	173
LPG, b/d	1,107	4.2
Butanes, b/d	146	0.6
Diesel Fuel, b/d	2,307	13
Fuel Oil, b/d	622	3.7
Alcohol, 10 ³ lb/d	510	3.8
Total fuel oil equivalent b/sd	44,950	270

Salable By-Products

Sulfur, st/d	103	--
Ammonia, st/d	61	--

Alternative Product Slates

Alternative operating modes/designs may be proposed to meet different product slates. The product slate will vary with feed coal composition.

The current Sasol operation steam reforms SNG to extinction to maximize liquid fuel yields.

5. ResidualsAir Emissions (see Appendix K)Aqueous Effluents

Zero discharge

Solid residues

	<u>Quantity (lb/hr)</u>
Ash	118,100
H ₂ O	20,000
Unreacted coal	7,050
Sulfur	70
Mineralized sulfur	2,600

Total	147,820
-------	---------

Tailing from catalyst plant = 3,100 lb/hr
 Spent F-T catalyst = 2,500 lb/hr

6. Reference

Schreiner, M., "Research Guidance Studies to Assess Gasoline from Coal by Methanol-to-Gasoline and Sasol-Type Fischer-Tropsch Technologies," Mobile Research and Development Corporation Report prepared for the U.S. Department of Energy (August 1978).

Ralph M. Parsons Company, "Fischer-Tropsch Complex Conceptual Design/Economic Analysis: Oil and SNG Production," Report prepared for United States Energy Research and Development Administration (January 1977).

Appendix D

SITING CHARACTERIZATION OF A REPRESENTATIVE METHANOL-TO-GASOLINE BASELINE PLANT

1. Plant Description

General Plant Data

Facility name:	Coal-to-gasoline via methanol-to-gasoline process (Mobil)
Prime input:	Coal, water
Prime output:	Gasoline
Day/yr of normal operation:	336
Overall thermal efficiency:	62% (HHV)
Assumed site for baseline plant:	Wyoming

List of Process Unit Operations

The following process units comprise the facility:

- Gasification (Lurgi dry ash, fixed-bed, pressure gasification)
- Raw gas shift
- Raw gas cooling
- Shifted gas cooling
- Gas purification (Rectisol)
- Sulfur recovery (Stretford)
- Gas liquor separation
- Phenol recovery (Phenosolvan)
- Ammonia recovery (Chemie Linz/Lurgi)
- Methanol synthesis (Lurgi low-pressure process)
- H₂ recovery (pressure swing)

Methanation

CO₂ removal (MEA wash)

SNG drying (TEG wash)

Methanol conversion (Mobil) fixed-bed process

Naphtha hydrotreating

Fractionation

HF alkylation

Oxygen production (air separation)

Boiler

Main superheater

Superheater

Ash handling

BFW preparation (deaerator and demineralizer)

CW makeup preparation

CW towers

Electric power generation

Gasoline blending

List of Pollution Control Units

The following pollution control units and/or environmental design standards apply to the plant waste streams:

- o Electrostatic stack gas precipitator (ESP)
- o Stack gas cleanup
- o Waste water treatment (biological)

The plant complex has been designed to meet local and federal environmental regulations in force in July 1977 for liquid and gaseous effluents.

Boiler stack gas cleanup facilities for SO₂ removal are provided to reduce the SO₂ emissions to 0.2 lb/10⁶ Btu of fired heat. In addition, an ESP is included to reduce the particulate matter to 0.03 lb/10⁶ Btu of fired heat duty.

The sulfur emission target specification is the design limit for the latest proposed commercial Wyoming SNG plant (Panhandle Project). Note: when calculating the "boiler" fired duty, the main superheater duty is included and LHV is the basis.

Sulfur emissions from the process units are reduced by treating all sulfur-containing offgases in a sulfur recovery (Stretford) unit. The tail gas stream containing 10 ppm H_2S from this unit is incinerated in the boiler to eliminate the hydrocarbons and to convert the COS and H_2S to SO_2 for removal in the stack gas cleanup facility.

The wet ash and solid wastes (e.g., from stack gas cleanup and water treating) are disposed of in a controlled landfill.

Water System Design

The following cooling system units and/or design philosophies apply to the plant water requirements:

The quality of the untreated fresh water assumed is the western location water quality. In summary, TDS equal 496 ppm and the total hardness is 232 ppm $CaCO_3$. It is assumed that the water is available at the plant gate.

All aqueous effluents are treated and recycled. Blowdown water is used for ash slurring, dust control, etc.

2. Resource Use

Feedstock

Quantity consumed by process directly: 22,816 st/d

Quantity consumed by on-site heat and power: 3,288 st/d

Total: 26,104 st/d

Nominal identification:	Wyoming sub-bituminous
Important physical properties:	See Table D-1
Important chemical properties:	See Table D-1
Feedstock preparation requirements:	Sizing

Water

Quantity consumed by process directly:	Total 6,300 gpm
Quantity consumed by cooling systems:	(extensive reuse)
Nominal sources:	River
Assumed quality pretreatment:	496 ppm TDS; 232 ppm CaCO_3
Ambient conditions assumed for cooling system design:	Summer, wet bulb 66°F
	Summer, dry bulb 95°F
	Relative humidity 70%

Chemicals and Catalysts

The following quantities are used: Less than 1 st/d

Energy

The plant energy requirements are supplied in the following manner:

- o On-site production using feedstock: see above
- o On-site production using by-product: all organic waste incinerated

3. Product OutputPrimary Products

	<u>Quantity</u>	<u>Energy Content (HHV)</u> <u>(10 Btu/d)</u>
Gasoline, b/d	22,045	117
SNG, 10 ⁶ scf/d	148.5	148
LPG, b/d	1,555	5.9
Butanes, b/d	2,205	8.4
Total, fuel oil equivalent, b/d	45,550	273

Salable By-Products

	<u>Quantity</u>	<u>Energy Content (HHV)</u> <u>(10 Btu/d)</u>
Sulfur, st/d	61	--
Ammonia, st/d	103	--

Alternative operating modes/designs may be proposed to meet different product slates:

The fluidized-bed mode of the Mobil MTG process is under development. It may ultimately offer higher gasoline yield and thermal efficiency.

4. Land and Labor

Land requirements: 500 acres

Labor requirements

See Figure D-1

5. Residuals

Air emissions

See Appendix K

Aqueous Effluents

Zero discharge

Solid residues

	<u>lb/hr^a</u>
Ash	111,000
H ₂ O	20,000
Unreacted coal	7,050
Sulfur	80
Mineralized sulfur	2,000
	<hr/>
Total	140,130

6. Reference

M. Schreiner, "Research Guidance Studies to Assess Gasoline from Coal by Methanol-to-Gasoline and Sasol-Type Fischer-Tropsch Technologies," Mobile Research and Development Corporation for the U.S. Department of Energy (August 1978).

^aAll one stream.

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FIGURE D-1. LABOR PROFILES FOR METHANOL-TO-GASOLINE BASELINE PLANT

Appendix E

SITING CHARACTERIZATION OF A REPRESENTATIVE
DIRECT LIQUEFACTION BASELINE PLANT1. Plant DescriptionGeneral Plant Data

Facility Name:	Direct coal liquefaction - base case (Exxon Donor Solvent Process)
Prime input:	Coal, water, purchased power
Prime output:	Liquid fuels
Day/yr of normal operation:	292
Overall thermal efficiency:	63% (HHV)
Assumed site for baseline plant:	Illinois

List of Process Unit Operations

The plant design follows that of the Exxon Donor Solvent (EDS) process, and information has been taken from Exxon's commercial design for a 60,000 b/d oil equivalent plant that was prepared for DOE (Figure E-1). Coal fed to the process is Illinois No. 6 bituminous, and the siting basis is mine-mouth, rural Illinois. For process feed, 24,000 st/d of coal are consumed. No coal is used for plant power generation; instead, electricity (175 MW) is imported.

By way of comparison with the other direct coal liquefaction processes (H-coal and SRC-II), the EDS process includes a flexicoker (Exxon technology) that consumes the heavy fraction from the liquefaction/fractionation stage to produce a low-Btu (120 Btu/scf) fuel gas. Another difference is the inclusion of a hydrogenation unit for

FIGURE E-1. BLOCK FLOW DIAGRAM OF BASE CASE DIRECT LIQUEFACTION

the solvent that is recycled from the fractionation unit to the liquefaction process.

The overall thermal efficiency for this process, defined as the higher heating value of products and by-products, divided by the thermal equivalent of the coal and power consumed, is 63.3%. The design occupancy is 0.8 for 292 day/yr operation.

The plant consists of two liquefaction trains. The train size is set by sizing limitations of the liquefaction reactor and flexicoker. This size also approaches the largest projected Illinois mine capacity (3.5 million st/y cleaned coal). A conveyor belt is envisioned to transport coal from the nearby mine, and rail facilities are needed to bring coal from the more distant mine.

Total coal storage of 40 days is required--10 days for live storage, plus 30 days of dead storage. Coal cleaning facilities are assumed to be located at the mine, rather than at the plant. Cleaned coal is fed by conveyor belt from the stocker-reclaimer to a feed-surge storage silo, and then to impact-mill coal crushers. The coal is reduced from 90% minus-1" to 95% minus-8 mesh. The crushed coal is then fed to the dryers by enclosed belt conveyors.

Dried coal is mixed with the hydrogen donor recycle solvent to form a slurry. This slurry is combined with hydrogen treat gas and heated in a furnace. The mixture is then fed to the tubular reactors, where the coal is liquefied noncatalytically in the presence of molecular hydrogen and the hydrogen donor solvent. A gas stream is separated from the reactor effluent and the gas is cooled to separate naphtha and solvent for recycling. A water wash stream is provided to prevent ammonium chloride from plugging the condensing system.

List of Pollution Control Units

The following pollution control units and/or environmental design standards apply to the plant waste streams.

NH_3 , H_2S , and CO_2 are removed by the water wash and DEA scrubbing. The recovered condensate and the liquids/solids stream are sent to atmospheric and vacuum distillation, where they are separated into a number of cuts.

Spent solvent is hydrogenated in fixed-bed catalytic reactors to restore the hydrogen able to be donated. Effluent from the reactors is cooled and separated into a hydrogen-rich gas and a hydrotreated liquid stream. The gas is scrubbed to recover NH_3 and H_2S .

The flexicoker receives vacuum bottoms slurry from the fractionation section. In the reaction section, the bottoms are pyrolyzed to additional liquid products and coke. Olefinic coker gas is sent to a DEA absorber for acid gas removal and then to cryogenic fractionation for preparation as steam-reformer feed. The coke is transported to a gasifier, where steam and air are added to form low-Btu gas, whose heating value is about 120 Btu/scf. This gas is scrubbed for particulate removal and passed through a Stretford absorber for removal of H_2S before being used for plant fuel.

Hydrogen for the process is generated by reforming the available methane and ethane. Conventional technology is used, wherein an activated potassium carbonate solution absorbs the CO_2 generated in the reforming and shift reactions, and then releases it to the atmosphere. No sulfur is present in this vent gas because it is completely removed by zinc oxide guard catalyst upstream of the reforming furnace.

Sour water is collected from several processing areas and fed to a stripping unit. The process used for this size operation will be one of the selective models, where NH_3 and $\text{H}_2\text{S}/\text{CO}_2$ are recovered separately. The Chevron "WWT" process and the Lurgi "CCL" process are both currently used commercially in this area. U.S. Steel's "Phosam-W" process has been designed for similar application on steel mill effluent, but it is not so commercially accepted as the other two. Using any of these types of unit, anhydrous NH_3 is recovered for

by-product sales, and H_2S and CO_2 are sent to a Claus sulfur recovery unit.

Rich DEA from the three on-site gas sweetening units is fed to DEA regeneration, where H_2S and CO_2 are stripped and combined with the other Claus unit feed gas.

About 96% of the sulfur in the Claus unit feed is converted to elemental sulfur by-product. The tail gas is fed to a cleanup unit to achieve a recovery of 99.9% of the incoming sulfur, limiting the final incinerator emissions to about 100 wppm SO_2 .

The stripped water from the sour water treating unit is pumped to a phenol extraction plant. Crude phenols are recovered and combined with the plant's naphtha product. The effluent water is sent to offsites, where it is treated via dissolved air floatation, biological oxidation, filtration, and activated carbon absorption. This treatment sequence is expected to satisfy the "Best Available Technology" (BAT) standards projected for the mid-1980s.

4. Water System Design

The following cooling system units and/or design philosophies apply to the plant water requirements:

The plant cooling water requirements for the base case have been reduced through moderate use of fin-fan coolers and recirculation of appropriate treated water streams for makeup water. The total circulation rate is 68,000 gpm.

2. Resource Use

Feedstock

Quantity consumed by process directly: 24,000 st/d
 Quantity consumed for on-site heat and power: None
 Nominal identification: Illinois #6 bituminous
 Important physical properties: (See Table E-1)
 Important chemical properties: (See Table E-1)
 Feedstock storage capacity: 40 days
 Feedstock preparation requirements: Sizing, drying

Water

Quantity consumed by process directly:
 Total, 8,050 gpm
 Quantity consumed by cooling systems:
 Nominal sources: River/industrial

Chemicals and Catalysts

The following quantities are used in the process units:

Catalysts: See Residuals

Chemicals (on-site):

2,800 gal/d	Stretford soln.
2,150 ft ³ /6 mo	CO ₂ removal soln. in H ₂ reformer
1,020 ft ³ /6 mo	Corrosion inhibitor in CO ₂ removal unit
75 gpm	20 ⁰ BE caustic in several parts of plant
120 gal/d	DEA makeup
3,800 lb/d	i-C ₃ ether for phenol extraction
400 ft ³ /mo	Commercial grade CaCl ₂ dihydrate for LPG dryers

Table E-1
STUDY PROPERTIES OF ILLINOIS NO. 6 COAL
(Wt.% dry basis)

Carbon	70.15
Hydrogen	5.07
Oxygen	10.24
Nitrogen	1.19
Sulfur	4.14
Chlorine	0.11
Ash	<u>9.10</u>
	100.00

Moisture = 16.5 wt.%

HHV (dry) = 12,660 Btu/lb

Energy

The plant energy requirements are supplied in the following manner:

On-site production using feedstock

On-site production using by-product

On-site production using product

See Table E-2

Purchased off-site

3. Product Output

Nominal output: 60,000 b/d oil equivalent

Primary Products

	<u>Rate</u>	<u>Comments</u>
LPG	8,000 b/d	C ₃ + C ₄
C ₅ -400°F Naphtha	22,000 b/d	
400-1,000°F Fuel Oil	29,800 b/d	0.5% sulfur

Salable By-products

Sulfur	700 lt/d	
NH ₃	1209 st/d	Anhydrous

4. Land and Labor

Land Requirements: 450 acres

Labor requirements

See Figure E-3.

Table E-2

EDS COMMERCIAL PLANT STUDY DESIGN: OVERALL ENERGY BALANCE, ILLINOIS BASE CASE

<u>Feed</u>	<u>Liquefaction + Solvent Hydro.</u>	<u>Flexicoker</u>	<u>Hydrogen Generation and Recovery</u>	<u>By-product Recovery Offsites, Miscellaneous</u>	<u>Net Balance</u>
Coal (Dry)	(100)	-	-	-	(100)
Power (1)	(1.5)	(1.8)	(3.0)	(0.8)	(7.1)
<u>Intermediates</u>					
Hydrogen	(17.8)	-	17.8	-	-
C ₁ /C ₂	11.9	3.9	(15.8)	-	-
H ₂ S, NH ₃	2.2	0.3	-	(2.5)	-
Bottoms	54.5	(54.5)	-	-	-
Fuel gas	(7.8)	20.5	(11.2)	(1.5)	-
Steam	(2.4)	2.1	0.9	(0.6)	-
Sensible heat	1.1	(1.1)	-	-	-
<u>Products</u>					
Liquids	47.9	18.2	-	-	66.1
S, NH ₃	-	-	-	1.7	1.7
<u>Losses</u>					
Ash	-	5.5	-	-	5.5
Stack	1.4	-	2.4	0.3	4.1
Water, air	10.5	6.9	7.2	3.4	28.0
Other	-	-	1.7	-	1.7

Note:

Power is evaluated as the coal equivalent of electric power (8,500 Btu/kWh)

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FIGURE E-2. LABOR PROFILES FOR EDS BASELINE PLANT

5. ResidualsAir Emissions

See Appendix K

Aqueous Effluent

The contaminant rates for total plant effluent, estimated for the treatment sequence discussed in Section 1, are as follows, for a discharge rate of 7,000 gpm (including rainwater runoff and a plant contingency):

<u>Contaminant</u>	<u>Concentration (ppm)</u>	<u>Rate (lb/hr)</u>
Oil	Less than 5	Less than 20
Phenols	Less than 1	Less than 4
H ₂ S	Less than 1	Less than 4
NH ₃	Less than 10	Less than 35
BOD ₅	10	35
COD	50-100	175-350
TSS	Less than 10	Less than 35
TDS	Around 3,200	Around 135 st/d

Solid Wastes

<u>Component</u>	<u>Average Rate (st/yr)</u>	<u>Comments</u>
Solvent Hydro. Rx. Catalyst	0	Ni-Mo 1/16" extrudate regenerated by contract supplier

Solv. hydro. feed filters	300	Gravel, 150 t/6 mo
H ₂ plant		
Hydrotreater catalyst	24	95 t/4 yr Co-Mo
ZnO catalyst	120	240 t/2 yr
Reformer catalyst	38	150 t/4 yr
Ni-Urania		
H.T. shift catalyst	80	160 t/2 yr Fr
Oxide		
L.T. shift catalyst	150	300 t/2 yr Cu
Oxide		
Methanater	35	140 t/4 yr Ni
Oxide		
Sulfur plant catalyst	90	180 t/2 yr Bauxite
Tailgas plant hydrog. rx. catalyst	12	24 t/2 yr
Alumina driers	8	15 t/2 yr
Activated carbon	0	Regenerated by contract supplier
Solids from heater decoking	300	75 t/3 mo Coke
Flexicoker solids	812,000	Ash and residue, 292 d/yr continuous to landfill as sludge
H ₂ plant carbon adsorption	32	8 t/3 mo
Biological sludge	2,920	365 d/yr

6. References

Exxon Research and Engineering Company, "Exxon Donor Solvent Coal Liquefaction Commercial Plant Study Design," Interim Report prepared for the U.S. Energy Research and Development Administration (February 1978).

Ralph M. Parsons Company, "Process Engineering Evaluations of Alternative Coal Liquefaction Concepts," for the Electric Power Research Institute (April 1978).

Appendix F

SITING CHARACTERIZATION OF REPRESENTATIVE
DIRECT LIQUEFACTION ALTERNATIVE PLANTS

1. Alternative 1--Addition of On-Site Coal-Fired Power Generation

Changes to the inputs and outputs from the base case that result from bringing a coal-fired power generation system within the plant battery limits for a plant self-sufficient in energy are shown in Table F-1.

The power plant is considered to have a flue gas desulfurization (FGD) unit included, because without one, the plant could not meet federal criteria for SO_2 emissions of $1.2 \text{ lb}/10^6 \text{ Btu}$ of fuel fired when operated on Illinois coal (3-4% sulfur). Removal of SO_2 is 90% efficient, which gives $0.65 \text{ lb}/10^6 \text{ Btu}$ emitted when the power plant is charged with the design 3.5% sulfur coal. The FGD spray tower absorber is preceded by electrostatic precipitators (ESP) for removal of 99%+ of the flyash. The FGD system is the nonregenerable, calcium-based limestone type--the FGD system furthest along in commercial development. Considerable quantities of solid waste (gypsum) are generated and sent to landfill.

2. Alternative 2--Addition of On-Site Power Generation Using Low-Btu Process Gas

In this alternative, the flexicoker shown in the base case is replaced with a partial oxidation unit (see Figure F-1). Bottoms from the liquefaction fractionation unit are sent to a Texaco- or Shell-type oxidation unit. Oxygen is separated from air and also fed to the unit. A medium-Btu gas (300 Btu/scf) is produced, instead of the low-Btu gas

Table F-1

CHANGES IN INPUTS AND OUTPUTS FROM BASE CASE FOR ALTERNATIVE 1.

<u>Add</u>	<u>To the Base Case Rate of</u>	<u>To give</u>	<u>Comments</u>
1,450 t/d	Coal feed rate of 24,000 t/d	25,450 t/d	Boiler fuel
1,930 gpm	River water intake rate of 7,350 gpm	9,280 gpm	For FGD system boiler makeup and additional cooling tower makeup.
88,000 t/yr	Raw materials	88,000 t/yr	Limestone
186,000 t/yr	Solid waste	1,002,000 t/yr	Additional sludge, consisting of gypsum from FGD unit, boiler flyash and boiler bottom ash.
1,050 gpm	Waste water rate of 5,400 gpm	6,450 gpm	Boiler blowdown and additional cooling tower blowdown
1,000 lb/hr	SO ₂ emissions	2,710 lb/hr	
730 lb/hr	NO _x emissions	1,260 lb/hr	
37 lb/hr	Particulate emissions	75 lb/hr	

in the case of the air-blown flexicoker gasifier. This gas is used to balance the plant's energy needs.

Because no hydrogen is produced from the partial oxidation step, it becomes necessary to reform all light hydrocarbons, methane through butane, to balance the liquefaction hydrogen needs. Therefore, no LPG is produced for sale. Inputs, products, and residuals for Alternative 2 are shown in Tables F-2, F-3, and F-4.

Compared to the base case, process solid emissions decline because much of the flexicoker residue is unconverted carbon. This is not characteristic of the partial oxidation process. The fuel gas is sweetened in a DEA absorber, to reduce emissions that are produced from the power generation cycle.

3. References

Bechtel Power Corporation, "Coal-Fired Power Plant Capital Cost Estimates," Report prepared for the Electric Power Research Institute (January 1977).

Exxon Research and Engineering Co., "Exxon Donor Solvent Coal Liquefaction Commercial Plant Study Design," Interim Report prepared for the U.S. Energy Research and Development Administration (February 1978).

FIGURE F-1. BLOCK FLOW DIAGRAM FOR DIRECT COAL LIQUEFACTION WITH BOTTOMS PARTIAL OXIDATION

Table F-2

**INPUTS FOR COAL LIQUEFACTION PLANT WITH PARTIAL OXIDATION
OF BOTTOMS TO BALANCE ENERGY NEEDS**
(Basis: 60,000 b/d oil equivalent production)

<u>Component</u>	<u>Rate</u>	<u>Comments</u>
Cleaned coal	25,700 t/d	Illinois #6 bituminous
Raw water	12,000 gpm	
Electricity	0	On-site generation
Catalysts and Chemicals	3,270 ft ³ /6 mo	H ₂ plant CO ₂ removal solution (K ₂ CO ₃)
	1,550 ft ³ /6 mo	H ₂ plant CO ₂ unit corrosion inhibitor
	75 gpm	20° Be caustic (received @ 50° Be and diluted)
	120 g/d	DEA makeup (100%)
	3,800 lb/d	iC ₃ ether
	400 ft ³ /mo	Commercial grade CaCl ₂

Table F-3

PRODUCTS FROM COAL LIQUEFACTION PLANT WITH PARTIAL OXIDATION

<u>Products</u>	<u>Rate</u>	<u>Comments</u>
LPG (C ₃ /C ₄)	0	Reformed for H ₂
C ₅ -400°F naphtha	26,000 b/d	
400-1,000°F Fuel Oil	33,700 b/d	
<u>By-Products</u>		
Sulfur	700 lt/d	
NH ₃	120 st/d	Anhydrous

Table F-4

RESIDUALS FROM COAL LIQUEFACTION PLANT OF PARTIAL OXIDATION

<u>Component</u>	<u>Average Rate</u>	<u>Comments</u>
Waste water	5,600 gpm	
Air emissions:		
SO ₂	2,400 lb/hr	
NO _x	1,300 lb/hr	
Particulates	49 lb/hr	
Solid wastes:		
H ₂ plant		
Hydrotreater catalyst	35	140 t/4 yr Co-Mo
ZnO catalyst	180	360 t/2 yr
Reformer catalyst	58	230 t/4 yr Ni-Urania
HT shift catalyst	120	240 t/2 yr Fe Oxide
LT shift catalyst	230	460 t/2 yr Cu Oxide
Methanater catalyst	53	210 t/4 yr Ni Oxide
Sulfur plant catalyst	90	180 t/2 yr Bauxite
Tailgas plant hydrog. rx. catalyst	12	24 t/2 yr
Alumina driers	8	15 t/2 yr
Activated carbon	0	Regenerated by contract supplier
Solids from heater decoking	300	75 t/3 mo Coke
Solids from partial oxidation	642,000	Ash and residue 292 d/yr continuous to landfill as sludge
H ₂ plant carbon adsorption	48	12 t/3 mo
Biological sludge	2,920	365 d/yr

Appendix G

SITING CHARACTERIZATION OF A REPRESENTATIVE
UNION SURFACE RETORTING BASELINE PLANT

1. Plant Description

General Plant Data

Facility Name: Union B Oil Shale Retorting (surface)

Prime Input: 128,000 st/d oil shale

Prime Output: 100,000 b/d 22.2° API crude shale oil

List of Process Unit Operations

The following process units comprise the facility (see Figure G-1):

- o Underground mine
- o Crushing
- o Retort
- o Retort gas heater
- o Power generation

List of Pollution Control Units

The following pollution control units and/or environmental design standards apply to the plant waste streams

- o Waste disposal site
- o Water treatment
- o Gas cleanup

Assumptions

100,000 b/d crude shale oil, 22° API
34 gal/ton F.A. shale
Crude Oil produced = 100% F.A.
Retort gas: 77 scf dry gas/ton of shale at 845 Btu/scf
4% fines and dust lost in mining and crushing to 2" to 1/8"
Spent shale = 1680 lb/ton raw shale
Spent shale density 60 lb/ft³, 5 wt.% water for dust control
Retort gas will be burned in recirculating gas heater as required, with excess used to make electricity
12 retorts, each with gas heater

2. Resource Use

Feedstock

Quantity consumed by process directly: 128,000 st/d
Quantity consumed for onsite heat and power: none
TOTAL: 128,000 st/d
Nominal identification: 34 gal/ton Fischer Assay shale

Mining Assumptions

Underground room and pillar mining

60% resource recovery at 500 ft. overburden
55% resource recovery at 1500 ft. overburden

DRAFT

FIGURE G-1. BLOCK FLOW DIAGRAM FOR UNION RETORTING PROCESS

Mining rate is 11,000 st/d per chamber

Power factor: 0.4 lb/st (dry mine)

0.6 lb/st (wet mine)

Roof-bolt cross-cuts

Loadhaul-dump-transport to 1000-t/hr feeder breaker

Break to -8" and transportation 42" belts

Ventilation 2.5×10^6 cfm

Diesel output presumed permissible

Water

	<u>gpm</u>
Quantity for revegetation and dust control	600
Quantity for spent shale cooling	3,000
Quantity for retort cooling and process use	<u>1,850</u>
TOTAL	5,450

Energy Consumption at Mine

Power:	240×10^6 kWh (7.95 kWh/ton)
Fuel:	2.9×10^6 gal (0.1 gal/ton)
Lube oil:	0.18×10^6 gal (0.006 gal/ton)

(For adit entry reduce power to 200×10^6 kWh)

3. Land and Labor Requirements

1. Land

Unknown

2. Labor

Construction labor: unknown

Operating Labor:

Productivity at mine 170 t/man-shift

Union's mine to work 2 shifts/day 5 days/week, with third shift for maintenance.

Total mining manpower: 1200

Work force: Mine 1200

(Plant 300

TOTAL 1500

4. Product Output

Primary Product

Shale oil: 100,000 b/sd, 22.2° API

Salable By-product

Sulfur: 67 t/sd

Ammonia: 6 t/sd

5. Residuals

Air Emissions

See Appendix K

Assumptions

Total duty of retort gas heaters:

103,700 t/d shale at 200 Btu/lb at 75% efficiency
= 55.3×10^9 Btu/d
(each heater duty = 192×10^6 Btu/hr)

Flue gas from heaters at 9:1 air/gas ratio
 750×10^6 scf/d

Heat to power generation: 25×10^9 Btu/d
at 12,000 Btu/kWh: 2.08×10^6 kWh/d
86,800 kW

Total retort gas: 96×10^6 scf/d
gas removed in H_2S cleanup = 1.5×10^6 scf/d
clean gas = 94.5×10^6 scf/d
at 850 Btu/scf = 80.3×10^9 Btu/d

$\frac{55.3}{80.3} =$ 68.9% gas required for retorts; 31.1% available for
power generation, etc.

H_2S in clean gas = 3072 scf/d
to retort heaters = 2116 scf/d
to power generation = 956 scf/d

Aqueous Effluent

Zero discharge; 600 gpm used for revegetation dust control

Solid Residue

Oil shale dust and fines: 500 t/d
Spent shale: 103,740 t/d
Ash: combined with spent shale

6. References

Banks, C. E. et al., "Technical and Economic Study of an Integrated Single Pass Mining System for Open Pit Mining of Deep Oil Shale Deposits," Phase I Report for Sun Oil Company (April 1975).

Cameron Engineers, Inc., "A Technical and Economic Study of Candidate Underground Mining Systems fo Deep, Thick Oil Shale Deposits," Prepared for the U.S. Bureau of Mines (October 1976).

Hopkins, J. M. et al., "Development of Union Oil Company Upflow Retorting Technology," paper presented at 81st National Meeting AIChE, Kansas City, MO (April 11, 1976).

Jee, C. K. et al., "Review and Analysis of Oil Shale Technologies, Volume 4 - Aboveground or Surface Technology," prepared for ERDA, FE-2343-6, by Booz, Allen & Hamilton, Inc., Bethesda, MD (August 1977).

Snyder, G. P., and J. R. Pownall, "Union Oil Company's Long Ridge Experimental Shale Oil Project," Proceedings, 11th Oil Shale Symposium, Colorado School of Mines Press, Golden, CO (November 1978).

Union Oil Company, "Union Oil Shale Retort Plant," a private study for Stanford Research Institute (September 1968).

Appendix H

SITING CHARACTERIZATION OF A REPRESENTATIVE
PARAHO SURFACE RETORTING BASELINE PLANT

1. Plant Description

General Plant Data

Facility Name: Paraho oil shale retorting (surface)

Prime Input: 160,000 st/d day oil shale

Prime Output: 96,000 b/d syncrude

List of Process Unit Operations

- o Underground Mine
- o Crushing
- o Retorts: Paraho direct heat, Paraho indirect heat, TOSCO II
- o Hydrogen plant
- o Hydrotreating

List of Pollution Control Units

The following pollution control units and/or environmental design standards apply to the plant waste streams (see Figure H-1):

- o High-Btu gas cleanup
- o Low-Btu gas cleanup
- o Water plant

Assumptions

96,000 b/d syncrude
28 gal/ton F.A. shale
Crude oil produced = 93.75% Fischer Assay
70% recovery of oil shale in mined horizon

White River at this location, 700 cfs
Climate: Rain, 4" May-Sept; 6" Oct-April
Timing: 50,000 b/d 8 years after startup
100,000 b/d 10 years after startup

The "White River Shale Project Detailed Development Plan (DDP)" submitted to Area Oil Shale Supervisor, U.S. Department of Interior, Grand Junction, Colorado, describes a facility that produces 97,000 b/d of synthetic crude oil from 28 gal/ton F.A. Shale.

The White River Shale Project has been suspended until legal problems concerning land ownership are resolved. It will probably be reactivated in late 1980. The retorting scheme may change from Paraho's to Union's process when the project is reactivated.

2. Resource Use

Feedstock

Quantity consumed by process directly: 160,000 st/d
Quantity consumed for onsite heat and power: none
TOTAL: 160,000 st/d
Nominal Identification 28 gal/ton F. A. shale

Mining Assumptions

55 ft of shale at 28 gpt
550 to 1225 ft of overburden

70% resource recovery

Ua 540×10^6 bbl of total resource

Ub 510×10^6 bbl of total resource

Water

5,960 gpm

Energy Consumption

1080 b/d diesel fuel

7710 b/d fuel oil (utilities)

2770 b/d fuel oil (process)

3. Land and Labor Requirements

Lease tracts Ua and Ub (developed as a single facility) are 120 miles by road from railroad at Craig, Colorado. (The combined area of tracts Ua + Ub equals 10,000 acres.

Over the 7-year construction period, 400,000 tons of material will be hauled to the site. The maximum load will be 100 tons. A temporary campsite will be established 5 miles north of the tract. The peak projected population will be 7000 in the tenth year. During commercial operation, the campsite will use 3 MW of electric power and 100,000 gal/day of potable water. At the peak of construction, 275 acres will be disturbed. One hundred thirty acres will be free of vegetation during commercial operations (excluding shale disposal site).

Abandonment: Disturbed areas will be restored as closely as possible to natural state. Shafts and mine portals will be sealed, and the mine will be allowed to fill with water. Disturbed areas will be rehabilitated and revegetated.

FIGURE H-1. BLOCK FLOW DIAGRAM FOR PARAHO RETORTING PROCESS AT TRACTS Ua AND b

Shale disposal areas will be monitored until stabilized (within ten years after abandonment). Runoff water and retention dams should be maintained until the land surface is fully stabilized and revegetated.

Labor

See Figure H-2

4. Product Output

Primary Product

Product: 96,000 b/d calendar day (cd)

50°F pour point

40°F API 0.025 wt.% S

0.034 wt.% N

Viscosity at 40°F/100°F: 13 cs/4cs

160,000 t/d rawshale yields 100,000 b/d crude shale oil
hydrotreat to 107,560 b/d C₅ syncrude

of which:	1080 b/d diesel fuel
	7710 b/d fuel oil (utility)
	2770 b/d fuel oil (process)

Net syncrude production: 97,000 b/d

Salable By-product

Sulfur: 160 st/d

Ammonia: 412 st/d

FIGURE H-2. LABOR PROFILE FOR PARAHO PLANT ON Ua AND b TRACTS
(Includes Room and Pillar Mining)

5. Residuals

Air Emissions

See Appendix K

Aqueous Effluent

Zero discharge; 2820 gpm waste water combined with shale disposal.

Solid Residues

Processed shale: 129,431 st/d

Sulfur from low-Btu gas cleanup: 85 st/d

Spent catalyst and filter aid: 1 st/d

6. References

Banks, C. E. et al., "Technical and Economic Study of an Integrated Single Pass Mining System for Open Pit Mining of Deep Oil Shale Deposits," Phase I Report for Sun Oil Company (April 1975).

Cameron Engineers, Inc., "A Technical and Economic Study of Candidate Underground Mining Systems fo Deep, Thick Oil Shale Deposits," Prepared for the U.S. Bureau of Mines (October 1976).

White River Shale Project. Detailed Development Plan - Federal Lease Tracts Ua and Ub, Volumes 1 and 2" (who, where, and date?).

Appendix I

SITING CHARACTERIZATION OF A REPRESENTATIVE
OCCIDENTAL MODIFIED IN-SITU RETORTING BASELINE PLANT

1. Plant Description

General Plant Data

Facility Name: Occidental modified in-situ retorting

Prime Input: 217,000 ton/d oil shale in-situ

Prime Output: 100,000 b/d crude shale oil

List of process unit operations

The following process units comprise the facility (see Figure I-1).

- o Retort preparation (mining)
- o Operating retorts (in-situ)
- o Oil/water separation
- o Steam plant.

List of Pollution Control Units

The following pollution control units and/or environmental design standards apply to the plant waste streams (see Figure I-1):

- o Gas cleanup
- o Water treatment

Assumptions

100,000 b/d crude shale oil
28 gal/ton Fischer Assay shale
Crude oil produces: 69% Fischer Assay
Retort gas: 12,748 scf dry gas/ton of shale at 80 Btu/scf

Oil production basis: 1% oil used to initiate combustion
15% oil burned and coked
15% oil never retorted

Announced schedule for Tract C-b: 57,000 b/sd retorts
operating by end of 1982.

25% voids and no production from mined shale stockpiled to
surface.

2. Resource Use

Feedstock

Quantity consumed by process directly: 217,000 st/d
Quantity consumed for onsite heat and power: none
TOTAL: 217,000 st/d
Nominal identification: 28 gal/ton F.A. shale

Note: 72,000 t/d of shale are stockpiled on surface because
of retort preparation.

Water

Net production from retorts: 1357 gpm
Net excess mine water: 528 gpm

FIGURE I-1. FLOW DIAGRAM FOR OCCIDENTAL MODIFIED IN-SITU PROCESS

Energy Consumption

Steam plant production:

1,488,000 lb/hr for retorts

175,000 lb/hr for offsite-

Energy Balance

$2766 \times 10^6 \text{ scf/d} \times 80 \text{ Btu/scf} = 221 \times 10^9 \text{ Btu/d total}$
energy available

$\frac{221 \times 10^9 \text{ Btu}}{100,000 \text{ bbl} \times 5.8 \times 10^6 \text{ Btu/bbl}} = 38\%$ (energy in gas = 38% of energy in oil produced)

Energy + Gas = 108% F.A.

28 gal/ton shale contains 16.25 wt.% organics and 2650 Btu/lb energy

$2,650 \times 2,000 = 5.3 \times 10^6 \text{ Btu/ton}$

Energy in oil produced = $2.77 \times 10^6 \text{ Btu/ton}$

52% of energy in shale is retained in product oil (-2% to ignite retort, net = 50%)

Energy in low Btu gas - 20% of energy in raw shale

Mining Use (Retort Preparation)

485,000,000 kWh/yr electric power

2,400,000 gal diesel fuel

140,000 gal lube oil

3. Land and Labor Requirements

Land

Surface disturbance, acres

Mine and access roads:	180
Surface process facilities:	130
Rock and shale storage:	2,190
Ponds and reservoirs:	<u>50</u>
Total:	2,550

Abandonment

Salvagable equipment removed from site
Buildings demolished and leveled close to grade
Hand surface paving broken in place
Pipes and culverts flushed, drained, and plugged
Mine shafts back-fitted
Retired retorts stabilized and eventually allowed to fill with water
Treatment ponds and ditches filled
Broken pavement covered with 1 foot of earth
Area rounded and graded
Vegetation established

Area monitored for hydrological effects of waterfilled retorts.
Postabandonment monitoring plans will be determined at the time.

Labor

See Figure I-3

Total mining manpower: 2,340
Permanent site personnel: 2,600

FIGURE I-2. LABOR PROFILE FOR OCCIDENTAL MODIFIED IN-SITU PROCESS

4. Product Output

Primary Product

Shale Oil: 100,000 b/d

Retort gas: 12,748 scf dry gas/ton of shale

Salable By-product

Steam (from retort gas): 175,800 lb/hr

5. Residuals

Air Emissions

See Appendix K

Water

Net production (to evaporation pond)

Oil water separation: 1357 gpm

Retort Preparation: 528 gm

Solid Residue

Mined shale (surface stockpile): 23,700,000 t/yr

Rubble left in place: 70,900,000 t/yr

Sulfur: 162 t/d

6. References

R. B. Stone et al., "Technical and Economic Study of the Modified In-Situ Process for Oil Shale," Vol. I and II Final Report USBM (November 1976)

H. E. McCarthy and C. Y. Cha, "Oxy-Modified In-Situ Process Development and Update," Quarterly of the Colorado School of Mines (4):85 (October 1976)

C. F. Clark and R. G. Murray, "Oil Shale," Energy Technology Economics Program, Report 9, prepared by SRI International (November 1978) (Client Private)

Ashland Oil Co., and Occidental Oil Shale, Inc., "Modifications to Detailed Development Plan, Oil Shale Tract C-b" (February 1977)

"Second Briefing on In-Situ Oil Technology," Lawrence Livermore Laboratories (October 18-19, 1978)

Appendix J

SUMMARY OF CHANGES IN THE PROPOSED PSD REVISIONS THAT ARE OF
POTENTIAL SIGNIFICANCE TO SYNTHETIC FUEL DEVELOPMENT

To understand the changes in the EPA regulations fully, it is essential to read the regulations.^a This appendix briefly summarizes changes to some of the key phrases in the regulations.

1. "potential to emit"

After application of emission controls at full design capacity (full design capacity means that limitations on hours of operation or amount of materials are not to be included in this calculation). Secondary emissions are not included in potential to emit. Generally, fugitive emissions (emissions that pass through an opening not used as ventilation, etc.) are not included in potential to emit calculations, except for certain types of sources, one of which is "fuel conversion plants."

2. "source"

Besides working to arrive at new definitions of "building," "structure," "facility," and "installation," EPA is proposing to reformulate its review policy. PSD review will be at the plant level; Basically, the activity is conceived as a single entity (enclosed in a bubble) and what is emitted from the entire activity is what counts for review purposes. In nonattainment areas, both the plant and individual pieces of equipment will be reviewed, except where there is a complete, satisfactory nonattainment regulation, in which case only the plant as a whole is subject to review.

^aFederal Register, Vol. 44, No. 173 (September 5, 1979).

3. "modification"

Net increase in potential to emit (old definition: exceed applicable 100/250 t/y threshold); crucial to the net increase idea is "offset," which means an actual design change reducing capacity to emit; offsets are only valid for the same pollutant with comparable health and welfare impacts.

4. "de minimus" exemptions

A two-tier pollutant specific exemption system that establishes cutoff levels below which various aspects of the PSD rules do not apply (see Attachment A, pp. 51937-38 for actual numbers). The "Guidelines for Significant Emission Rates" serve two purposes: One, they determine whether a major source must apply BACT and perform an air quality analysis for the given pollutant. This is particularly important for PSD review because once one pollutant triggers review, in theory all pollutants emitted by that source are subject to PSD review.

Second, the emission guideline numbers determine if a modification is subject to the PSD rule--a de minimus determination for pollutants for which the modified source is major exempts that modification from the PSD rule. (E.g., a source already emitting 150 t/y SO₂ emissions is modified. SO₂ emissions increase 5 t/y, whereas the guideline is 10 t/y. Result: no BACT or air quality analysis is required for the modification.)

"Guidelines for Significant Ambient Air Quality Impacts" is used if emissions are greater than the numbers in the Emission Rate Guidelines but less than the major new source 100/250 t/y threshold. A source may monitor its emissions to ascertain if the ambient air quality impact is less than the figure in the Significant Ambient Air Quality Impact Guidelines. If so, a detailed ambient impact analysis is not required. (E.g, a source emits 10 t/y of PM, where 10 t/y of PM is the emission rate cutoff. BACT is required. However, if the source establishes

through monitoring that the ambient impact of those emissions is less than 5 mg/m³, 24-hr, no ambient impact analysis is required.) It would appear that this policy will allow the administrator to track increment consumption of smaller sources, while exempting these sources from costly impact analyses.

It should be emphasized that the Ambient Impact Guidelines do not apply to pollutants for which a new major source would emit in excess of the 10/250 t/y threshold. Also, the Ambient Impact Guidelines do not apply to major construction that would locate in a nonattainment area or would adversely impact a Class I area.

5. "50-ton exemption"

Caveat: Conversations with EPA, Standards Implementation Branch, have revealed several ambiguities in the proposed "50-ton exemption" provision. It is not clear if the exemption applies when the emission rate of each pollutant regulated under the Act is less than 50 t/y, after BACT, or when post-BACT emissions of only two pollutants--SO₂ and particulates--are each less than 50 t/y (e.g., a source is modified. SO₂ emissions increase 35 t/y. NO_x emissions increase 70 t/y. Is the exemption applicable to the SO₂ emissions, even though NO_x emissions exceed the cutoff?)

EPS's "off-the-cuff" view is that each pollutant's emissions must be less than 50 t/y for the exemption to apply. Thus, in the above example, the exemption would be inapplicable even though SO₂ emissions are below the cutoff.

In regard to the nature of the exemption itself, according to EPA, the provision provides that any modification^b that results in a net

^bExcept a modification that would affect a Class I area or interfere with the attainment of SO₂ or PM standards.

increase in emissions of less than 50 t/y (after BACT) of each pollutant emitted by the source is exempted, for PSD purposes, from the following provisions:

- (1) Air quality review
- (2) Additional impact analyses (soils, vegetation, etc.)
- (3) Monitoring.

A modified source that exceeds the de minimus emission rate cutoff but with emissions after BACT of less than 50 t/y for each pollutant can, under this exemption, by-pass the monitoring option to determine whether it is below the ambient impact cutoff levels that trigger an air quality analysis requirement.

6. "geographic applicability"

Under the old policy, PSD review was required for any major source locating in a nonattainment area if that source affected a clean air area anywhere. The court in Alabama Power v. Costle said EPA could require PSD review of these sources only if the effect was on a clean air area in another state. EPA is petitioning the court to reinstate the old policy in the court's final opinion. Even if EPA's effort fails, it would appear that states can still promulgate regulations requiring sources in nonattainment areas to undergo PSD review for intrastate impacts. In reality, however, many state legislatures are passing laws limiting their local AQCR, PSD rulemaking powers to a level "no more" stringent than federal rules require.

7. "baseline concentration"

Instead of the uniform August 7, 1977 baseline date, the court in Alabama v. Costle decreed that baseline concentrations are to be determined as of the date after August 7, 1977 that the first complete application for a permit is filed to locate in a PSD area; generally, the "area" subject to the baseline determination will be all the clean

areas in the AQCR. New definitions of major stationary source and major modification will be used to trigger baseline dates. (Sources that did not qualify as major under existing regulations but would become so under the proposed new regulations do not trigger a baseline determination because no PSD application has been filed. Sources that qualify as major under the existing regulations, but not under those proposed, would also not trigger a baseline determination.)

Thus, it appears that the source that qualifies under both existing and new regulations is the one that triggers a baseline determination in the clean areas within a AQCR. Note that this change could have major significance for existing area designations and increment consumption determinations.

8. "BACT"

BACT is required under the ACT for each regulated pollutant that the source emits. The old policy required BACT only for each pollutant for which the source/modification would be "major." However, BACT could be avoided for small emission outputs under the "de minimus" provision.

Note, however, the "de minimus" provisions may be irrelevant in this context: Even if a source's emissions exceed the de minimus cutoff and if it is assumed that no NSPS applies, it could be determined that BACT is not required at all for minor emissions. On the basis of the statutorily mandated criterion--"the relative cost of various controls"--the administrator could decide that no control is most cost-effective.

9. "ambient monitoring"

Preconstruction ambient air quality analysis is required for all regulated pollutants under the Act, not just criteria pollutants as under existing regulations. The 50-ton exemption for modifications and

the de minimus ambient impact schedule will exempt some emissions.^c
Given the state of the art relative to monitoring, modeling requirements may well have to be substituted.

10. "notification"

Under existing regulations, no notice is required if a source owner determines that construction is not major. The proposed rule requires preconstruction notice to the administrator of this determination. Furthermore, in the case of a modification, written notice is required to preserve future offset credit resulting from soon-to-occur reductions in emissions (e.g., shutdown, cleanup).

11. "innovative technology waiver"

A provision paralleling that under NSPS (CAA Section 111(j)): BACT would be defined as the innovative control equipment (valid for 7 years after permit issuance or 4 years after the source commences operation, whichever is earlier). EPA is seeking comments on its legal authority to allow temporary increment violations under this provision, although not allowing ambient standards violation.

^cEPA will conduct a case-by-case analysis of ambient impact of a proposed source with Class I impacting potential.

Appendix K.

**POLLUTANT MISSIONS AND STACK PARAMETERS FOR SELECTED
SYNFUEL CONVERSION FACILITIES**

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Table K-1

STACK PARAMETERS AND EMISSION RATES FOR THE 76,000 B/D
C-s TRACT PLANT (MIS AND TOSCO) WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°)	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	TOSCO Preheater	378	50	4	100	3.6	9.3	20.1	7.0	72
2	TOSCO Elutriator	98	93	4	100	1.8	9.6	3.5	0.11	3.5
3	Moisturizer	70	93	4	100	1.0	22.3	1.7	—	—
4	Gas Plant	8.7	388	1	45	1.2	7.7	0.01	0.04	1.3
5	Thermal Oxidizer	80	82	1	45	3.8	7.1	0.12	5.2	8.4
6	Steam Plant	2790	204	2	100	12	12.3	53	64	310
7	Mine Ventilation	1940	17	2	45	6.4	30	1.1	0.17	22

Table K-2

STACK PARAMETERS AND EMISSION RATES FOR THE 50,000 B/D
COLONY PLANT (TOSCO) WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°).	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	Hydrogen unit	148	244	4	24.4	1.76	15.2	1.44	3.44	10.4
2	Naphtha hydrogenation	3.3	451	1	22.9	0.76	7.3	0.025	0.05	0.16
3	Gas oil hydrogenation: feed heater	9.7	508	2	22.9	0.76	10.7	0.05	0.12	0.34
4	Gas oil hydrogenation: fired reboiler	26.9	394	1	45.8	1.76	11.0	0.20	0.48	1.41
5	Sulfur plant	43	120	1	64.0	2.44	9.2	--	11.9	--
6	Delayed coker	18.3	192	1	53.4	2.28	4.6	0.14	0.35	1.06
7	Steam superheater-- ball stack	128	102	6	94.6	1.38	14.2	4.74	11.9	14.3
8	Raw shale preheat	600	74	6	94.6	2.84	15.8	10.2	6.4	166
9	Processed shale moisturizer	128	240	6	94.6	1.38	14.2	5.35	--	--
10	Primary crusher	118	16	1	15.2	2.40	25.2	5.4	--	--
11	Final crusher	135	16	4	22.0	1.52	18.6	4.16	--	--
12	Fine ore storage	17	16	1	4.6	1.22	14.6	0.53	--	--
13	Utility boilers	54.5	221	2	16.8	2.14	7.6	0.36	0.90	2.72

Table K-3

STACK PARAMETERS AND EMISSION RATES FOR THE 57,000 B/D
C-b TRACT PLANT (OCCIDENTAL MTS) WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°)	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	Thermal oxidizer	1690	500	4	125	4.5	26.6	4.0	9.1	32
2	Low-Btu gas combustion	1380	204	4	125	4.2	24.9	5.3	12.5	42
3	Mine ventilation	223	17	1	88	3.0	31.6	1.1	0.17	21.7

Table K-4

STACK PARAMETERS AND EMISSION RATES FOR THE 50,000 B/D
UNION PLANT WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°)	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	Power house	114	260	2	50	2.0	18.0	0.6	19.5	14
2	Retort gas heaters	280	315	8	50	1.4	22.7	1.3	43.5	30.5
3	Gas cleanup	2.3	38	1	76	0.7	5.8	--	1.3	--
4	Crude stabilizer	40	315	1	76	1.4	25.8	0.1	0.5	0.75
5	Mine ventilation	1070	16	4	15	4.0	21.4	14.5	3.2	46
6	Secondary crusher	32.6	16	2	20	1.0	20.7	1.1	--	--

Table K-5

STACK PARAMETERS AND EMISSION RATES FOR A 45,000 B/D
METHANE-TO-GASOLINE PLANT WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°).	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	Utility boiler/ incinerator	990	220	1	50	8	20	8.8	84	147

Table K-6

STACK PARAMETERS AND EMISSION RATES FOR A 45,000 B/D
FISCHER-TROPSCH PLANT WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°).	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	Utility boiler/ incinerator	1250	220	1	50	8.9	20	13.3	115	223
2	Catalyst plant	116	17	1	50	3.25	20	43.2	--	--

Table K-7

STACK PARAMETERS AND EMISSION RATES FOR A 60,000 B/D EXXON DONOR
SOLVENT PLANT (PURCHASED ELECTRICITY) WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°).	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	Coal drier	56	75	3	20	1.9	20	3.0	1.7	5.4
2	Liquefaction Furnace	195	350	2	25	3.15	25	0.64	76	22
3	Solvent hydrogenation feed preheat furnace	14	75	2	25	1.34	10	0.10	10	3.0
4	Hydrogen reformer furnace	123	250	4	25	2.5	25	0.96	110	32
5	Sulfur plant tail gas incinerator	41	120	2	65	2.28	10	—	8.2	32
6	Utility boiler	48	220	1	20	2.46	10	0.10	11	3.4

Table K-8

STACK PARAMETERS AND EMISSION RATES FOR A 60,000 B/D EXXON DONOR
SOLVENT PLANT (ON-SITE ELECTRICITY GENERATION) WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m ³ /s)	Temp. (C°).	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s)		
								Particulates	SO ₂	NO _x
1	Coal drier	56	75	3	20	1.9	20	3.0	17	5.4
2	Liquefaction Furnace	195	350	2	25	3.15	25	0.64	76	22
3	Solvent hydrogenation feed preheat furnace	14	75	2	25	1.34	10	0.10	10	3.0
4	Hydrogen reformer furnace	123	250	4	25	2.5	25	0.96	110	32
5	Sulfur plant tail gas incinerator	41	120	2	65	2.28	10	—	4.1	0.40
6	Utility boiler	48	220	1	20	2.46	10	0.10	11	3.4
7	Power plant	394	220	1	50	4.48	25	4.7	130	92

Appendix L

**ANALYSIS OF SURFACE WATER FLOW BY RIVER BASIN AND
MAPS OF RIVER BASINS STUDIED**

FIGURE L-1. DRAINAGE BASIN MAP OF NORTHERN GREAT PLAINS STUDY AREA

DRAFT

FIGURE L-2. DRAINAGE BASIN MAP OF FOUR CORNERS/ROCKY MOUNTAIN STUDY AREA

DRAFT

FIGURE L-3. DRAINAGE BASIN MAP OF ILLINOIS BASIN STUDY AREA

DRAFT

FIGURE L-4. DRAINAGE BASIN MAP OF APPALACHIAN STUDY AREA

Table L-1

APPALACHIA - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow Competing At Gage Demands		Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir Yield		5-yr Sum (10 ³ af)	Estimated Reservoir Size	
		(cfs)	(cfs)								(cfs)	(10 ³ af/yr)		(10 ³ af)	Rating
Susquehanna 1570500	24100	34600	2800	1	19	2800	5300	8100	78	H					
Allegheny 3049500	11410	19500	890	2	38	930	2500	3400	84	H					
Monongahela 3085000	7337	12400	570	3	57	630	2100	2700	82	H					
Beaver 3105500	2235	2400	110	1	19	130	480	610	85	H					
Mahoning 3098000	898	861	45	1	19	64	140	200	82	H					
Tuscarawas 3129000	2443	2474	270	1	19	290	390	680	72	M					
Muskingum 3150000	7422	7380	820	1	19	840	1100	1900	75	M					
Kanawha 3198000	10419	14600	1400	2	38	1400	2800	4200	78	M					
Ohio #1 and #2 3206000	13736	80800	680	9	170	850	12000	13000	88	H					
Tug Fork 3214000	1185	1390	59	1	19	78	110	190	75	M					
Ohio #3 3216600	4915	94200	240	2	38	280	22000	22000	90	H					
Licking 324950	827	1050	210	1	19	230	33	260	55	L	52	38	190	90	L
Kentucky 3284000	3955	5260	990	1	19	1000	220	1200	59	L	240	170	870	40	M
Cumberland 3414000	5790	9020	1400	1	19	1400	500	1900	75	M					

Table L-2

ILLINOIS BASIN - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow At Gage (cfs)	Competing Demands (cfs)	Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir Yield (cfs)	Yield (10 ³ af/yr)	5-yr Sum (10 ³ af)	Estimated Reservoir Size (10 ³ af)	Rating
White 3374000	11125	11400	780	1	19	800	1400	2200	75	M					
Wabash #2 3377500	9292	26900	650	3	57	710	3900	4600	86	H					
Illinois 5585500	26028	21100	1400	5	95	1500	6100	7600	80	H					
Kaskaskia 5594100	4393	3420	1100	2	38	1100	120	1200	60	M					
Big Muddy 5599500	2162	1770	530	1	19	550	24	570	42	L	43	31	155	25	ML
Green 3320000	7564	10900	1900	1	19	1900	850	2800	61	M					
Tradewater 3383000	255	327	66	1	19	85	1	86	43	L	20	14	72	25	ML
Ohio #4 3322000	15194	139000	3800	2	38	3800	21000	25000	85	H					

Table L-3

NORTHERN GREAT PLAINS - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow At Gage (cfs)	Competing Demands (cfs)	Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir Yield (cfs)	(10 ³ af/yr)	5-yr Sum (10 ³ af)	Estimated Reservoir Size (10 ³ af)	Rating
Big Horn #1 6279500	12775	2280	600	1	13	610	740	1350	60	M					
Powder 6317000	6050	273	46	2	26	72	7	79	63	M					
Belle Fourche 6426500	1670	20	60	1	13	73	0.2	73	5	L	13	9	50	U*	L
North Platte #2 6646800	5404	1480	70	2	26	96	730	830	82	H					
Laramie 6662000	2174	132	28	1	13	41	7	48	50	L					
Musselshell 6127500	4568	202	140	1	13	150	17	170	30	L	30	22	110	150	L
Missouri #1 6132000	57556	8880	580	1	13	590	1900	2500	88	H					
Poplar 6181000	3174	132	150	1	13	160	3	160	12	L	16	12	60	25	M

*U = Unknown, the y-axis intersection was off-scale

Table L-3 (Continued)

NORTHERN GREAT PLAINS - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow At Gage (cfs)	Competing Demands (cfs)	Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir Yield (cfs)	Yield (10 ³ at/yr)	5-yr Sum (10 ³ at)	Estimated Reservoir Size (10 ³ at)	Rating
Missouri #2 6185500	91557	10400	1100	5	65	1200	3200	4400	84	B					
Big Horn #2 6294700	22885	4050	280	2	26	310	1700	2000	84	B					
Tongue 6308500	5379	459	46	3	39	85	63	150	70	M					
Yellowstone #1 6309000	48253	11,600	270	3	39	310	3900	4200	87	H					
Yellowstone #2 6329500	69103	12800	270	6	78	350	4000	4400	87	B					
Souris 5116000	9470	145	93	1	13	110	0.4	110	18	L	13	9	50	19	HL
Little Missouri #1 6335500	4640	331	25	2	26	51	0.9	52	40	L	27	20	100	25	HL
Little Missouri #2 6337000	8310	592	25	3	39	64	0.9	65	51	L	40	29	145	25	HL

Table L-3 (Continued)

NORTHERN GREAT PLAINS - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow At Gage (cfs)	Competing Demands (cfs)	Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir Yield (cfs)	Yield (10 ³ af/yr)	5-yr Sum (10 ³ af)	Estimated Reservoir Size (10 ³ af)	Rating
Knife 6340500	2240	176	20	2	26	46	9	55	30	L	35	25	125	65	L
Heart 6349000	3310	250	50	2	26	76	4	80	33	L	30	22	110	50	ML
Cannonball 635400	4100	237	25	2	26	51	0.8	52	33	L	27	29	140	70	L
Grand 6357800	5370	219	71	2	26	100	3	100	35	L	29	21	100	13	ML
Moreau 6359500	2660	134	10	1	13	23	0.7	24	31	L	14	10	50	10	ML
Cheyenne 6439300	22230	817	560	3	39	600	62	660	22	L	100	73	370	50	ML
Missouri #3 6440000	243500	22800	320	16	210	530	6310	6800	88	B					

Table L-4

FOUR CORNERS/ROCKY MOUNTAIN - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow At Gage (cfs)	Competing Demands (cfs)	Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir (cfs)	Yield (10 ³ af/yr)	5-yr Sum (10 ³ af)	Estimated Reservoir Size (10 ³ af)	Rating
Green #1 9217000	14000	1700	430	1	13	440	410	850	55	L	420	300	1500	250	L
North Platte #1 6630000	8134	1090	110	1	13	120	210	330	65	M					
South Platte #2 6754000 (To represent Arkansas River Basin)	5598	779	190	1	13	200	120	320	67	M					
Colorado #1 9093700	7370	3570	1900	1 Coal 2 Oil Shale	40	1900	1500	3400	23	L	1500	1100	5500	750	L
Yampa 9251000	3410	1560	280	2	26	310	170	480	45	L	200	140	700	50	ML
Little Snake 9260000	3730	567	180	1	13	190	9	200	37	L	22	16	80	20	ML
Dolores 9180000	4580	730	480	2	26	510	84	590	25	L	110	80	400	60	L

Table L-4 (Continued)

FOUR CORNERS/ROCKY MOUNTAINS - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow At Gage		Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir Yield		5-yr Sum (10 ³ af)	Estimated Reservoir Size (10 ³ af)	Rating
		(cfs)	Competing Demands (cfs)								(cfs)	(10 ³ af/yr)			
Duchesne 9302000	3920	575	1500	1	13	1500	58	1600	7	L	71	50	250	40	ML
White 9306900	5120	598	260	1 Coal 1 Oil Shale	25	290	220	510	30	L	250	180	900	40	ML
Green #2 9315000	40600	6330	1900	4	52	2000	1400	3400	45	L	1500	1100	5500	1000	L
San Rafael 9328000	927	104	100	1	13	110	12	120	15	L	25	18	90	5	ML
Muddy Creek 9332800	1552	24	30	1	13	40	0.3	40	13	L	13	9	45	20	ML
San Juan #2 9379500	23000	2410	320	2	26	350	450	800	66	M					
Virgin 9408150	1533	193	23	1	13	40	62	100	65	M					

Table L-4 (Continued)

FOUR CORNERS/ROCKY MOUNTAINS - WATER QUANTITY ANALYSIS

River Basin/Gage	Size of Drainage Basin (mi ²)	Average 1990 Flow At Gage (cfs)	Competing Demands (cfs)	Synfuel Plants	Synfuel Demand (cfs)	Sum Demand (cfs)	Instream Flow Req (cfs)	Total Drainage Basin Demand (cfs)	Time Demand Met (%)	Rating	Required Reservoir Yield (cfs)	Yield (10 ³ af/yr)	5-yr Sum (10 ³ ar)	Estimated Reservoir Size (10 ³ ar)	Rating
Sevier 10180000	950	140	70	1	13	80	42	120	40	L	55	40	200	75	L
Rio Grande 8330000	17440	1030	1300	3	39	1300	42	1400	20	L	81	60	300	70	L
Rio San Jose 8351500	3660	12	170	1	13	180	0.2	180	1	L	13	9	45	U*	L
San Juan #1 936800	12900	2080	1600	3	39	1600	410	2000	29	L	450	330	1700	300	L
Little Colorado 9402000	26500	222	330	1	13	340	0.3	340	13	L	13	9	45	20	ML
Colorado #2 9402500	137800	15400	3500	7	90	3600	4600	8200	50	L	4700	3400	17000	7000	L

*U = Unknown, the y-axis intersection was off-scale.

APPENDIX M

**SOICOECONOMIC IMPACT MITIGATION ISSUES APPROPRIATE
TO THE SITING OF SYNTHETIC FUELS PLANTS**

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CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
Site Acceptability and Socioeconomic Impacts	1
Increasing Site Acceptability with Impacts Mitigation . . .	4
II. MITIGATION OPTIONS	6
Who Acts to Mitigate?	6
How Easy and Timely Will Implementation Be?	9
How Do the Programs Deal with Risk?	10
III. PRESENT MITIGATION MECHANISMS	12
IV. IMPLICATIONS	17
REFERENCES	19
APPENDIX A	

I. INTRODUCTION

This paper has been prepared on a quick response, limited budget basis to assist SRI with a larger project to screen potential sites for new synfuels plants (SFP's). The primary purpose of the larger project is to identify those counties which--based on resource availability, physical environmental characteristics, and socioeconomic characteristics--could most easily accommodate SFP's. The SFP's envisioned are large-scale, with anticipated construction work forces of 5,000-10,000 employees and permanent work forces of approximately 3,000.

Site Acceptability and Socioeconomic Impacts

Development of large-scale energy projects can have a wide variety of social and economic consequences--some positive and others negative. In screening for potential synfuels locations, the potential negative impacts deserve special attention. These may be separated into two relatively distinct categories: rapid growth "boom town" impacts and "conflict" impacts.

Rapid growth impacts

● Public finance problems

- Public sector cash flow problems caused by lags in receipt of public revenues and required lead times for public expenditures.
- Abnormal risks for the local public sector. (These occur where the energy facility is large relative to the existing tax base and where the facility itself faces uncertainties--e.g., untried technologies, vulnerability to changes in world energy prices or national energy policy, or vulnerability to delays due to environmental litigation.

- Housing and other private infrastructure problems.

- Inability to expand the infrastructure. (This may be due to the absence of experienced entrepreneurs, the unavailability of short-term construction and/or long-term mortgage credit, and/or inability to assemble the land needed for new development.)
- Abnormal risks to the private service sector (for the reasons cited above for the public sector).
- High costs which make new infrastructure projects economically infeasible. (This may be due to inability to compete with the new energy project for skilled construction labor, increased speculative values on land, requirements for abnormally high returns on investment to compensate for higher risks.)

- Social disruption

- Quality of life reductions and social stress associated with the unavailability and/or high cost of public and private services.
- Unmet needs for new services (particularly social services such as alcoholism and child abuse prevention programs).
- Requirements for changes from small town to more urban life styles (leading, again, to personal and societal stress).

Conflict impacts

- Competition for scarce resources

- Air quality decrements. (Use of allowable degradation of air quality for synfuels may preclude recruitment of more jobs-intensive industries.)
- Water (e.g., the potential for SFP's outbidding agricultural uses for available water).
- Labor (especially skilled construction workers presently employed by the local housing industry and city and county maintenance crews).

- Jurisdictional conflicts and mismatches.

- State vs. federal, federal vs. federal, and other conflicts over regulatory authority and/or regulatory objectives.

- Mismatches between those public entities receiving new SFP-related public revenues and those being required to address SFP-related growth and other impacts. (The adversely affected entities may be the municipalities within counties which have SFP sites, adjacent counties, all local public entities in adjacent states, and/or local public entities near Indian reservations which have SFP sites.)
- Conflicts between alternative life-styles. (These are especially noticeable where existing local life-styles and values are relatively homogeneous and where they differ from those expected in incoming SFP employees. The clearest example is Indian reservations. Some of these issues may also arise in ranching communities with certain sociopolitical structures, in recreation-oriented communities, in Mormon communities, and/or rural Appalachian communities with certain sociopolitical structures.)*

The presence of strongly adverse impacts affects synfuels site acceptability in several ways. First, they can cause increased effort and costly delays in getting SFP's on line. This may be caused by either rapid growth or conflict impacts. Severe reductions in the quality of life resulting from unmitigated rapid growth problems have been found to sharply escalate both the costs and the time to complete large-scale resource projects.** Regulatory conflicts can produce regulatory delays. Also conflicts between life-styles can produce political opposition which may lead to delays.

*For more examples, and indications of what types of local environments receive which categories of impacts, see Appendix A.

**For example, see John S. Gilmore, "Boomtowns May Hinder Energy Resource Development", Science, 191 (February 13, 1976), pp. 535-540.

Second, these impacts can represent significant reductions in residents' quality of life. Attempts should be made to avoid this, just as efforts should be made to avoid significant adverse impacts on air quality or flora or fauna.

In terms of Council on Environmental Quality categories, rapid growth impacts are mostly short-to-intermediate term in duration (not permanent) and mitigable. Many of the conflict impacts are permanent; they are also more difficult to mitigate.

Finally, these impacts may actually affect project viability. Worker productivity, worker turnover, and long-term community relations can be affected by both rapid growth and conflict impacts.

Increasing Site Acceptability with Impacts Mitigation

It is conceptually possible to avoid or ameliorate virtually any adverse rapid growth impact. All of these problems relate to information, timing, expertise, and money. New relationships and/or institutions can be established, or old ones altered, to provide information and training, to assist in scheduling new investment, and to provide financial assistance. For this reason, the presence of rapid growth problems only (i.e., without the presence of other conflicts) seldom represents an absolute constraint to the development of an SFP or any other new project. It represents a warning that mitigation efforts will be required. How costly these new requirements may be, and how realistic it is to assume that they can be carried out

successfully and quickly enough to avoid and/or ameliorate the problems varies depending on the specific problem and the means used for mitigation.

The acceptability of SFP sites in terms of rapid growth impacts, therefore, depends as much on the costs and feasibility of mitigation as on any initial determination of the areas potentially facing high growth rates.

II. MITIGATION OPTIONS

The options for dealing with rapid growth or conflict impacts, and their effectiveness, obviously depend on the precise nature and severity of the problem(s). They can, however, be arranged and generally discussed in terms of three other questions: who acts to mitigate, how easy and timely will implementation be, and how do the programs deal with risk?

Who Acts to Mitigate?

Actions may be undertaken by any of a number of parties-at-interest. The four most common groups are federal agencies, states, incoming energy firms, and local residents themselves (either through local government or through quasi-public groups). The first issue which usually emerges in discussions over who should act is "who should have responsibility for the costs?"

Arguments that the federal government should bear primary responsibility for the costs include the following:

- The Federal constitutional responsibility for providing for the general welfare. (This argument is usually accompanied by discussions of interstate equity: all residents benefit from the energy, therefore, all should share responsibility for minimizing the social costs and disruption near the sites.)
- Federal policies and federal resource ownership affect the rate and magnitude of energy development (thus they are a major factor in determining the number and severity of socioeconomic problems).
- Many adverse impacts are interstate in nature. (A frequently cited example is the coal mines in Decker, Montana which have led to substantial growth in Sheridan County, Wyoming. Another example is the effect of increased coal highway and/or rail coal haulage on states not receiving significant energy-related revenues (e.g., Nebraska).

- Much of the relevant resources are on Indian-owned lands; many of the tribes involved already have a substantial dependence on Federal actions and Federal funds.
- It is in the Federal interest to encourage the development of domestic energy resources, and mitigating adverse socio-economic impacts could contribute significantly to this goal. (This argument becomes more direct if a Federal agency is also the energy developer.)

Arguments against Federal involvement include the following:

- The Federal government may find it incongruous to furnish funds to accommodate rapid economic growth at the same time that economically declining areas need financial assistance.
- The Federal government may wish to avoid establishing and administering yet another new program of financial assistance to state and local governments.

Arguments for state governments' assuming primary responsibility center on their generally constituted responsibility to provide for the health, safety and welfare of their citizens, to levy taxes, and to regulate at least some industrial activities. These powers offer the base for impact assistance and are so used in some states.*

However, many states have relatively rigid fiscal structures, limiting their ability to redistribute present revenues without changing legislative or constitutional provisions sanctified by years of precedent or to quickly add new taxes and streams of revenues. Also urban-dominated legislatures have not been particularly concerned with the largely rural problems of impact assistance, particularly when they are seen as originating with Federal policies or actions.

*For example, the Kentucky Economic Aid Program (formerly the Coal Producing County Development Fund), the Montana Coal Board Program, and the North Dakota Coal Development Impact Office.

Local officials interviewed by DRI have on occasion expressed concern that state financial assistance programs allocate available funds on the basis of political clout rather than magnitude of energy-related impacts. Some rapid energy development proponents interviewed by DRI have expressed concern that, should the states assume primary responsibility and ultimately pass new energy-based taxes to pay for assistance programs, there would be a significant period of confusion followed by "OPEC-like" behavior in establishing tax levels.

Arguments for energy developers to assume primary responsibility include the facts that they (1) are close to the problems; (2) have successful and profitable operations which may depend on solving the problems; and (3) have an historic precedent for large-scale internalization of impact costs resulting from their practice of providing company towns.

However, the energy firms (1) are usually dubious of company town because of administrative difficulties and accumulated bad publicity; (2) have differing corporate philosophies making doubtful any generalizations about their willingness to voluntarily handle impacts; and (3) have responsibilities to their owners making it difficult for them to accept community-wide assistance responsibility rather than responsibility solely for their own employees.

Local entities clearly have the greatest incentive and clearest responsibility for the problems. Any mitigation effort depends on considerable local efforts to manage the process of change and

reduce conflicts. However, since the basic cause of most rapid growth problems and many conflicts is the absence of necessary resources at the local level (often because of state constitutional or legislative constraints), it is unrealistic to assume most problems will be mitigated without some form of external assistance.*

The parties-at-interest who bear the cost of mitigation may or may not be the same as the parties actually initiating mitigation and/or participating in the decision-making process. For example, the Wyoming industrial siting process, which is state-initiated, places much of the cost burden on incoming industry, but leaves primary responsibility for coordination at the industry-local government level. Section 601 of the Powerplant and Industrial Fuel Use Act uses federal dollars, but places much of the application coordination and review process at the state level.**

How Easy and Timely will Implementation Be?

From an SFP program management perspective, the timeliness of mitigation, the costs of getting a mitigation program in place, and the degree of certainty SFP officials and local officials can feel that mitigation will be available when it is needed are critical issues.

*For example, should Meeker, Colorado seek to address all of its public sector cash flow problems stemming from Ca and Cb oil shale development, without external assistance, the ad valorem tax rate to existing residences might have to be more than doubled. (Gilmore, Moore, Hammond, and Coddington, Analysis of Financing Problems in Coal and Oil Shale Boomtowns, Washington: Federal Energy Administration, June 1976.)

**Much of this section is based on Gilmore and Hammond, Draft Legislative Environmental Impact Statement for the Inland Energy Impact Assistance Act of 1979, Washington: Department of Commerce, 1979.

As a rough indicator of these issues, it is useful to categorize each mitigation option into one of the following groups.

1. Easy to mitigate. This usually means that all institutions (e.g., siting mechanisms, taxing mechanisms, revenues transfer and decision-making mechanisms) are in place. Usually all that is needed is a decision to commit mitigation funds and that decision is to be made by parties with some incentive to facilitate the development process. (Example: Section 601 for energy-impact areas planning assistance.)
2. Potentially difficult to mitigate. This usually involves a new legislative or administrative action, but the action is to be taken by parties with a clear incentive to facilitate the process and no major conflicts exist. (Example: a new program requiring relatively non-controversial action by state legislatures.)
3. Potentially infeasible to mitigate. This may, for example, require institutional change which must be preceded by resolution of controversy. (Example: a loan guarantee program requiring state involvement in a manner which conflicts with state constitutional provisions against committing the full faith and credit of the state. Second example: a state siting bill which places the burden for handling public sector cash flow problems on incoming industry before a legislature in a state which has unemployment problems.)

From the local perspective, still other mitigation feasibility criteria are: "How much information and expertise is required for a local entity to apply for assistance; how quick is the application turnaround; and how frequently may one apply?"

How Do the Programs Deal with Risk?

Much of the uncertainty concerning the timing, magnitude, and duration of SFP population impacts simply cannot be reduced. Any impact mitigation effort must allow for this. Basically, three options exist:

1. Attempt to avoid adverse impacts altogether by acting early. (Examples: Inducing employees to live where impacts are minimized. This may involve new road construction from the SFP site. Second example: Building needed school rooms in advance of the arrival of the SFP work force.)

2. Ameliorate impacts as they begin to become apparent.
(Example: Adding modular classrooms as needed.)
3. Ameliorate impacts after they become clear. (Example:
Allowing a school district to apply for construction
funds after it has demonstrated that SFP-related enroll-
ment has reached a certain level and that it has ex-
hausted its own bonding capability.)

Avoiding impacts (the first option) is the strategy most certain to prevent problems. It is also usually the least expensive strategy.* However, there is the risk that facilities will be constructed which will never be needed. This is politically infeasible if local funds are involved; it also places external funding agencies in a potentially politically vulnerable position.

Ameliorating impacts as they begin to appear requires special assistance implementation systems. Funding must be made available on a very flexible, quick response basis. Unfortunately, the timing of assistance also means that local services projects may be subject to the same difficulties as the SFP projects (e.g., difficulty in employee recruitment due to housing shortages and other reductions in the local quality of life).

Ameliorating impacts after they become clear realistically means simply accepting unmitigated adverse impacts for a substantial period of time. Obviously this is the lowest risk project for either local or external funding sources.

*For example, the school is built while land prices are still relatively low and the school contractor does not have to compete with the SFP contractor for available labor.

III. PRESENT MITIGATION MECHANISMS

This section summarizes currently available impact assistance programs in terms of the problems addressed and the responsibility for funding. A considerably more extensive (although less recent) analysis exists in a previous DRI report.*

Table 1 summarizes existing programs applicable to assist in mitigating rapid growth public finance problems.

Programs are generally available for planning assistance and public facilities construction. For example, the Section 601 of the Powerplant and Industrial Fuel Use Act of 1978, as amended, contains a current provision to provide both planning development and site acquisition/site development grants to states whose Governors have requested and received impact designations on areas effected by coal or uranium production, processing or transportation. While this program does not provide assistance to areas impacted by oil shale development, it remains an open question where liquefaction, and/or gasification will qualify as "coal processing" activities for purposes of coverage. The FY 80 allocations of funds for planning and site acquisition have been made and no requests for either gasification or liquefaction impact mitigation funds were received. However, legislation currently before the Congress would render this question moot since it would amend the current 601 program to both include synfuels explicitly and increase both the size of the program and the definition of impacts eligible for assistance.

*Moore, Hammond, Gilmore, Flory, Coddington, and Donald, Mitigating Adverse Socioeconomic Impacts of Energy Development: Present Programs and Mechanisms and Further Policy Options, Washington: Department of Energy, January 1978.

TABLE 1. EXISTING PROGRAMS TO MITIGATE
RAPID GROWTH PUBLIC FINANCE PROBLEMS

NEEDS	FEDERAL PROGRAMS	STATE PROGRAMS	INDUSTRY PROGRAMS
Planning	FmHA Sec.601 is most readily available source.* Coastal Energy Impact Program (CEIP) is available for coastal states. Others (e.g., HUD701, EDA title III, EPA 208, Soil Conservation Service Section III, Civil Service Commission) are possible but less certain and less timely.	Most states have state and/or sub-state regional planning staffs. Assistance level to local communities varies greatly among states.	Some industries have sponsored detailed planning assistance projects (e.g., Rio Blanco Oil Shale Project) themselves; many have donated funds for local governments to hire planners (particularly in the Rocky Mountain West).
Facilities Construction	Sec.601 is most accessible source, but funding is limited and uncertain. DOI Mineral Leasing Act funds are available for projects on federal land. (Technically, these funds can even be borrowed in advance for facilities construction). Appalachian Regional Commission has accessible programs. In some areas, other FmHA programs have worked. Other less certain and less timely sources exist for specific types of projects (e.g., EPA 201, EDA title IX, LEAA.)	Some states (e.g., Wyoming, Colorado, West Virginia) have funds available for facilities design. Some Western states have used mineral leasing royalties and/or severance taxes to set up the funds.	There are isolated instances of industry building needed facilities for the community (e.g., Missouri Basin Electric Project in Wheatland, Wyoming).
Operating Costs	(No major programs, other than for planning, although services assistance is allowable under FmHA601).	Some returns to counties of mineral leasing royalties have been applied for operating subsidies; North Dakota returns substantial shares of coal severance and coal conversion excise taxes to local government entities.	(No major programs, other than for planning).

*As previously pointed out, current (FY80) impact assistance funds from Section 601 do not apply to impacts from oil shale facilities and may not apply to coal liquefaction/gasification facilities, depending upon whether they are considered to be "coal processing" facilities under the Act. Legislation currently before the Congress would expand the definition of impact-creating activities to explicitly include all synfuel facilities.

Many of the available programs for facilities are usable only to ameliorate problems after they have clearly manifested themselves. There is also no relationship between the funding levels of the programs and the pace of energy development. Accelerated development would require increased funding. Little is available to assist in impact avoidance or early problem amelioration. There are no major programs to assist with public operating costs (e.g., salaries) during local entities' cash flow crunch.

Table 2 summarizes available housing and other private services programs. By far the most effective source of housing to date has been the energy industry itself. However, industry involvement ranges from almost the company town to no involvement at all. In general, potential housing developers (those who are not associated with energy firms) and other potential entrepreneurs can rely on little assistance from anyone.

Some social services programs exist to aid communities in preparing for increased services demands. Federal grants have been made, primarily on a pilot program basis, to selected areas (e.g., the Wyoming Human Services Project).

There are no ongoing assistance programs which are clearly capable of mitigating conflicts impacts. This is with good reason. Many differ in terms of needs for assistance on a case by case basis. Many may not be amenable to mitigation. Those which are amenable to mitigation are likely to require initiation of action by the SFP project management. Examples may include commitments to train and hire local residents (particularly on or near Indian

**TABLE 2. EXISTING PROGRAMS TO MITIGATE RAPID GROWTH HOUSING
AND OTHER PRIVATE SERVICES PROBLEMS**

NEEDS	FEDERAL PROGRAMS	STATE PROGRAMS	INDUSTRY PROGRAMS
Land Assembly	Eminent domain may now be used under FmHA 601. FmHA and Appalachian Regional Commission have both been active in Appalachia.	West Virginia has attempted to exercise eminent domain--this is still under litigation.	Industry has, in several Western instances, acquired large parcels for later resale to qualified developers (e.g., ARCO and SUNOCO in Gillette, Wyoming). Western firms tied to railroads and Appalachian land companies are in a unique position to assist.
Entrepreneurial Skills and Incentives	-----	Some success with state housing corporations (e.g., West Virginia Housing Development Fund).	Energy firms have been involved in housing in varying degrees--from assisting in attracting qualified developers and providing incentives such as loan guarantees and land write-downs to actually acting as developers. Little involvement in other services.
Mortgage Financing	FHA mortgage guarantees are frequently required to access secondary mortgage market. Western financial institutions have resisted them due to red tape. Appalachian areas have great difficulty meeting FHA design standards due to terrain.	Some states have attempted "loans to lenders" programs. These have had problems. When they work, they are expensive--\$1 of public debt buys only \$1 of mortgage debt.	A few firms have instituted lease-purchase plans with rental payments applicable as down payments on housing.
Commercial Financing	SBA has limited assistance available. It has seldom been used.	-----	-----
Housing Subsidies	HUI, other housing subsidies are typically unavailable due to low income requirements.	Some states have mortgage subsidy programs, but energy employees generally have incomes too high to qualify.	Some energy firms have subsidized their employees, both in rentals and purchase prices.

reservations), coordination of SFP projects with water reclamation projects, and/or commitments to shared decision-making--even on such traditionally internal issues as the phasing of construction employment.

IV. IMPLICATIONS

As of this writing, several options exist for improving existing mitigation mechanisms. These include the proposed Inland Energy Impact Assistance Bill (thought to have a poor chance of passage) and a proposed extension of the funding levels and capabilities of the FmHA Section 601 program.* Additional efforts towards mitigation may or may not be included in any future legislation to stimulate SFP development.

The extent to which new programs are needed depends to some extent on the nature of the synfuels program. The more secure a future is given to a synfuels plant by Federal incentives, the better public and private markets will work to furnish labor and capital in the host communities. If a long term assured synfuels price and purchase incentive creates greater perceptions of permanence and continuity of plant operations than the perceptions generated by construction loan guarantees, then the price and purchase incentives will reduce boom town impacts.

At the other end of the spectrum is a plant that is clearly labeled "experimental" or "demonstration." Such a plant will be perceived as a short term operation and will offer little stimulus to the conventional capital markets to accommodate growth in the host community. In the latter case, the added uncertainty of the "experimental" label will aggravate the negative impacts by discouraging the supply side of the capital market. Greater impact assistance will be necessary, and should be anticipated in a synfuels development program.

*This program was established by Section 601 of the Powerplant and Industrial Fuel Use Act of 1978.

Some combination of existing programs and new programs could easily handle the majority of those public sector cash flow problems which do not also involve jurisdictional mismatches. Therefore, the likely presence of public sector cash flow problems should probably not be viewed as a dominant issue in synfuels site screening.

Other rapid growth problems--i.e., housing and other private services problems and unmet needs for new social services--should be taken seriously. However, they can if necessary be eliminated by a combination of efforts by SFP project management and local officials.

Initial site screening should concentrate on the conflict impacts. One or more of these--e.g., irresolvable conflicts with an Indian tribe--may be sufficient to eliminate a site from consideration.

Ideally, initial site screening would be based not solely on the potential existence of socioeconomic problems, but also on the ease with which they could be mitigated. Depending on the categories for ease of mitigation previously described in Section II, the screening categories might be:

1. Clearly acceptable--no significant adverse rapid growth impacts or conflict impacts.
2. Acceptable--only problems which are deemed easy to mitigate (e.g., public finance cash flow problems).
3. Potentially acceptable--some problems which may be difficult to mitigate (e.g., housing requires new capital from outside the region and steep terrain is involved). This is the category where SFP management mitigation efforts might move a site into a higher category.
4. Potentially unacceptable--problems exist which are potentially infeasible to mitigate.
5. Clearly infeasible--unresolvable conflict impacts.

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**APPENDIX A: COMMON SOCIOECONOMIC
IMPACT PROBLEMS, SIX STATES**

(Taken from: Gilmore, Flory, Hammond, Moore, and Coddington,
Socioeconomic Impact Mitigation Mechanisms in Six States--
Categories, Generalization, and Unresolved Issues, prepared
for Office of Planning, Analysis and Evaluation, U.S.
Department of Energy, Denver: Denver Research Institute,
Sept. 1977, pp. 21-22.)

TABLE 1. COMMON SOCIOECONOMIC IMPACT PROBLEMS, SIX STATES

	Colorado	Montana	Massachusetts	Kentucky	Louisiana	Illinois
Factors increasing uncertainty, thus aggravating some impacts and making impact assessments and mitigation decisions more difficult.	Timing and magnitude of oil shale development; availability of water; site-specific coal development projects	Site-specific coal development profiles; possible energy conversion facilities; availability of natural gas.	Availability and price of oil and gas; Potential of OCS development; safety of nuclear reactors.	Demand for higher sulphur coal; prospect of UMWA leadership crisis.	Federal policy on use of natural gas for feedstock; substitution of coal for gas in power generation; impact of lower oil and gas production on state revenues.	Nuclear safety; demand for high sulphur coal.
IMPACT PROBLEM						
1) Jurisdictional and regulatory conflict and mismatches.	Conflicts among counties and municipalities over energy-related tax base; conflicts between states over tax revenues vs. absorbing impact costs (Utah, for example).	Conflicts among counties and municipalities over energy-related tax base; conflict among Indian tribes, state and energy developers; potential conflicts with Wyoming and North Dakota.	Conflicts among towns over energy-related tax base and willingness to absorb people; conflicts with energy producing states.	Conflicts among counties and municipalities over coal tax revenues.	Conflict with federal government for offshore oil and gas royalties; conflict among school districts for decreasing state revenues; defining boundaries of coastal zone.	Possible conflicts between counties and municipalities over ad valorem taxes.
2) Competition for scarce resources (water, land, air, fishing and recreation areas, energy)	Competition among agriculture and energy industry for water and land.	Competition for water.	Competition for use of available clean air margin.	Competition among housing industry and others over available land suitable for homes.	Competition for natural gas among out-of-state and local petrochemical industry feedstock needs.	Competition over land between agricultural and mining interests.
3) Shifts in comparative advantage (opportunities, threats) for attracting industry or other economic activity.	Central location of Denver re energy development in region will stimulate growth; rural areas in western part of state will gain jobs and tax base; agriculture will have more difficulty.	Availability of coal and other natural resources should stimulate economic growth; possibility of some energy conversion will add jobs.	Dependency on outside energy resources reduces ability to attract industry; difficult to benefit from offshore development.	Growth in coal mining will stimulate economy; possibility of energy conversion facilities will add jobs; increased demand for labor may aggravate labor relations and productivity problems.	Reduced availability of low cost natural gas alters ability to attract petrochemical industry; declining tax revenues reduce ability to offer special incentives (no property taxes for 10 years) to industry; super port could stimulate economic growth.	Opportunities for energy conversion (coal gasification) and related jobs.

TABLE 1. COMMON SOCIOECONOMIC IMPACT PROBLEMS, SIX STATES (continued)

Impact Problem	Colorado	Montana	Massachusetts	Kentucky	Louisiana	Illinois
4) Hyperurbanization-- public infrastructure unavailability	More than 20 areas in western Colorado expected to experi- ence such problems.	A limited number of local areas likely to experience such problems.	Townships around nu- clear power plant site experience some limited problems.	Rapid coal or energy conversion develop- ment in east or west central Kentucky will lead to many infrastructure, high- way and social dis- ruptions.	Development of the super port off the Gulf Coast, or min- ing of lignite in northwest could lead to hyper-urbaniza- tion in predom- antly rural areas.	Rapid growth prob- lems of a minor nature could occur with construction of energy conversion plants in rural areas.
5) Hyperurbanization-- housing shortages and/or inflation	Very serious problem in rural areas; be- coming serious in metro areas due to shortages of water and natural gas.	Impacted areas have been aided by hous- ing provided by energy developers; private housing in- dustry not able to function effectively in energy impacted areas.	Exclusionary zoning makes it difficult to supply housing in many parts of state.	Lack of flat land suitable for hous- ing is serious prob- lem in eastern Kentucky.	Shortage of land and subsidence problems on Gulf Coast make housing expensive and in short supply.	No serious impacts anticipated.
6) Hyperurbanization-- social disruption MA-3	Rapid pop. growth leads to increases in crime, alcohol- ism, delinquency and marital problems; disruption of rural (agricultural) life style; problems for elderly.	Dislocation of ran- clers; rapid popu- lation growth leads to increases in crime, alcoholism, etc.; disruption of traditional life styles.	Primary social prob- lem is likely to be lack of suitable housing (see above).	Competition for labor could lead to more labor conflict; disruption of tradi- tional life style with influx of new people.	Disruption of tradi- tional fishing in- dustry due to super port and other oil and gas development; potential social disruption if lig- nite developed.	Some disruption of farmers if surface mining increases.

Source: See Tables 1 through 6, Appendix.

APPENDIX N

ATTITUDES TOWARD

ENERGY DEVELOPMENT AS INDICATORS OF

COMMUNITY RECEPTIVITY TO SYNFUELS SITING

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TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
SECTION I: OVERVIEW OF ATTITUDINAL SURVEYS	2
The Socioeconomic Longitudinal Monitoring Project	2
The Construction Worker Profile	5
Oak Ridge National Laboratory Studies of Citizens and Community Leaders at a Nuclear Power Plant Site	8
Boom Town Growth Management: A Case Study of Rock Springs-Green River, Wyoming	12
Attitudes and Opinions Related to the Development of an Oil Shale Industry	14
A Study of Criteria for Assessing and Monitoring Oil Shale Development in Colorado	17
SECTION II: ANALYSIS OF ATTITUDINAL STUDIES	20
The Fallacy of Assuming There is a Monolithic Community Attitude	20
Individuals Hold Contradictory Attitudes	21
Attitudes Frequently Do Not Predict Behavior	21
Attitudinal Change Over Time	22
The Influence of the Type of Development	23
The Number of Variables Related to Attitudes	23
Surveys Call Attention to Issues and May in Themselves Influence Attitudes	24
Methodologies Limit Use of Results	25
SECTION III: THE DYNAMICS OF ATTITUDES AND COMMUNITY RECEPTIVITY	27
SECTION IV: AN ALTERNATIVE APPROACH TO ANALYZING COMMUNITY RECEPTIVITY	31
The Role of Community Attitude Surveys	31
An Alternative Approach to the Analysis of Community Receptivity	33
Conclusion	38
REFERENCES	39
APPENDIX I	
APPENDIX II	

INTRODUCTION

This working paper examines the potential and limitations of measurements of attitudes toward energy development as indicators of community receptivity. It is divided into four sections. The first section presents an overview of several representative attitudinal surveys. The second section analyzes these surveys in order to assess their usefulness as indices of community receptivity to the siting of an energy development project. Because attitude surveys are found to have limited usefulness as indicators of community receptivity, the third and fourth sections present an alternative approach to the analysis of community receptivity.

SECTION I: OVERVIEW OF ATTITUDINAL SURVEYS

Many surveys of citizens' attitudes toward energy related development have been conducted in the course of preparing environmental impact statements or by researchers seeking to document the effect of such development on communities. The results of a large proportion of these studies, however, are not reported in widely circulated or easily accessible literature. The purpose of this section is to provide an overview of some representative attitudinal surveys, not an exhaustive review of the literature. Each of the surveys is discussed in terms of its methodology, major findings, and implications.

The Socioeconomic Longitudinal Monitoring Project

Methodology. The University of Wyoming, under contract with the Old West Regional Commission, conducted a two year socioeconomic monitoring project in four western counties - two of the counties (Platte County, Wyoming and McLean County, North Dakota) were experiencing rapid growth from the construction of coal fired electrical generation plants. The other two (Kimball County, Nebraska and Wheatland County, Montana) were control counties that had not experienced growth. The impacted and control counties were matched on such variables as population, employment base, income, education, and age structure.

The purposes of the study were to (1) compare actual socioeconomic changes which accompany growth with prior projections and

(2) determine--by use of the control design--the amount of change that is attributable to energy development.

Attitudinal data was collected as part of a household survey that also collected data on demographic characteristics, employment history, and satisfaction with community facilities and services.

A random sample was selected from all identifiable households and a mailed questionnaire administered each year over a two year period. Table I presents the sampling information.

TABLE I
Sampling Information for Longitudinal Monitoring Project

<u>County and Date of Survey</u>	<u>Estimated County Population</u>	<u>Completed Sample Size</u>
Platte County		
1975	7,000	339
1977	8,253	321
Kimball County (Control for Platte)		
1976	5,340	280
1977	5,500	241
McLean County		
1976	12,525	277
1977	13,285	262
Wheatland County (Control for McLean)		
1976	2,600	206
1977	2,600	171

Major findings. The data collected dealt with attitudes (1) toward economic opportunity, (2) social change, and (3) environmental concern.

Individuals in both the impact and control counties, expected that economic benefits would accrue from energy-related development, such as better schools, more jobs, or increased income. It should be noted that persons in the impact counties continued to have a positive view of economic development although significant growth and change was occurring in their counties. The authors relate this finding to the historical trend of outmigration and economic instability in the region. They hypothesize that individuals feel that development should be encouraged in order to reverse the past trend of economic decline.

When asked about the amount and type of economic development they would prefer, respondents in all four counties preferred moderate growth and any other type of development other than the heavy industrial development associated with energy development. The preferred order of development in both 1976 and 1977 in all four counties was (1) agricultural, (2) light industry, (3) retail trade, (4) recreation, and (5) heavy industry. The significance of this finding is that it illustrates that contradictory attitudes can be held by individuals with regard to an issue (e.g., energy development is seen as economically beneficial, but not preferred). It is obvious that attitudes are not monolithic and that the translation to an inference of "community receptivity" is a complex undertaking.

With regard to attitudes toward the social change accompanying energy development, respondents in both the impact and control counties

expected that the social change would be disruptive. Individuals in the impacted counties clearly perceived social changes in their communities more negatively. It is assumed that their attitudes are based on their actual experiences over the two year period of the study. Again, the difference in polarity of attitudes with reference to energy development should be noted (e.g., economic development is rated positively, social change negatively).

The authors point out that attitudes may not be consistent with behavior and thus may be poor predictors of behavior. For example, respondents in Platte County view energy development as economically beneficial but socially disruptive. They also have a desire to protect the environment. On the basis of these attitudes, it might be assumed that they are not accepting of development. They have, however, in fact been highly receptive to energy development. They have accepted and indeed supported industry in the construction of a coal-fired electrical generation plant (see pages 21-22).

The Construction Worker Profile

Methodology. In 1975 the Old West Regional Commission supported a study of the characteristics of the work force necessary to construct mining, conversion and transportation facilities for energy development in the west. The purpose of the study was to collect primary data on construction work forces and the sources of impacts felt by communities in the region.

As part of the data collection effort, a household survey was completed in two pre-impact communities, five currently affected

communities, and two post-impact communities. Some attitudinal data was included in the survey. Table II presents the sampling information for the study.

TABLE II
Sampling Information for Construction Worker Profile

<u>Survey Community</u>	<u>Population Size</u>	<u>Sample Size</u>
Post Impact		
Langdon, North Dakota	4,000	92
Conrad, Montana	3,117	87
Currently Affected		
Forsyth, Montana	2,700	193
Colstrip, Montana	3,000	148
Center, North Dakota	890	68
Rock Springs, Wyoming	26,000	432
Green River, Wyoming	9,000	254
Pre-Impact		
Killdeer, North Dakota	615	67
St. George, Utah	11,000	91

Major findings. Attitudes were analyzed by length of residence (e.g., "oldtimer"--one who lived in the community before construction began--versus "newcomer" status) and, in some cases, by education and income of the respondents.

Attitudes toward effects of projects. In the currently affected communities, oldtimers were asked whether the effects of the construction project were the same, better, or worse than they had originally expected. The majority (52.4%) felt the effects were about what they expected. Residents who had lived in the communities for fifteen years or longer, however, more frequently felt the effects were worse than expected (40%).

Higher income respondents evaluated the projects' effects more positively, on the other hand.

In the post-impact communities, more long time respondents than in the currently impacted communities felt the effects were better than expected (24% compared to 15%). Long time residents in post-impact communities also felt the results were worse than expected less frequently (25% compared to 33% in the currently affected communities). The authors point out that it is possible that residents of the currently affected communities were more negative about development because they were still experiencing negative impacts, while the period of severe impacts was over in the post-impact communities.

The survey asked long time residents in the currently affected and post-impact communities whether or not they were glad that the development projects were in the area. Sixty-seven percent of the oldtimers in the currently affected communities said they were glad. The reasons given for this attitude related to economic gain (e.g., "job opportunities" and "financial gain"). This is a significant finding in that the currently affected communities included communities such as Rock Springs, Wyoming, where severe disruption was occurring. This result, however, does not represent a monolithic community attitude. Again, residents living in the community over 15 years were more frequently unhappy the project came to the area (40% compared to 22% of those living in the community less than 15 years) while those with higher incomes were glad the project had located in the area.

Attitudes of residents in the pre-impact communities. The two pre-impact communities were Killdeer, North Dakota and St. George, Utah. Killdeer, population 615, was the site for a proposed coal gasification plant. St. George, population 11,000, was the potential site for the construction of an electrical generating plant and reservoir. The communities contrast quite significantly in terms of size and existing infrastructure capable of managing growth. St. George was not only larger, but also had well organized municipal leadership.

In both Killdeer and St. George over 95% of the respondents expected their community to change. The expected effects in each community were related to the infrastructure available to manage growth. Thus, in St. George 63.7% felt the proposed development would be beneficial, whereas in Killdeer 41.8% felt the development would be good. In Killdeer 50.7% felt the effects would be bad (contrasted with 15.4% in St. George). In both communities the perceived benefits were in the economic realm.

Oak Ridge National Laboratory Studies of Citizens and Community Leaders at a Nuclear Power Plant Site

Methodology. The TVA began construction of its first four-unit nuclear power plant in 1976, near Hartsville (Trousdale County), Tennessee. Units #1 and #2 are scheduled for completion by 1984; units #3 and #4 will be completed in the late 1980's.

In January 1975, 288 county residents were interviewed. They were then reinterviewed in August 1975. The county population at that time was about 5,000. The purpose of the citizens survey, administered during the prelicensing phase, was to determine what factors related to favorable or unfavorable attitudes toward the facility.

A second study of community leaders was conducted in 1977. At this time construction had been underway for 11 months. Thirty-seven key community leaders were interviewed. The purposes of the study were (1) to determine major local issues, (2) to determine the value orientations of the leadership in the community, and (3) to compare the differences between leaders and citizens in expectations of future events and general support and opposition to the facility.

Major findings of the 1975 citizens survey. Sixty-nine percent of the 288 respondents supported construction of the proposed nuclear plant. The remaining 31% were project opponents. The two groups were further analyzed according to the characteristics which were related to support or opposition.

Support for the project was prevalent among Blacks, males, managers and proprietors, salespersons, clerical workers, blue collar workers, and among employed persons in general. Opposition to the project was found among farmers and farm workers, residents of farms, females, and the unemployed.

All respondents to the survey felt that changes for the community would be both economic and social. As in other surveys, the economic changes were seen as beneficial while the social changes

were viewed as disruptive. Respondents were not as concerned about environmental safety and pollution. The difference between supporters and opponents was one of degree. For example, both groups agreed that social disruption would occur; however, they were apparently willing to trade social disruption for economic expansion.

The citizens survey also examined the influence of the type of development on attitudes. Respondents were asked if they would favor a similar facility that burned coal instead of using nuclear fuel. Results indicated that the differences in type of development (nuclear versus coal-fired plant) may have been critical for support or opposition to the nuclear plant for 25% of the respondents. Thus the type of proposed energy development influences attitudes toward the development.

Major findings of the 1977 survey of community leaders. Community leaders (e.g., government officials and leading businessmen and professionals) were more supportive of the plant than the community at large. Eighty-six percent of the community leaders were supporters as contrasted with 69% of the citizens. This is important in that community leaders have more immediate influence on the decision making process than do other local residents whose influence is primarily expressed through the ballot. This suggests that attitudes of community leaders would be important to index in estimating community receptivity.

Although they gave realistic estimates of support for the nuclear plant, community leaders were found to significantly underestimate the degree of community opposition. When discussing this

issue, the leaders pointed out that regardless of the distribution of support and opposition in the community, the community had accepted the facility. The important implication to note is the distinction between attitudes (e.g., verbal statements of support or opposition) and behavior (e.g., acceptance by the community).

Similar to the findings of the citizens survey, community leaders expected both economic growth and social disruption as a result of the plant. They also minimized the likelihood of negative environmental impacts.

The study of community leaders further included a ranking of eight "value orientations". This data is important because it indicates the types of issues that are salient to decision makers in a community and thus can affect community receptivity. The issues, in order of importance, are:

1. promotion of housing development,
2. maintenance and extension of the "quality of life" (e.g., schools, water, recreation, other community facilities and services),
3. safeguarding conditions to guarantee economic growth,
4. efficient and fair community administration,
5. promotion of citizen participation,
6. preserving the environmental quality of the area,
7. preserving cultural heritage and traditional values, and
8. avoidance of conflict between population groups.

Boom Town Growth Management: A Case Study of Rock Springs-Green River, Wyoming

Methodology. The University of Denver Research Institute, sponsored by the Rocky Mountain Energy Company, conducted research during 1974 in Sweetwater County, Wyoming. The county as a whole, and especially Rock Springs and Green River, was experiencing rapid growth from construction of a coal-fired electrical generation plant and expanding trona mine and plant operations. Rock Springs is often cited as a classic example of a boomtown that has suffered extreme negative impacts.

The purpose of the study was to gain a broad understanding of the area's impact problems--then, from this base, to develop a growth management plan for responsible officials.

To provide data for these purposes, a questionnaire was administered to 400 randomly selected households. The county population at that time was 36,900. The survey collected data that would (1) identify key characteristics of residents that would aid in community development policy making; (2) identify the community's problems as perceived by its citizens; and (3) identify perceptions and attitudes which would assist housing development decisions. The researchers state that they are 95 percent confident that their results have no greater than a 5 percent margin of error.

Major findings. The two major community problems were seen as the shortage of suitable housing and a lack of adequate medical facilities. Nearly one-third of the citizens were leaving the county for routine medical care. The perception of housing as a pressing

problem stemmed from the necessity to settle for inconveniently located mobile homes. To obtain better housing, individuals were willing to commute to work and pay an additional \$50 a month in rent. Other identified problems were poor traffic flows, and congestion and the lack of entertainment and recreational facilities, especially for women and children.

Newcomers in the community rated the most positive aspects of the community as the availability of economic opportunity. They mentioned good salaries, good employment opportunities, and overall job satisfaction. The problem areas identified by newcomers were inadequate housing, high prices, lack of entertainment, and poor streets and roads. As indicated by other studies, individuals held contradictory attitudes. Economic advantages were positively valued, whereas social disruption was negatively valued in this area where energy development was occurring.

Newcomers were more positive in the evaluation of the direction in which they saw the community moving. Forty-three percent of the newcomers felt the county was improving compared to 29 percent of the oldtimers. Only 20 percent of the newcomers rated the community "as going down hill", whereas 48 percent of the oldtimers felt this was the case. Apparently, as in other surveys, long time residents in the communities viewed the social disruption more negatively.

Attitudes and Opinions Related to the Development of an Oil Shale Industry

Methodology. Bickert, Browne and Coddington and Associates conducted research in four western Colorado counties in 1973 for the Oil Shale Regional Planning Commission and the Colorado West Area Council of Governments. The counties, Garfield, Mesa, Rio Blanco and Moffat, contain significant oil shale deposits. Full scale development of these deposits was expected to imminently impact these counties at the time of the study.

The purpose of the study was to gather and report information on the attitudes, opinions, and behavior of residents which directly related to the social impact of the development of an oil shale industry in western Colorado.

Attitudinal data was collected in two surveys in 1973. The first was of residents of Garfield, Mesa, and Rio Blanco counties. The second was of public officials in the same three counties plus Moffat.

The survey of residents consisted of interviews with 200 randomly selected households in each of the three counties. No population figures for the counties or confidence intervals are contained in the report. The report does state that the statistical results were weighted to reflect the relative population size of the counties.

The survey of public officials consisted of a somewhat shorter version of the questionnaire used in the resident survey.

Major findings. The data collected fell into three major groupings: (1) general attitudes about the area's quality of life; (2) reactions to more specific aspects of life in the area; and (3) attitudes toward the development of an oil shale industry in the region.

Regarding the latter category, more than 70 percent of the respondents advocated encouraging additional industry. Public officials and the general public agreed that preferred development would be retail business, shopping facilities and non-polluting small industry. The least preferred development was heavy industry. The tourist industry was an item of disagreement. The general public was somewhat negative toward growth in the tourist sector, whereas public officials thought it desirable.

The response to prospective oil shale development was positive, although public officials were more unequivocal in their support than residents in general. Officials foresaw not only the improvement of the local economy, but also that substantial growth, by overloading existing services, would produce pressure to improve and expand them.

The negative potential of such development was minimized. The two most feared effects were overcrowding and pollution. Sixty percent of the residents predicted no negative environmental effects.

Public officials advocated some growth regulation, using such tools as zoning and planning. Most individuals agreed that proper planning could mitigate potential negative impacts.

Discussion. A year after this study on January 19, 1974, the U.S. Senate Subcommittee on Interior and Insular Affairs held hearings in Grand Junction, Colorado on the economic impact of the oil shale industry in western Colorado. Senator Haskell of Colorado presided and characterized the hearings as a "fact finding expedition" whose purpose was to consider the economic impact of leasing public lands for development of the oil shale industry.

Statements were delivered at the hearings by local public officials, industry representatives, various special interest groups, growth management experts, water resources experts, environmental officials, and a physician. One of the speakers was the mayor of Grand Junction, Colorado, Stanley R. Anderson.

Mayor Anderson described what had transpired since the Oil Shale Regional Planning Commission study was completed (the BEC study discussed above). He indicated that the study had stimulated discussion among elected officials at all levels of government who had previously not communicated with each other systematically. They began to identify mutual problems and seek solutions to these problems. On January 5, 1974, mayors, city council and school board members, and city managers from Rifle, Glenwood Springs, Grand Valley, and Silt met, drafted, and adopted a resolution on growth expressing serious concern for the negative impacts of development and the need for impact assistance. This resolution was read at the hearings. Its text is contained in Appendix I.

This series of events illustrates a number of considerations with regard to attitude surveys. First, the attitudes of public officials documented one year prior to the hearings would not have predicted the behavioral outcome of the passage of a resolution expressing strong concern for negative impacts. Secondly, it is obvious that the attitudes of the public officials had changed in this period of time. Attitudinal surveys taken at one point in time do not allow for such change. Lastly, the attitudinal survey drew attention to the possible problems related to development and stimulated action on the part of local officials.

A Study of Criteria for Assessing and Monitoring Oil Shale Development in Colorado

Methodology. Booz, Allen and Hamilton, in cooperation with the Denver Research Institute, under contract from the Colorado Energy Research Institute, conducted a study of the perceptions of parties-at-interest to oil shale development in Colorado from October 1978 to February 1979.

The objectives of the study included (1) supplementing methods for identifying and understanding perspectives of parties-at-interest and (2) obtaining data useful to the State in oil shale decision making.

Based on its familiarity with the oil shale industry and Western Slope infrastructures, the Denver Research Institute selected the parties-at-interest to be interviewed. Criteria for

selection were that the individual and the organization represented be strongly affected by oil shale development in Colorado, well-informed regarding oil shale development, and opinion leaders or designated representatives of the party-at-interest categories. Fifty-two such persons were personally interviewed in Grand Junction, Meeker, Rangely, Rifle, Denver, and Washington, D.C. by trained research personnel.

Major findings. Respondents ranked the significance of possible outcomes of oil shale industry development. These outcomes were categorized as "key" if they were in the top 25 percent by frequency of ranking. A summary of the party-at-interest groups and key outcomes designated by each group is given in Table III.

TABLE III
Key Outcomes Identified by Parties-At-Interest
to Oil Shale Development in Colorado

<u>Party-at-Interest</u>	<u>Number of Respondents*</u>	<u>Key Issues Identified</u>
oil shale industry respondents	4	corporate earnings
federal government officials	5	public services environment recreation
state government officials	6	public services water supply recreation housing employment environment decrease in agri- cultural land

*These numbers are not the same as the total respondents because many respondents were counted in several different categories; i.e., one person may be a legislator, businessman, and local resident.

TABLE III - Continued

local government officials and public service providers	11	public services environment crime housing population growth transportation water supply transients
local businessmen	20	public services water supply increased employment and business crime capital availability mental health
other local resi- dents	27	public services environment recreation decreased recreational land increased employment crime water supply population growth permanent housing cost of living transients urbanization of life- style transporation
environmentalists	4	environment water supply

This study is of interest as an illustration of the various parties-at-interest that are affected by a proposed energy development. Both the community and the attitudes of individuals display variety. The study also illustrates an alternative approach, the key informant interview technique, to surveys of community attitudes.

SECTION II: ANALYSIS OF ATTITUDINAL STUDIES

The previous section provided an overview of representative attitudinal surveys. The purpose of this section is to critically analyze these studies in order to assess their usefulness as indices of community receptivity to the siting of an energy development project. The analysis will highlight some of the major limitations of the attitudinal studies conducted to date and provide a basis for the development of an alternative approach to community receptivity.

The Fallacy of Assuming There is a Monolithic Community Attitude

For purposes of a siting study, it would be tempting to assume that a mass survey of citizens in a community regarding a possible development would provide a measure of community receptivity. However, it is important to remember that a community is composed of a number of interest groups (parties-at-interest), such as businessmen, agriculturalists, or local public officials. Each of these groups may have divergent attitudes that are masked by a survey. For example, if respondents are asked to indicate their support for the proposed development on a scale of one to five, the mean answer for all respondents might be three, indicating neutrality, but the range of answers might be from one (high support) on the part of local officials to five (opposition) on the part of agriculturalists.

Although attitudinal surveys commonly do breakdowns on such demographic variables as age, occupation, education, and length of residence, they usually are not designed to identify significant parties-at-interest within a community (e.g., local officials would

be missed in the example above). Of particular interest in a siting study would be the identification of parties-at-interest who have power over the decision making process or who potentially would attempt to halt development, such as an environmental group through litigation. Current studies have dealt with this issue in a limited way by identifying key public officials and community leaders as a discrete group. Interestingly, the studies (Oak Ridge National Laboratory and Bickert, Browne, and Coddington, for example) find that public officials are more supportive of energy related economic development than the general citizenry.

Individuals Hold Contradictory Attitudes

One consistent finding in the studies reviewed was that individuals frequently hold divergent and potentially contradictory attitudes toward potential economic development. Economic opportunities such as increased job opportunities or increased income are felt to be positive outcomes of development, while potential social disruption is viewed negatively. Without further information or a theoretical framework for analysis, one would be hard put to determine which attitude (economic opportunity or social disruption) should be used as an indicator of community receptivity.

Attitudes Frequently Do Not Predict Behavior

An excellent example of the fact that attitudes frequently do not predict behavior exists in Platte County, Wyoming. Attitudinal data collected for the Socioeconomic Longitudinal Monitoring Project indicated that citizens in Platte County preferred least the type of

industrial development occurring in the county, viewed the social changes negatively, and were committed to protecting the environment. Although they did perceive the economic changes beneficially, such findings might be interpreted as lack of community receptivity to development. However, when construction of the power plant and reservoir was threatened midway by an injunction stemming from an environmental concern for the extinction of the whooping crane, the total community rallied to the support of industry.

There are several influencing factors to be aware of in this chain of events. A two year pre-planning period and strong state plant siting legislation had allowed the community to put in place many impact mitigation procedures. These procedures have been quite successful in preserving the quality of life in the community. These factors appear to have influenced community response to a greater extent than initial attitudes may have indicated,

Attitudinal Change Over Time

Attitudes can change over time. The Platte County example given above may have involved attitude change on the part of some individuals. A more concretely substantiated example of change, however, is the change in attitudes of public officials in four western Colorado counties. The attitudinal data collected by Bickert, Browne, and Coddington in 1973 indicated a high level of support and little concern for potential negative impacts on the part of public officials. However, one year later these same public officials passed a resolution emphasizing the negative consequences of growth and the need for impact assistance.

This resolution was eventually read into the proceedings of a hearing of the Subcommittee on Public Lands of the Senate Interior Committee (see Appendix I).

Attitudinal surveys are limited to the extent that they do not adequately account for the possibility of change. Thus an index of community receptivity based on attitudinal data collected at one point in time does not allow for the possibility of changing the circumstances upon which the attitude is based with policy, mitigation procedures, or experience.

The Influence of the Type of Development

The type of energy development influences attitudes toward economic development. A good example of this fact is contained in the Oak Ridge National Laboratory studies of citizens in a county where a nuclear power plant was to be constructed. In this case, results indicated that the type of development (e.g., coal-fired versus nuclear power plant) would have been critical to the support or opposition of 25 percent of the respondents. With regard to synfuels siting, this consideration is further compounded by the fact that the general citizenry has had no experience with such development. Thus there is little informational basis for attitude formation.

The Number of Variables Related to Attitudes

Surveys of attitudes toward energy related growth have identified various factors that relate to positive or negative attitudes. For example, the Construction Worker Profile study found that

respondents who had lived in a community over 15 years were more likely to have negative attitudes toward economic development. The relationships between sex, age, occupation, and education and attitudes are also frequently the subject of analysis.

There are two major difficulties with using relationships found in the existing literature as site screening criteria. First, most studies do not indicate the level of confidence in the results (e.g., a statement such as "we are 95% confident that the true population value for any variable in the study will not differ from our results more than 20%"). Thus it is impossible to evaluate the validity of the stated relationships in many cases. Secondly, there simply is not enough data supporting any one relationship so that one would feel comfortable generalizing beyond a specific study population.

Surveys Call Attention to Issues and May in Themselves Influence Attitudes

Attitudinal surveys are not unobtrusive data collection techniques. To the extent that they call attention to an issue they may influence attitudes, exacerbate a problem, and/or become self fulfilling prophecies. For example, the Mayor of Grand Junction, Colorado, referring to the attitudinal study conducted by Bickert, Browne, and Coddington, made the following remark:

"One result of these studies has been the conversation between elected officials in all levels of local government. . . . On January 5, mayors, city council and school board members, and city managers from Rifle, Glenwood Springs, Grand Valley and Silt met in Rifle and drafted a resolution concerning growth." (Hearing before the Subcommittee on Public Lands of the Committee on Interior and Insular Affairs, United States Senate; Grand Junction, Colorado, January 19, 1974; p. 15.)

Thus it is important to realize the possible influence of using a survey technique and to assess the risks and benefits.

Methodologies Limit Use of Results

There are a number of methodological limitations to existing surveys of attitudes toward energy related developments. These limitations influence the degree of confidence one can have in the results and the resultant willingness to use the results as site screening criteria. In addition, they suggest areas for consideration if a new study were to be undertaken.

Many studies do not provide information on the representativeness of the sample or the degree of confidence in the results. Studies utilizing mailed questionnaires do not evaluate the return rate--a particularly critical methodological problem. In addition, some of the studies use questionable proxy variables. For example, in the Construction Worker Profile "community integration", a complex phenomenon, was measured by asking people to rank the three places where they met most of their friends.

Lastly, because there are virtually no longitudinal attitude surveys, inferences about changes in attitudes are not well documented. The Socioeconomic Longitudinal Monitoring Project lasted only two years--hardly a longitudinal study. This limitation is serious in that the possibility of changing attitudes through mitigation efforts, for example, is an important factor for assessing community receptivity.

SECTION III: THE DYNAMICS OF ATTITUDES AND COMMUNITY RECEPTIVITY

Attitudes are cognitions, not behaviors. Attitudes include two components: beliefs about an object or topic and an emotional response. For example, a respondent may be favorable toward a syn-fuel development (emotional response), and expect it to provide jobs (belief). The concept of community receptivity, on the other hand, implies behavioral responses. For example, a community where groups do not attempt to delay construction through litigation, where the citizens are willing to vote in a sales tax to help defray the costs of rapid growth, and where private entrepreneurs are willing to assume the risk of expanding their businesses would be said to be receptive to growth. Receptivity is indicated by accepting behaviors.

As the overview of attitudinal surveys has indicated, attitudes are not always reflected in behavior. Therefore, in an analysis of community receptivity, it is necessary to provide a framework for linking attitudes with behavior. One analytical framework that has worked quite well for social scientists has been a field theoretical approach.*

*Milton Yinger, Toward a Field Theory of Behavior: Personality and Social Structure. New York: McGraw-Hill, 1965.

The basic premise of field theory is that behavior is the result of the interaction between the individual and the social environment. Thus to predict behavior it is necessary to analyze both individual attributes (e.g., attitudes) as well as situational attributes (e.g., the demographics of a community). Figure 1 is a diagram of this approach.

Figure 1
Diagram of Field Theoretical Approach

To apply this approach to an analysis of community receptivity, it would be necessary to first identify the various parties-at-interest. The types of variables that would then be examined are listed in Figure 2.

Attributes of Individuals Who Belong to a Party-at-Interest Category

attitudes
length of residence
education
occupation
income
age
housing type

Community Attributes

Demographics

population size
employment base
growth rate (population and employment)
income
age structure

Community Assimilative Capability

infrastructure
proximity
tax structure
trade advantage
amount of farm consolidation
political structure--
opinion leaders

Land Use/Natural Resources

natural resource availability
long term implications

Project Variables

type of project
company attitude
size and phasing of work force
simultaneous development

Behavior

receptivity
permitting outcomes
mitigation outcomes
social assimilation outcomes
secondary economic growth outcomes

Figure 2
Field Theoretical Analysis of Community Receptivity

It is obvious from this analysis that attitude measurement alone is not a sufficient predictor of community receptivity. Individual attributes, such as attitudes, interact with the social environment to produce a behavioral response. A complete analysis of community receptivity would have to take both individual and community characteristics into account.

SECTION IV: AN ALTERNATIVE APPROACH TO ANALYZING COMMUNITY RECEPTIVITY

Because the field theoretical analysis is complex and requires extensive data collection, it may not be appropriate for initial and/or multiple site screening. It has been presented to illustrate the fact that attitudes alone are not particularly good indicators of community receptivity. In addition, it emphasizes the distinction between cognitions (attitudes) and behaviors (receptivity) and the necessity for linkage. In this section, the role of conventional attitudinal surveys will be discussed and an alternative approach to analyzing community receptivity will be presented.

The Role of Community Attitude Surveys

Community surveys are frequently used to obtain attitudinal data for inclusion in an environmental impact statement. They provide baseline information on citizens' attitudes toward growth and the general perceived quality of life in the community. They are virtually never re-administered over a sufficient length of time to allow generalizations to be made about changes in the perceived quality of life or the linkages between attitudes and community receptivity. Thus they are somewhat useful as indicators of the perceived quality of life at one point in time. Because of the limitations discussed in Section II, they are not useful as sources of generalizations that could be used as site screening criteria.

Comprehensive citizens surveys may also indicate the popularity of a proposed energy development. They are not market studies

(e.g., studies that attempt to predict accepting or rejecting consumer behavior with regard to a product as evidenced by willingness to purchase the product). Respondents, in most cases, are not able to make a personal decision as to whether or not they will accept the proposed energy development that in fact influences the siting process.

This observation raises an important point. That is, citizen attitudes become important indicators only in situations where they can be translated into behavior. For example, attitudes of the general citizenry may predict voting behavior. With regard to energy development, they may indicate whether or not citizens will support public officials who encourage growth or will pass a bond issue to pay for growth. It should be noted, however, that this translation of attitudes into behavior typically does not influence the siting process. Rather, it has more effect on the course of events after development has begun. For example, it is common to find that after three or four years of rapid energy related growth, citizens in small, rural communities vote in public officials who are more willing and able to cope with growth.

Thus attitudinal surveys may have more usefulness as indicators of long range community response to growth than as initial siting criteria. The danger remains, however, that when they are used to predict behavior in the too distant future, the measurements do not allow for attitudinal change based on policy, mitigation procedures, or experience.

An Alternative Approach to the Analysis of Community Receptivity

This working paper has emphasized the fact that attitudes are indicators of community receptivity only to the extent that they are translated into behavior. Traditional community surveys of attitudes toward energy related development are, for a number of reasons given earlier, not well suited for this type of analysis. The question remains as to how to approach an analysis of community receptivity to synfuels development.

The authors' recommended approach is based on the premise that the key variable for a site screening analysis is the articulated and voter approved goals of state and local governments. These goals represent attitudes that have been translated into behavior. They are the product of the collective attitudes of key decision makers and other parties-at-interest. Community receptivity can then be indexed by analyzing these articulated goals.

For purposes of site screening, analysis should take place at two levels: state and local. The steps in such an analysis are given below.

Analysis of state level policies and legislation dealing with energy related growth. A number of states that are currently or potentially affected by energy related development have policies relating to such development. For example, Montana has a "strip and ship" policy, whereas Illinois has a policy encouraging the use of Illinois coal within the state. Obviously such policy pronouncements will influence the initial reaction of states and localities to proposed synfuels locations.

In addition, as of 1977, eighteen states and Puerto Rico had environmental policy/protection requirements. Fourteen of these states plus Puerto Rico had legislatively enacted these requirements (the others administratively adopted the requirements).^{*} There is considerable variety in these state NEPA's. They should be examined as they relate to state and local receptivity to synfuels location.

Another source of information relating to receptivity is impact mitigation legislation. For example, Wyoming, Montana, and North Dakota have legislatively made provision for impact assistance to localities. Adequate mitigation procedures can significantly influence local receptivity to development as the case study of Platte County illustrates.

Site specific analysis. It cannot be assumed that state level policies and legislation exactly mirror the sentiments of local community leaders. For example, at the hearings on the economic impact of the oil shale industry in Western Colorado, the mayor of Grand Junction observed that he and others had resented previous hearings being held in Denver where the issues to be discussed were local ones. Consequently, he had not attended these earlier meetings. It is important, therefore, to conduct

^{*}James McEvoy III and Thomas Dietz, eds., Handbook for Environmental Planning: The Social Consequences of Environmental Change. New York: John Wiley, pp. 11-12.

site specific analyses, although such analyses might be most feasible after an initial screening has focused attention on a manageable number of sites.

At the local level it would first be necessary to identify the various parties-at-interest within the community. Typical parties-at-interest are public officials, agriculturalists, businessmen, industry representatives, senior citizens, or human service professionals. It is suggested that the parties-at-interest be identified by using a key informant interviewing technique. That is, a trained interviewer conducts a series of open-ended interviews in the community for the purpose of identifying categories of individuals that are considered significant by community persons. Representatives of the various party-at-interest groups are then interviewed to determine their attitudes toward development, issues they feel are important, and possible actions they might undertake.

Although community surveys theoretically could identify significant parties-at-interest, in reality they rarely do more than a superficial job. For example, although survey data may allow a separate analysis of agriculturalists or senior citizens, it would be unusual to collect data from a community survey that would allow identification of public officials or environmentalists. For this reason, and because of the other limitations of community attitudinal surveys, key informant interviewing is the

recommended approach to identifying parties-at-interest, their respective attitudes, and prospective actions. The study done by Booz, Allen and Hamilton with the aid of the Denver Research Institute is an illustration of this technique.

To make the translation from attitudes of parties-at-interest to an inference of community receptivity, it is necessary to (1) make a judgment as to which parties-at-interest exert most influence on the decision making process with regard to plant siting, and (2) to identify the articulated goals of such parties-at-interest. Again, this is best accomplished by trained interviewers/researchers who are placed in the community.

Public officials are an obvious example of a category of community persons who exert influence on the decision making process. Resolutions passed by county commissions or city councils are examples of articulated goals. Appendix II provides an example of such resolutions.

Other indicators of community receptivity. Thus far the recommended approach has focused on the analysis of individual attributes as they relate to community receptivity (e.g., attitudes of influential parties-at-interest articulated as goals, policies, or legislation). However, as the field theoretical approach to the analysis of behavior emphasizes, community receptivity is the result of the interaction between individual attributes and the social context. The social context includes the types of variables listed under "community attributes" in Figure 2, page 29.

For the purposes of initial site screening, some rough estimations of community receptivity based on community attributes could be made using variables and sources such as those listed in Table IV.

TABLE IV
Examples of Community Attributes and Sources of
Data for Community Receptivity Screening

<u>Attribute</u>	<u>Source of Data</u>
● Ability to diffuse impacts	● Maps showing proximity to other localities capable of absorbing population
● Construction labor force within the county	● Telephone interviews with union hiring halls
● History of industrialization	● REIS, census data
● Local government capacity	● Census of Governments: full time employment per 10,000 population
● Retail and service capability	● REIS location quotient for service and retail sectors
● Health care	● State health department: physicians per 10,000 population
● Community behavior regarding industrial development	● Requests for EDA, FmHA, economic development grants; existence of an <u>active</u> overall economic development plan

Conclusion

This section has proposed an approach to an analysis of community receptivity that does not rely on an attitudinal survey. To some extent it focuses on initial community receptivity as expressed by goals and policies that would allow construction of an energy related development. It is extremely important to note, however, that community receptivity over the course of development is also related to such factors as community support for mitigation procedures, willingness to achieve social assimilation, and growth of the secondary sector of the economy. All human behavioral responses are complex phenomena that are influenced by complex feedback relationships. The recommended approach, as well as attitudinal indices of community receptivity, is limited to the extent that it does not account for these feedback relationships.

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APPENDIX I:
GROWTH RESOLUTION WESTERN COLORADO

RESOLUTION CONCERNING GROWTH ADOPTED BY
THE REGION XL COUNCIL OF GOVERNMENTS, SCHOOL DISTRICTS,
CITIES AND TOWNS OF THE REGION AS AN
ACCURATE STATEMENT OF FACTS CONCERNING GROWTH*

The western slopes of the Rocky Mountains of Colorado, Utah, and Wyoming have long been known as repository of vast mineral resources and have, more recently, become the center of a growing tourism and recreation industry.

The national energy crisis has focused attention on the region as a most promising supplier of resources to meet the present emergency as well as future needs. Accelerated growth and its resultant demand for expanded and improved urban services may come from one or several sources, but it appears to be a fact of life in the future of western Colorado.

Services provided by most local and county governments in the region have been confined traditionally to barest minimum simply because of limits imposed by a depressed, seasonal economy.

Service levels are increasing slowly and will continually be improved. But major new growth demand, without accompanying resource increases, can be expected to overload governmental systems and public facilities to their detriment and possible destruction.

Governmental systems and processes, like their counterparts in the private sector, have developed traditional methods of operations.

*"Economic Impact of the Oil Shale Industry in Western Colorado." Hearing before the Subcommittee on Public Lands of the Committee on Interior and Insular Affairs, United States Senate, Ninety-Third Congress, Grand Junction, Colorado, January 19, 1974.

A minimum of 18 months is presently required for preliminary design and approval for highways, waterworks, sewer treatment plants, and other facilities requiring State and/or Federal assistance. Experience indicates that a similar schedule is necessary for final plans, for bid lettings and construction of most public facilities. These schedules and activities are predicated on the immediate availability of funds for their initiation and completion.

Unlike elements of the private sector, local governments are severely restricted from appropriating, obligating, or spending moneys which they do not have. The availability of funds is a statutory requisite to applications for Federal and State grants-in-aid and for the initiation of activity to seek bids and award contracts for public improvements.

Lacking adequate plans and financing and the technical and professional staffs in a sufficiency and of a competency to obtain them, the suggestion that communities appear reluctant to proceed with the planning process is a gross understatement.

We are simply incapable of generating such activities or the revenues they require on short notice. Local governmental agencies have traditionally been denied the research and development capabilities that have become the basis of success in industry.

If, as has been suggested, the national energy crisis is the result of poor planning and miscalculation at the national level, where virtually unlimited funds have been available, how can we now expect or require that limited local resources are equal to the task of its solution?

Local communities can and will participate in research and in planning and development for growth. But we must be accorded an equal status in the decisionmaking process from the beginning, and equal share in the benefits as well as in the costs.

In short, we must be allowed to determine our own destinies. Considering the foregoing, we submit that any major growth impact or demand must be with an eye to preventing the boom or bust frustrations of the past, to protecting our developing socioeconomic situations and to preserving the natural, physical, and human resources of the region.

A comprehensive plan based on the best and most complete information obtainable must precede the development of public facilities. Such a plan must begin with acceptable methods for its financing and continue through firm commitments for funding all improvements which it contemplates.

The goals and objectives of the planning process will be the first to inventory the quantity and quality of existing community facilities and services, assuming that growth activity has no responsibility for existing inadequacies. Secondly, the planning process will identify the needs and demands occasioned by growth and provide for their satisfaction on a cost-benefit basis without undue burden on the existing population.

The regional plan should be the culmination of specific plans drawn from and by each urban area, coordinated through the existing county planning agencies and consolidated under existing regional

agencies. We assume intrastate planning and coordination will be carried out as determined by the Governor.

Only through coordinated planning can needless duplication, waste and frustration be prevented and historical animosities within and between jurisdictions be eliminated. The single point of contention at the outset of impacted growth will be for the allocation of front-end moneys.

Both the stimulators of growth impact and the local governmental agencies which are expected to respond to that impact, will require vast sums initially. Means must be found for equitable participation and reciprocity on both short- and long-term commitments by each participant.

It should be remembered, however, that there is no method by which local government can "write off" or subsidize research and development activity. The local public official simply cannot gamble, speculate or hedge public moneys or public resources. Once begun, planning and development of public facilities must proceed to completion or be relegated to waste.

Governmental agencies and officials at all levels must be as committed to the solution of growth problems as are those representatives of the private sector who propose growth activity. That commitment must also extend to the fulfillment of responsibility for high levels of public service and preservation of the public health, safety and general welfare.

It must be clearly understood that no authority exists for compromising this responsibility. Any conflict between expediency or private economic advantages and the public welfare must be resolved in favor of the latter or constitute an admission of the failure of man's capacity for self-government.

APPENDIX II:
GROWTH RESOLUTIONS KITSAP COUNTY, WASHINGTON

RESOLUTION NO. 211-1973

WHEREAS, the U. S. Navy has selected Kitsap County as the site for the home base of the proposed Trident Submarine; and,

WHEREAS, Kitsap County will have to prepare for the impact caused by the Trident Project; and,

WHEREAS, a specific work program and funding for said program will have to be prepared to deal with the impact of the project; now, therefore,

BE IT RESOLVED by the Board of Kitsap County Commissioners, in regular session assembled, that a Task Force be created to coordinate the efforts of local governmental agencies in developing specific work programs and grant applications; and

BE IT FURTHER RESOLVED that the Chairman of the Kitsap County Board of Commissioners will assume the Chairmanship of said Task Force which will be comprised of persons representing the following agencies: The Region X Federal Regional Council, the State of Washington through the Office of Community Development, the Puget Sound Governmental Conference, the Central Puget Sound Economic Development District, and the Kitsap County Board of Commissioners.

ADOPTED this 12th day of November, 1973.

BOARD OF COMMISSIONERS
KITSAP COUNTY, WASHINGTON

Chairman

Commissioner

Commissioner

ATTEST:

Clerk of the Board

RESOLUTION NO. 212-1973

WHEREAS, there is a need to identify local concerns in preparing for the location of the Trident Submarine Base; and,

WHEREAS, a Coordinating Committee to assist the Task Force in developing specific work programs and grant applications is necessary; now, therefore,

BE IT RESOLVED by the Board of Kitsap County Commissioners, in regular session assembled, that a Kitsap County Trident Coordinating Committee be created to identify areas of concern;

BE IT FURTHER RESOLVED that the Chairman of the Kitsap County Board of Commissioners shall preside over all meetings of this Kitsap County Trident Coordinating Committee which will have the membership of the following agencies and organizations: Kitsap County Board of Commissioners; Jefferson and Mason County Commissioners; Bremerton City Council; Mayors of Port Orchard, Poulsbo, and Winslow; representative of each School Board in Kitsap County; representative of Fire Commissioners Association; representative of the Hood Canal Advisory Committee; representative of the Take Stock Committee, Hood Canal Environmental Council, and one representative from the Chamber of Commerce;

BE IT FURTHER RESOLVED that the Coordinating Committee may be expanded to include other representatives if necessary.

ADOPTED this 12th day of November, 1973.

BOARD OF COMMISSIONERS
KITSAP COUNTY, WASHINGTON

Chairman

Commissioner

Commissioner

ATTEST:

Clerk of the Board

Appendix O

STATUS OF DISTURBED LAND REHABILITATION

1. General Progress

Current status. Although the U.S. Department of Agriculture's participation in mined land conservation began as early as the 1930s, until recently most approaches to land rehabilitation have been fragmentary and have not been approached from an ecological perspective (Wali et al., 1977). Nonetheless, significant progress has been made in rehabilitating disturbed land and extensive research is being carried out in this field today.

Extensive bibliographies on land reclamation and ecological effects of coal strip mining have been prepared by Gleason (1979), Ralston et al. (1977), Vories et al. (1977b), and Dalsted et al. (1974). These bibliographies cover research carried out (1) by federal agencies--for example, the Forest Service's Surface Environment and Mining Project, or SEAM (Weissenborn 1977), the USFWS's Office of Biological Services and the Denver Wildlife Research Center, the Department of Energy (DOE), Bureau of Land Management (BLM), the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), and the U.S. Bureau of Mines (USBM); (2) at national laboratories (in the Land Reclamation Program at Argonne National Laboratory (Kennedy et al., 1977; Carter and Johnson 1978) and in studies at Oak Ridge National Laboratory and Pacific Northwest Laboratories); (3) at universities, both in the East and the West; (4) by regional organizations (including research sponsored by the Old West Regional Commission, the Four Corners Regional Commission, the Western Governors Regional Energy Policy Office, the Northern Great Plains

Resources Program, and by river basin commissions such as the Ohio River Basin Commission); and (5) research conducted or sponsored by state agencies and by industry.

Progress has been made in revegetation techniques, increasing the availability of a wide range of plant materials suitable for mined land reclamation, changing company attitudes towards accepting the responsibility of mined land reclamation, and in training reclamation environmental engineers.

Rehabilitating land is now not so much of a technologically constraining factor in site selection as it was a decade ago, although legal requirements are becoming increasingly stringent. Given a well-engineered premining rehabilitation plan that is skillfully implemented before, during, and after the mining operation, almost any area can be reclaimed for some type of useful purpose. The degree of difficulty and thus the resulting costs vary considerably, however, depending on a number of factors (Powell et al., 1977; O'Neil, 1977; Hodder, 1978). The general factors used in assessing the redevelopment potential of a surface mining area are similar throughout the country, although specific issues vary considerably from one regional ecosystem to another.

Major categories useful in determining the rehabilitation potential of mined land include:

- o Climate (e.g., seasonality, amount of, and variation in, precipitation; temperature extremes and averages; amount of evaporation; length of growing season)
- o Physical and chemical characteristics of the overburden (e.g., structural stability, permeability, porosity, fertility, pH, salinity)
- o Geohydrological, topographical, and biological features

- o Coal mining techniques used
- o Methods of reshaping physical environment, including final grading practices
- o Magnitude and topography of the disturbed lands
- o Plant material availability
- o Revegetation techniques (e.g., mechanisms of seeding, timing of reclamation activities, plant material selection, nature of soil amendments)
- o Rehabilitation purpose
- o Economic constraints, including economic analysis of the mine's operation
- o Institutional and legal constraints.

Problems Remaining. One major unsolved problem is restoring groundwater resources in disturbed lands (Hodder, 1978; Power et al., 1978). In the past, reclamation has emphasized establishing a stable, useful plant cover, and in a large majority of cases such efforts have been successful. Greater attention is now being directed to maintaining the hydrological regime of an area (Smith et al., 1978). Of particular concern is protecting the integrity of the shallow aquifers that are a common source of water for livestock and subirrigated farmlands in the semiarid West (Hodder, 1978). Means of protecting the integrity of the groundwater system include intelligent handling of overburden by taking its chemical and physical components into account, appropriate spoils segregation, and well-planned topographic design for the reclaimed land--issues that Hodder (1978) considers the "crux of reclamation in the near future."

Although much more experience has been gained in restoring and controlling surface water resources than in restoring groundwater resources, potential problems still remain in maintaining the integrity of aquatic habitat characteristics. Even though water quality laws are both numerous and extensive, deterioration of surface water quality may be a problem in certain areas of the East and the West if large-scale synfuel operations are developed. Acid mine drainage and associated toxic material pollution, which are characteristic of the East, may not generally prove to be a significant problem in the West, where the overburden soils are usually alkaline. Nevertheless, the leaching of soluble salts from mine spoils and the transport of those salts to receiving water systems have been shown to occur, resulting in water quality deterioration (McWhorter et al., 1975; McWhorter and Rowe, 1975). Even with the best rehabilitation plans, a certain amount of erosion-induced sedimentation will probably also occur in both the West and the East as a result of extensive mining operations. Although precautionary measures for controlling erosion have been well-established, watershed vegetation that is either directly or indirectly damaged as a result of synfuel operations can accelerate erosion, thereby increasing sediment loads in receiving streams. Sediments can smother eggs and aquatic insects, reduce the light available for photosynthesis, and impair the ability of aquatic organisms to breathe in their environment. Increased sedimentation can also result from road building and digging, because these activities disrupt the natural soil cover and facilitate erosion.

Reduction in surface vegetation in a region can markedly affect the aquatic habitat in other ways. Loss of streamside vegetation permits more direct sunlight to strike the stream, resulting in increased temperatures. The elevated temperatures result in a concomitant increase in evaporation, which reduces stream flow and wetted area. More sunlight can also result in increased plant activity that can lead to algae blooms or large growths of aquatic macrophytes. The increased plant biomass can result in loss of habitat for other aquatic organisms.

Other hydrological alterations that can potentially affect aquatic habitats negatively, and that are sometimes carried out during mining operations, include channelizing and rerouting existing streams, constructing impoundments, and reducing stream flow. In addition to the stream bed itself, associated stream-bank vegetation is usually completely denuded during stream channelization projects and may result in rapid erosion if measures such as rip-rapping are not quickly implemented. Even with such measures, the altered aquatic habitat usually does not provide sufficient depth for larger organisms or sufficient shallow areas suitable for nursery and food production. In view of the disruption of the banks and stream bed, such altered areas are difficult to reclaim to their original productivity.

Impoundment and reduction of stream flows can also have marked effects on the stream environment. The impoundment itself constitutes a substantial change for species accustomed to living in lotic environments. Certain of these species may find themselves at a competitive disadvantage or unable to find habitat necessary to complete their life cycle. The impoundment can also act as a nutrient sink, preventing materials from entering the downstream food web. Impoundments as well as direct pumping also act to reduce instream flows. Flow reduction can result in increased water temperatures, reduced dissolved oxygen and nutrient levels, and reduced wetted area--the shallow stream edge that is very important as a nursery and food production area for many aquatic organisms.

According to many environmental reclamation engineers, one of the principal land rehabilitation problems today is encountered in the reclamation laws themselves. Often state and federal regulations are very rigid, and do not adequately recognize that the best methods of rehabilitating disturbed lands are site-specific. Thus, regulations that may be generally appropriate are often completely inappropriate for specific sites (La Fevers, 1977; Reiss, 1977; Cull et al., in press). In addition, the inflexibility of many of the regulations does not allow for adjustment for technological advances (which are occurring

rapidly). On the other hand, practices are sometimes legislated that are not now economically feasible. As one reclamation engineer explains, rehabilitation problems arise only when state and federal rules do not cooperate with nature's laws (Murray, 1979).

Examples of problems with current state and federal reclamation laws include requirements for:

- (1) Completing reclamation activities within 12 months of the expiration of the mining permit. In the arid Southwest, this requirement might encourage the use of rapid-growth vegetation that "looks good" but lacks the stamina for permanent endurance under harsh, arid environmental conditions. According to La Fevers (1977), a necessary requisite of effective reclamation in the Southwest is allowing ample time for successful types of vegetation to become established.
- (2) Replacing topsoil. Sometimes the spoils materials may be higher in nutrients and of better physical quality than surface materials, or at least equally as good as topsoil (Aldon and Springfield, 1977).
- (3) Using specific kinds of plant materials and mulches. Sometimes these materials are not locally available or not so suitable for a given site as other materials.
- (4) Leveling the final grade. In certain regions, this process cannot be done without greatly compacting the soil and thus reducing its productivity.
- (5) Building reclamation ponds to keep contaminated water from running into streams. This requirement seems to make little sense in arid regions with high evapotranspiration rates and where the mining operation is far from any stream.

- (6) Reclaiming land to prior conditions. Prior conditions may be a badly overgrazed range or not represent a land use that is currently the best use (Leaming, 1977; La Fevers, 1978).

Requirement (6) raises the larger problem of defining what is proper "reclamation" or "rehabilitation." These terms are still variously interpreted depending on the philosophy of resource management. Some maintain that it is essential to occupy the land and make it productive for man's needs, wants, and economic gain. Others consider it an obligation to set aside or restrict human activity on what remains of the available land.

Despite the shortcomings of the mined-land regulations, environmentalists, reclamation engineers, and regulators agree that most companies would not be vigorously pursuing advanced rehabilitation procedures were it not for federal and state requirements. Such regulations are needed to safeguard the environment.

Other rehabilitation problems that are currently being investigated include:

- (1) Developing a more economical means of tree and shrub establishment in arid areas. It has been estimated that it cost \$14 to reestablish every rabbitbrush at the Navajo Mine in New Mexico.
- (2) Developing an even more diverse plant material suitable for revegetating disturbed lands than currently exists and reducing their costs. Some seeds cost \$159 per kilogram and are scarce even at this price. Although a great number of species have been tested (Plummer, 1977), many more possibilities remain.

- (3) Designing seeding mixtures composed of species mutually compatible for a given seeding technique (Cull et al., in press).
- (4) Developing methods of economically reclaiming extremely rich soils to their original fertility, which are easily managed by standard agricultural machinery (McCormack, 1976).
- (5) Where appropriate, developing rehabilitation techniques that maximize the value of the land for wildlife. Generally, reclamation for grazing lands does not provide diversity in composition and structure or the topography and water conditions required to support a variety of wildlife species. Indeed, the great variety of ecological niches available at some older orphaned mines that have revegetated naturally appears to support greater wildlife diversity than the large reclaimed mines that are used primarily by a few large mammal species (Evans et al., 1978).
- (6) Developing a coordinated, comprehensive postmining use plan in designing the revegetation of an entire mine site (Cull et al., in press).
- (7) Establishing whether long-term (more than 10 years) physical and biological stability of rehabilitated lands can be achieved. Assurance of long-term stability cannot be gained without lengthy experiments.
- (8) Determining what constitutes toxic concentration levels of salts and trace elements in the overburden. Research is required to indicate the levels of such elements in soil and spoil that do indeed constitute a threat to hydrological systems, plant growth, and forage quality (Cull et al., in press).

- (9) Overcoming general economic restraints. Reclamation costs sometimes run as much as 30 times the value of the land (La Fevers, 1977). Defining economics as the study of the allocation of limited resources among alternative uses, Leaming (1977) states that problems of mined land reclamation are basically problems of allocating human and nonhuman resources among alternative and often competing uses.

2. Western Regions

Surface Coal Mining. Much progress has been made in Western rehabilitation practices since 1974, when the National Academy of Science's book, Rehabilitation of Western Coal Lands was released. Some major advancements have been recorded in the published proceedings of the University of Arizona's symposium, "Disturbed Land Use and Reclamation in the Southwest" (Thames, 1977) and those from the Arizona Lands Reclamation Symposium that the American Association for the Advancement of Science sponsored in Denver, Colorado in 1977 (Wright, 1978). In addition, Evans et al. (1978) include information about the reclamation history on all Western surface-mined lands greater than 4 hectares, which they inventoried in compiling their Atlas of Western Surface-Mined Lands for the U.S. Fish and Wildlife Service (FWS). FWS has prepared a manual on the effects of surface mining in the western United States on fish and wildlife resources and on the ways these effects can be mitigated (Moore et al., 1977).

Notable progress has been made in developing methods of manipulation of soil surfaces to improve erosion control, increase infiltration, conserve soil moisture, and protect seedlings from the harsh, semiarid western climate (Hodder, 1978). Contouring and sloping the surface to harvest precipitation is hardly new; such practices were well-developed as "runoff farming" in the Negev Desert as early as 2000 B.C. (Evenari et al., 1971). The concept of microcatchments can be

described as a new-old idea. Other advancements include improving hydroseeding or hydraulic seeding methods (the application of a slurry of seed and water to soil), which greatly aids in vegetation establishment (Kay, 1977); determining good mulching techniques (Kay, 1977); and developing seed production centers and nurseries in the west (e.g., the Plant Material Centers established by SCS, such as the Upper Colorado Environmental Plant Center near Meeker, Colorado, and the extensive plant breeding program at the U.S. Forest Service's Shrub Sciences Laboratory in Provo, Utah; Monsen and Plummer, 1978). The best adapted species to meet environmental extremes are often local ecotypes of dominant species that can tolerate high levels of salinity, are compatible with domestic and wildlife uses, and have aesthetically desirable features. Several native plant species have been found to have tolerances for salt levels considerably greater than those found in the ocean (McKell, 1977). Successful plant selection, breeding, and field testing programs have produced several varieties of the genus Atriplex (saltbush or shadscale) that have proved adaptable to drought and salinity, as well as being vigorous--vital attributes for successful revegetation in many areas in the arid West (Carter et al., 1979).

Additional progress has been made in initiating planting innovations; for example, tubelings--usually seedlings of woody species planted and nursery-developed in paper cores or tubes that can be directly transplanted into the field when the root system extends from the bottom and sides of the tube (Hodder, 1978), and developing water-efficient irrigation techniques such as trickle irrigation (DeRemer and Bach, 1977). Nonetheless, in certain areas quite a few revegetation problems remain, including aridity, toxic and infertile soils, and reestablishing species diversity and woody species.

Although the habitats vary considerably, many of the western areas are xeric rangelands. Until the late 1960s, reclamation in the semiarid West invariably meant irrigation of drylands to make them productive. Reclamation emphasis has since focused on treating surface-mined

spoils. Moreover, range management is no longer considered only in terms of livestock management but now extends to wildlife and recreational potential.

Regardless of the land uses desired, however, in many areas of the two western study areas, the availability of water still determines whether rehabilitation succeeds or fails. Successful reclamation in the arid or semiarid West, in fact, is defined as the development of an environment that conserves and efficiently uses precipitation by productive vegetation (Power et al., 1978). Reclamation technology has thus been designed to enhance infiltration; reduce runoff, soil water evaporation and leaching; and increase root absorption of soil water and dry matter production per unit of water used. Saline and sodic soils, which occur commonly in the West, reduce the moisture available. These soils restrict the amount of water a plant can absorb and decrease water infiltration rates (Barth, 1977). In highly sodic soils, runoff and erosion rates increase, leaving less water stored in the soil for use by vegetation. Although reclamation techniques have been developed to reclaim such soils, many are inadequate or very expensive. The most practicable means consists of covering undesirable spoils with good soil (Power et al., 1978). Even though successful revegetation can thus result, underground or surface water may be contaminated with salts, both from natural runoff or infiltration from exposed spoils, or from operations designed to leach salt from the plant-growing medium. The salt content of many western rivers has now reached critical levels, and therefore increases in salinity would be detrimental. Successful reclamation today rehabilitates shallow aquifers and other hydrological characteristics to predisturbance characteristics.

Oil Shale Lands. Since 1965, considerable research has been carried out on the potential impacts and mitigation procedures of oil shale mining. Although the first full-scale processing plant, consisting of a crusher and a retort, began operating near De Beque, Colorado, in 1918, the oil shale boom of the early 1900s was shortlived. Other, more profitable sources of crude oil were discovered

(Sims et al., 1974). It was not until the 1960s, when adequate sources of petroleum became critical, that research on oil shale, including environmental studies, was renewed.

A preliminary assessment of oil shale mining impacts has been summarized recently by Crawford et al. (1977). Specific problem areas with wildlife that should be addressed have been analyzed by Burke (1975) and the possible effects of oil shale mining on aquatic habitats have been analyzed by Everhart et al. (1973); Goettl et al. (1978); and Gray et al. (1978). Ongoing oil shale research has been tabulated by EPA (1976) and Crawford et al. (1977), and more recently by USGS (1979).

The problems involved with rehabilitating oil shale lands have been great, especially the disposal and revegetation of the toxic, saline spent shale. Equally great, however, has been the strong commitment of government and industry to protect the environment. The extensive environmental studies, including the baseline data requirements and detailed development plans that are required by the Federal Prototype Oil Shale Program before oil shale is mined on federally leased lands, have been described by the USGS's Area Oil Shale Office (1979). Of the country's known oil shale reserves, 80% are on federal lands.

The Federal Prototype Oil Shale Program began in 1971 when the U.S. Department of the Interior announced the federal oil shale leasing program. Before this time, private industry had already begun environmental programs for rehabilitating areas mined for oil shale. Colony Development Operations' program began in 1964 (Kilburn, 1973; Block et al., 1973; Culbertson et al., 1979). By 1967, they had initiated systematic investigations of revegetation of spent shale (USDI, 1973). In 1977, BLM released the Final Environmental Impact Statement on the proposed development of oil shale resources by the Colony Development Operation (BLM, 1977).

Union Oil established revegetation plots in 1966 (Kilburn, 1977), and TOSCO Corporation has spent more than a decade studying the

properties and problems of spent shale that result from the use of the TOSCO II retorting process, in addition to developing techniques for reclaiming it (Merino et al., 1977).

The information base from which environmental predictions are made is becoming more voluminous each year. Colony Development Operation alone has concluded more than 100 environmental studies and has published them in a 20-volume Environmental Impact Analysis (1974). Additional environmental studies conducted by the Committee on Oil Shale Environmental Problems (COSEP) have been published, including a revegetation study by Cook (1974) and a socioeconomic one by THK Associates (1974). These studies have been equally funded by the State of Colorado, the Department of the Interior, and various industries, primarily oil companies.

More recently, Rio Blanco Oil Shale Company completed a 3-year revegetation experiment at Tract C-a that was initiated in July 1975 (Braun, 1979), and Colorado State University (CSU) has been extensively involved in disturbed land research in their 20-hectare Intensive Study Site in Piceance Basin (Cook, 1979). With a good basis from their earlier research on revegetating disturbed areas in Piceance Basin (e.g., see Sims and Redente, 1974), CSU (with DOE funding) is providing guidelines for the rehabilitation potential and practices of Colorado oil shale lands. With an interdisciplinary team of range scientists, agronomists, botanists, and microbiologists, CSU researchers are studying such areas as the effects of seeding techniques, species mixtures, fertilizers, ecotypes, and mycorrhizal fungi. Numerous other research projects on rehabilitating oil shale lands are in progress at CSU and elsewhere.

The test plots that have been established throughout the Piceance Basin have demonstrated that revegetation of processed shale is feasible but will require either the replacement of top soil or intensive management for initial plant establishment. Questions remain on the long-term (more than 10 years) stability of spent shale embankments, on

scaling problems that may arise on the erosion potential of spent shale embankments when going from small, experimental plots to large embankments, and on the long-term hydrological implications of spent shale disposal. Nonetheless, significant progress has been made in developing environmentally acceptable ways of disposing of spent shale.

Both native and introduced species have been established with varying degrees of success, depending on the treatment methods, species selected, the aspect and slope of the plot, and the physical and chemical characteristics of the spent shale. The differences in spent shales are a function of the origin of the raw shale and the retorting process for converting raw oil shale to crude petroleum, particularly in regard to the particle size when crushed, and the retorting temperatures. High-temperature retorting of 780-800°C produces spent shales that have high pHs (11-12) and that often have cementitious properties because most of the carbonaceous material has burned off (Harbert and Berg, 1978). The Paraho Direct Mode is an example of a retorting technology that has been designed to burn off most of the organic material (Crawford et al., 1977). The resulting decarbonized shale is extremely difficult to revegetate; however, the cementitious properties may be used to advantage in creating an impermeable disposal pile.

Unlike the dark gray to black, coarse, gravelly material of Paraho spent shale, the TOSCO II retorting process produces a fine, dry, black powder with an organic residue that is highly saline and more difficult to wet (McKell, 1977). The Union B retorting process produces a clinker type of spent shale with an organic residue. Lower temperature retorting processes such as that in the TOSCO II and the Union B processes commonly produce spent shale that is extremely salty and deficient in nitrogen and phosphorous, but with a lower pH than that retorted at high temperatures.

All of these different chemical and physical properties of spent shale significantly affect the success of land rehabilitation programs. It has been suggested that consideration needs to be given to

spent shale disposal when designing the retorting process (Harbert et al., 1978).

Colony Development Operation and other industries appear pleased with their success in growing plants directly in processed shale. Colony's plots were established 8 years ago and the vegetation is growing well today in many of their plots. Union Oil also has demonstration plots showing good establishment of plants on carbonized Process B shale. This year, CSU has established for Union Oil new, steeper plots that more closely resemble the embankment environment proposed by Union for shale disposal.

Similarly to Colony Development and Union Oil, TOSCO Corporation plans to dispose of shale by forming it into a stable embankment on the surface, preferably in a shallow canyon or valley, and revegetating the surface with a self-sustaining plant community (Merino et al., 1977). However, there is a growing trend to cover the retorted shale with soil rather than intensively managing the spent shale as the plant-growing medium. After 2 years of study at the CSU Intensive Study Site, into which 13,600 metric tons of retorted Paraho shale had been transferred from the Anvil Points facility, Redente and Ruzzo (1979) have concluded that Paraho retorted shale cannot be directly revegetated within an environmentally acceptable period without large inputs of water and fertilizer and prolonged management. They suggest soil coverings as deep as 1 meter to establish an effective long-term plant cover. Successful revegetation has been achieved using artificial soil profiles over shale.

Similarly, one of the sites in Rio Blanco Oil Shale Company's revegetation experimental program involved an artificial soil slope about 1.5 meters deep. It was constructed over TOSCO II-retorted shale obtained from Colony Development. Good plant establishment of diverse species has been achieved with little supplementary irrigation. Soil conductivity measurements during the first and second growing seasons indicate the resalination of the artificial soil profile has not

occurred (Braun, 1979). An artificial soil profile of a sufficient depth appears to be an effective method for inhibiting upward capillary migration of toxic elements. In other experiments (Harbert et al., 1978), resalinization has been shown to occur when only 15 centimeters of soil cover was placed over leached spent TOSCO shale. When 30 centimeters of soil was placed over unleached spent TOSCO shale, resalinization did not occur.

Fewer resalinization problems occurred with coarse-textured TOSCO spent shale. McKell, of Utah State University, in discussing rehabilitation practices of Paraho spent shale under the arid conditions of the Uinta Basin of northeastern Utah, has suggested effective but limited use of topsoil. He notes that both water and soil resources are limited in the Uinta Basin. Average soil depth of Tracts U-a and U-b is less than 45 centimeters on the upland areas. In addition, he notes the high costs of stockpiling soil, and of massive topsoiling practices that would be required with commercial-sized retorting operations. McKell has proposed employing native drought- and salinity-tolerant plant species by transplanting container-grown stock into topsoiled trenches about 48 x 75 centimeters, and surface-shaping the pile to harvest precipitation (McKell, 1977).

A number of researchers have been troubled by rodents when revegetating spent shale. Not only do rodents burrow through the shale and topsoil and intermix the two, they have also decimated the plants in experimental plots. At least certain kinds of spent shale appear to be ideal habitats for them, and revegetation success may thus strongly depend on rodent control.

In addition, establishment of certain woody species important to wildlife remain a problem. In studies at Tract C-a, fourwing, winterfat, bitterbrush, and big sagebrush were successfully established, but mountain mahogany and pinyon pine were not (Braun, 1979).

Hydrological concerns about surface waste disposal of spent shale also appear to have been minimized. Salts and other soluble substances mobilized by water contacting retorted shale can be potentially controlled or contained. Constructing drainage systems and providing impoundments below disposal areas can, in principle, contain the salts that may be extracted. Colony Development Operation has committed itself to a zero water discharge policy and proposed constructing dams and holding ponds to contain runoff. The embankments are of such low permeability that after compaction, water does not percolate through to surrounding aquifers, or does so very slowly (BLM, 1974; Kilburn, 1977; Merino et al., 1977). Weaver (1974) has pointed out that use and consumption of groundwater high in dissolved solids in mining could actually reduce the contribution of these materials to the surface water and result in an actual reduction downstream.

However, according to Crawford et al. (1977), despite controls, some runoff and percolated waters may eventually reach other ground and surface waters. Spent shale that has cementitious properties and is particularly impermeable may pose fewer long-term environmental problems (Harbert et al., 1978). Several current studies are investigating the movement of salts and other potentially toxic materials in spent shale, including the erosion potential of shale when disposed on the surface. These investigations include those at Battelle Northwest Laboratories (Rouston et al., 1979), CSU, the University of Colorado, and the Colorado School of Mines. Regardless of any potential water quality problems from leaching of toxic materials, disposal of spent shale in canyons will alter natural drainage ways and will require special measures to reroute natural flows either beneath or around the piles (Cook, 1974).

A modified in situ retorting process, like that Occidental Oil Shale Company proposes at Tract C-b, will reduce some of the established environmental problems (e.g., considerably reducing the amount of spent shale to be disposed of on the surface and reducing air pollution and water requirements), but also raises several new ones. One of the major

concerns is the effect of modified in situ mining on existing aquifers and groundwater quality. The question remains whether mined-out areas can be satisfactorily sealed off. Environmental research on in situ oil shale mining is quite recent. The scope of this study did not permit us to thoroughly investigate these problems.

3. Eastern Regions

Reclamation laws in the Illinois Basin date back to the early 1940s. A 1941 Indiana law required that tree seedlings be planted on ungraded spoils. In 1954, Kentucky adopted legislation regulating surface mining. Nearly all the land up to the early 1960s, however, exhibited a typical washboard, ridge-and-valley topography. The predominant trend in reclamation since the 1940s has been toward requiring increasing inputs to the reclamation programs to ensure the eventual reuse of the mined areas (La Fevers, 1977).

The first surface mine act in Illinois, the Open Cut Land Reclamation Act, became effective in 1962. The grading and revegetation requirements were minimal: the area was to be seeded in a "workmanlike manner." The Act was amended in 1968 to include minimum standards for vegetative groundcover and the elimination of toxic wastes that might accumulate during mining. In 1971, the even stricter Surface-Mined Land Conservation and Reclamation Act became effective. Mined lands that were to be reclaimed for pasture had to be graded to a rolling topography traversible by maintenance machinery; no slopes could exceed 15% grade, and lands must be returned to within 4% of the original slope; specific texture standards had to be achieved in the upper 1.3 meters of reclaimed lands, and certain lands had to be returned to "row crops" (Christy et al., 1979).

In the same year (1971), use of both pre- (before 1962) and post-law surface-mined lands was surveyed in Illinois. No use was observed on almost one-half of the lands, and about 60% of the observed

uses were agricultural, primarily for pasture and hay areas (Haynes et al., 1975c).

In 1975, the Illinois Surface-Mined Land and Reclamation Act was amended to include even more stringent requirements, particularly for lands reclaimed to row-crop standards where the surface soil layer and the root medium layer together must be a minimum of 1.3 meters thick and meet strict texture standards. In the amended Act, premining soil capabilities are used as a guide for requiring certain lands to be reclaimed to row-cropping conditions. The amended Act requires the operator to identify projected land uses after reclamation. Historical land use received no consideration in the determination of which lands must be reclaimed to row-crop capabilities (Christy et al., 1979).

As Table O-1 indicates, until the 1974 Act was passed, only a small percentage of surface-mined land was being returned to agricultural cropland in Illinois. In Indiana, less than 1% of the surface-mined land had been returned to cropland through 1974 (La Fevers, 1977). McCormack (1976) has explained the importance of preserving the productive capacity of the land through soil conservation practices versus choosing a low-intensity land use that requires little care in the placement of the spoil. The conservation ethic would dictate that the plant growth capability of the natural resources not be diminished when extracting coal. More than 30% of the surface-minable coal in the Midwest lies beneath prime agricultural land (Carter, 1979). Even with underground mining, the aboveground facilities will preempt a certain amount of land, and undesirable impacts such as subsidence may occur.

Land reclamation problems in Appalachia relate principally to acid mine drainage, soil erosion, and siltation. Acid-forming materials lie in or adjacent to coal seams. When coal refuse is exposed to the atmosphere, oxidation and hydrolyzation occur, and strong acids result. In addition to causing water pollution problems, acid materials also retard revegetation if they are not properly handled.

Table O-1

LAND USES OF ILLINOIS SURFACE MINES

	<u>Percent</u>	
	<u>Before Mining</u>	<u>After Mining</u>
Land reclaimed and released from bond under the 1968 Act (2,061 hectares)		
Agricultural crops	71	0
Pasture	12	86
Forest	15	1
Other uses	2	13
Land reclaimed and released from bond under the 1971 Act (4,196 hectares)		
Agricultural crops	61	19
Pasture	36	53
Other uses	3	28
Land reclaimed under 1975 Act (1,404 hectares)		
Agricultural crops	60	55 ^a
Pasture	13	29 ^a
Other uses	27	16 ^a

^aProjected land uses.

Source: Christy et al. (1979).

The steep slopes in areas of high rainfall promote erosion that both inhibits revegetation and may lead to siltation of streams. Establishment of the initial vegetation cover is not often so difficult as maintaining that stand. Landslides, which have occurred frequently in strip-mined lands in eastern Kentucky and West Virginia (Hill, 1971), further aggravate the problem of reclamation in Appalachia.

Techniques and practices are being developed that can be employed before and during mining operations to mitigate or eliminate adverse effects to Appalachia, and legislatures in these states are adopting stricter reclamation laws. In some instances, however, technology has not advanced to the point required to bring reclamation into full compliance (Powell et al., 1977). Nonetheless, a number of successful revegetation efforts have been carried out in Appalachia, including vineyards and pasture in eastern Kentucky (Hill, 1971).

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