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Washington, D.C. 20585

FOREWORD

Assuring the achievement of national environmental protection goals and advising the Secretary of Energy on conformance of the Department of Energy's activities with environmental laws requires ready access to a vast and varied information based on energy technologies, environmental quality, and natural resource management. While much of this information is available in various Government documents, some is not published, and the particular sets of information relevant to energy-environment assessments come from a number of different sources.

Environmental management debates, often conducted in a hurried atmosphere, initiate an immediate requirement for new analytical information for a particular topic under consideration. When a new subject is begun, the previously developed information is filed for later reference. Information assembled in this manner is generally not available in the open literature because it takes time and resources to organize information for purposes other than environmental management decision inputs. There is usually little incentive for taking the additional time and resources to transform the information for other users or develop it in a format for additional applications.

The Environmental Handbook Series is designed to overcome the deficiencies of information utility and transfer. Each of the works in this series brings together information in format useful to both public and private sectors. It serves as a basic reference document to enrich decision making and analysis of energy and the environment both inside and outside the Government.

To accelerate the availability of these handbooks, they are issued as periodicals, with early publication of prototypes followed by prompt publication of succeeding editions, incorporating users' comments. Accordingly, your comments on the content and overall utility of these handbooks are welcomed. The development and maintenance of the environmental media information handbooks is assigned to our Regional Impacts Division.

Peter House, Director
Office of Environmental Programs

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TABLE OF CONTENTS

LIST OF TABLES

(Sections 2 and 3)

LIST OF TABLES
(cont.)

LIST OF FIGURES

(Sections 2 and 3)

(Section 4)

See Sublistings as follows:

1. INTRODUCTION

The Nation's pursuit of energy independence through developing new energy technologies and enhancing the recovery and utilization of domestic energy resources has caused heightened concerns over potential conflicts with environmental quality. Rapid increases in domestic energy production may impose additional burdens upon the nation's air and water resources and cause changes in land use. In an attempt to identify and evaluate these potential conflicts, the Department of Energy's Assistant Secretary for Environment has instituted an environmental quality media program which addresses the potential impact of domestic energy development on air quality, water quality and availability, solid/hazardous waste management, and land use. This program is designed to provide readers with a general understanding of the issues associated with energy development and for the four environmental media, and to construct a data base from which estimates of potential future impacts can be identified and measured.

Specifically, this report addresses the land use impacts of past and future energy development and summarizes the major federal and state legislation which influences the potential land use impacts of energy facilities and can thus influence the locations and timing of energy development. In addition, this report describes and presents the data which are used to measure, and in some cases, predict the potential conflicts between energy development and alternative uses of the nation's land resources.

The topics section of this report is divided into three parts. The first part describes the myriad of federal, state and local legislation which have a direct or indirect impact upon the use of land for energy development. The second part addresses the potential land use impacts associated with the extraction, conversion and combustion of energy resources, as well as the disposal of wastes generated by these processes. For each fuel or energy resource in each phase of the fuel cycle, the discussion describes the kinds of land use impacts caused by development activity and qualifies the area of land required per unit of resource extracted, converted or burned. The third part of the topics section discusses the conflicts that might arise between agriculture and energy development as projected under a number of DOE mid-term (1990) energy supply and demand scenarios. The type of croplands likely to be affected and the magnitude of potential conflict are identified and assessed. Some of the major issues identified in this report are summarized below.

LEGAL TOPICS

Comprehensive national energy siting legislation inventories have never been undertaken at the federal level, and comprehensive land use legislation has never been passed. Thus, federal legislation affects energy facility siting through a number of individual laws. Laws designed to protect specific sectors of the environment (i.e., air quality, water quality) often regulate the indirect, off-site impacts of energy development. Others are designated to protect or preserve fragile lands such as wetlands or floodplains, and thus prohibit development in certain areas. The goal of the myriad of federal laws is to allow economic and energy development to proceed while ensuring adequate environmental protection. A number of these laws are pertinent to the problem of potential energy/land use conflicts. They include the National Environmental Protection Act, Clean Air Act, Federal Water Pollution Control Act, Coastal Zone Management Act, Wild and Scenic Rivers Act, and others.

Air quality legislation will have effects on energy development in terms of the emission limitations required for new facilities and in the possible restrictions on the location of new facilities. Nonattainment will likely have minimal effects on utility siting, but more significant impacts on industrial development and major fuel burning installations. Prevention of significant deterioration (PSD) designations have the potential for precluding some sites from use for energy development (Class I areas) or may limit the scale and co-location of new facilities (Class II areas).

Federal and state legislation in the areas of water quality and water use can produce conflicts with the use of land for energy-related activities and can impact the land use requirements of such activities. Possible conflicts include:

- Development may be precluded in an area, for example, on a stream that has been designated as a wild and scenic river.
- Development may be possible, but because of particularly strict requirements on effluents, it may be most reasonable to avoid development in an area; for example, development on streams that are water quality limited may entail extra expenses or difficulties in obtaining permits.
- Development may not be constrained, but legal constraints may influence the land required for certain activities; for example, land may be required for waste disposal areas or for cooling structures.

Another legislative constraint on land use, especially regarding energy development, is federal lands. The federal government owns and administers 760 million acres of land, one-third of the land area of the United States. Most of this land is concentrated in the western states and Alaska, where 30 percent to 90 percent of the land area in each state is under federal control. It has been estimated that 40 percent of the nation's coal reserves, 50 percent of the oil and gas fields, 80 percent of the oil fields, 40 percent of the uranium deposits and 60 percent of the geothermal fields lie beneath federal land. The recovery of these resources is directly dependent on federal land management policies. In addition, state and local governments have been active recently in attempting to assess their authority to impose land use controls on federal lands.

EXTRACTION

Estimates of the acreage potentially disturbed by coal surface mining or undermined by deep mining in 1990 range from 61,700 to 100,000 acres under different scenarios. In all cases, the greatest amount of land disturbed occurs in the Appalachians, the Central West and the Great Plains. Projected 1990 levels of land use for oil extraction range from 190,000 to 220,000 acres, while land use for natural gas is estimated to be 151,000 acres in 1990. As with oil, unless major changes in natural gas production occurs, changes in land use by 1990 will be minimal in comparison to 1975 levels.

The most serious environmental and health consequences of oil shale mining and conversion are due to the disposal of wastes. While some of the spent shale can be returned to the mine for disposal, the excess may be disposed of by filling in canyons or building mesas. By considering the conservative estimate of 40 feet average spent shale depth, the amount of land required for disposal would approach 600 acres per year which may not be trivial when considering the relatively small area in which oil shale production will occur. The issue, however, is not only the amount of area covered, but also the ability of the spent shale to be reclaimed. It is likely that the revegetation process will require irrigation to initiate and sustain coverage; irrigation may be severely constrained by the local water supply in this area.

COMBUSTION

The combustion of coal, oil, gas, and other fuels in stationary facilities to produce electricity, process steam, or space heat encompasses a wide range of facility characteristics and each may affect land use in a different way.

As with any industrial development, the direct consumption of land by utility and industrial combustors is highly variable, depending upon such aspects as land availability, location of coal and water resources and existing environmental conditions. Land usage patterns for electric utilities (particularly coal-fired utilities) are much more clearly pronounced than those of industrial combustion for energy production. Electric utilities generally require larger parcels of land and have greater water requirements than most industrial facilities. Also, the siting of industrial plants is dictated mainly by market factors, transportation networks, and availability of workforce.

AGRICULTURAL LANDS

Energy development can contribute to the loss of prime agricultural lands, both directly and indirectly. Direct effects include the pre-emption of agricultural land for utility sites, cooling ponds or reservoirs, mines, fuel processing and transportation facilities, electricity transmission corridors, and residential/commercial expansion to accommodate the new population attracted by energy jobs. The loss of agricultural lands to surface mining, especially those lands devoted to row crops, is a controversial issue. The likelihood of impacting prime agricultural lands can be high in some areas of the country. For instance, 40 to 50 percent of the strippable reserve base in many of the midwestern states may be covered by prime farmlands. In the West, many coal deposits and agricultural lands are found together in alluvial valleys; this conflict has yet to be resolved. In the East, this kind of conflict is less likely since much of the eastern coal is found in the mountains, well removed from farmlands.

Energy developments can also affect the productivity of croplands not directly removed by construction or mining. An important issue in the West is the competition for limited surface and groundwater supplies between farmers, who need the water for irrigation and livestock, and energy developments, that need the water for power plant cooling or coal washing. Coal mining can also affect water supplies by interrupting and destroying shallow aquifers which may supply irrigation or livestock water in some areas. In California and the Midwest, the possible effects on crops of sulfur dioxide (SO_2) emissions from fossil fuel-fired power plants have been of concern. Exposure to SO_2 can cause visible damage and decreased yield in many crop plants; soybeans, grains, non-citrus fruits, and many vegetable crops are particularly sensitive to SO_2. Hydrogen sulfide (H_2S) emissions from geothermal developments, primarily occurring in California, may cause similar problems. Transmission lines through croplands may also affect productivity. Although agricultural activities can usually continue in transmission right-of-ways, crop dusting and the use of most large farm equipment, including center-pivot irrigation systems, could be curtailed.

The use of biomass as an energy source will require that large acreages of land be devoted to crop production for energy uses. Millions of acres may be converted from other rural uses, and biomass production would consume far more land than any other energy activity. The direct impacts of this conversion are very small, however, since the land surface is not covered or destroyed as it is in the case of mining, drilling, the construction of conversion or combustion facilities, or solid waste disposal, and the use of common soil conservation and soil management practices should minimize the depletion of soil fertility that could result. Although national dependence on alcohol as a petroleum replacement is a long-term energy production decision, the decision to use a certain land area for energy purposes is essentially a short-term one that can be renewed annually when the crops are planted.

Section 3 of this report is a discussion of the data presented in Section 4. The data presented are arranged in four categories. The first category consists of national and regional maps and tables which describe the natural physical characteristics of land forms in the United States. The second group of data provides a current baseline description of the major uses of land in terms of agricultural uses, existing energy and minerals development, and urban uses. The data in the third category describes federal and state land management policies as reflected in national maps and in tables while the fourth group consists of tabular data specifying the land requirements for development of future fuel resources. None of the data sets contained in any of these categories are all-inclusive. Rather, the data presented represents a compilation of existing data that were available at the time of this printing. New data will be added as this document is updated.

Finally, the fifth section of this report is a glossary of terms and acronyms used to describe and measure land use impacts of energy development. Because legislation designed to protect other elements of the environment also impact land use, this glossary contains explanations of terms associated with air quality, water quality and quantity, and solid waste management.

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2. LAND USE TOPICS

It has been roughly estimated that the amount of land occupied by energy-related activities in the U.S. in 1975 was approximately 1.1 million acres or 1,762 square miles.[1] This estimate does not include abandoned surface-mined lands or those undergoing reclamation, nor the amount of land covered by hydroelectric reservoirs or devoted to transmission corridors. Adding these areas could triple the estimate given above, yielding a total area that accounts for about 0.1 percent to 0.2 percent of the land area in the continental United States. Comparing this estimate to the amount of land devoted to other uses in 1971,[2] one finds that energy-related activities occupied about the same amount of land as did airports or railroads, only one-seventh of the area occupied by highways, and only one-tenth of the area devoted to urban uses.

These kinds of comparisions can be misleading, however, since land use impacts are often much greater at the local level than national or regional comparisons might suggest. Land use changes associated with energy development can have a significant impact on the quality of the physical, social, economic and visual environment of the area surrounding the development, imposing costs and providing benefits to the local population that are not shared by the larger constituency which the energy development is meant to benefit.

A worst-case estimate of the land required for energy activities by 1990 indicates that an additional 18.6 to 57.7 million acres may be required for energy development.[1] While most of this acreage would be in croplands devoted to energy production, only 1.8 to 2.0 million acres would be in the more intensive uses that are more likely to cause adverse land use impacts. Land use conflicts may arise when a proposed use will preclude the continuation of the existing uses of the land, and when the existing uses are perceived to be irrecoverable, irreplaceable, and/or of more value than the proposed use.

The purpose of this section is to provide the reader with a general understanding of the existing or potential topics concerning the utilization of the nation's land resources for energy development. The section is divided into three subsections. The first subsection describes the myriad of federal, state and local laws that have a direct or indirect impact upon the use of lands for energy development. This subsection addresses also the effect of federal land management programs concerning the use of lands in the public domain on future energy activities. Major federal legislation that applies to potential land use impacts of energy development is discussed in this subsection and the kinds of state and local laws that might have a similar effect on land use decisions are described.

The second part of Section 2 addresses the potential land use impacts associated with the extraction, conversion, and combustion of energy resources, as well as the disposal of wastes generated by these processes. For each fuel or energy source in each part of the fuel cycle, the discussion describes the kinds of direct and indirect land use impacts caused by development activity and quantifies the area of land required per unit of resource extracted, converted, or burned, and per unit of waste generated. Finally, the amount and types of land (particularly agricultural) impacted by each activity in the past, and potential land requirements in the mid-future (1990) are estimated and discussed. Several energy-related activities are not discussed in detail in this report, most notably, transportation and transmission and the disposal of toxic substances. It should be noted, however, that the latter topic is emerging as an important environmental topic and could have significant land use implications.

Land requirements for the transportation and/or transmission of energy resources are not discussed in this report because growth in this sector is not anticipated to be significant in the mid-term (i.e. by 1990). Rather than building new transportation networks, it is anticipated that the capacity of existing networks will be augmented to accommodate increased loads thereby minimizing land use impacts. The third part of the section identifies the conflicts that might arise between agriculture and energy development as projected under a number of DOE mid-term (1990) scenarios. The types of croplands likely to be affected and the magnitude of potential conflicts are identified and assessed. Special attention is devoted to balancing the rate of land use with the length of use and recoverability of agricultural land reallocations.

CURRENT LEGAL TOPICS

Legislation that attempts to control land use changes has been developed at many levels of government. Land use planning and control have traditionally been the domain of local governments, and community zoning regulations or land use plans have often been developed that specify the general use for particular plots of land. Many states have enacted land use legislation, particularly for the protection of fragile lands and to guide local efforts. Certain classes of lands, such as wetlands and flood plains, may be limited by state or federal law to uses which do not destroy the natural functions of the lands. No general land use legislation yet exists at the federal level for lands not in the public domain, though a number of federal legislative interpretations exist which indirectly affect land use decisions.

Although comprehensive energy siting legislative inventories, as such, have never been undertaken at the federal level, and comprehensive national land use legislation has never been passed, federal legislation affects energy facility siting through a number of individual laws. Laws designed to protect specific sectors of the environment (e.g., air quality, water quality) often regulate the indirect, offsite impacts of energy development. Others are designed to protect or preserve fragile lands and thus prohibit development in certain areas. The goal of the myriad of federal laws and regulations is to allow economic and energy development to proceed while ensuring adequate environmental protection. A number of these laws are pertinent to the problem of potential energy/land use conflicts.

Water Legislation and Energy Development

Federal and state legislation in the areas of water quality and water use can produce conflicts with the use of land for energy-related activities and can impact the land use requirements of such activities. Both the actual siting and the rate of land use can be influenced. The purpose of this section is to identify and briefly discuss the state and federal legislation that can produce impacts on energy-related land use. The areas of water quality and water use are considered separately and general discussions of laws pertinent to land use and specific issues in each area are presented.

Water Quality Legislation and Conflicts

The relevant water quality legislation is primarily federal and involves two major laws: the Federal Water Pollution Control Act, as amended (popularly called the Clean Water Act) and the Safe Drinking Water Act. Both of these pieces of legislation impact, or have the potential for impacting, energy-related land use. The provisions outlined below either affect the amount of land required for energy development or constrain energy siting alternatives.

- *Increased Use of Land Needed to Meet Effluent Requirements.* Stringent effluent requirements result in a smaller amount of pollutants discharged to water bodies. The consequence is increased generation of solid waste and, therefore, larger solid waste storage areas. Land may also be needed for pollution control operations (e.g., evaporation ponds, sedimentation basins) or for cooling facilities. Zero discharge requirements increase these needs. Land use impacts should be similar in all parts of the country, although they may be influenced somewhat by climate (zero discharge will be more common in arid areas).
- *Restrictions on Energy Development in Water Quality Limited Areas.* The Clean Water Act requires that discharges not cause violations of ambient water quality standards. This fact may tend to restrict development in areas with serious water pollution problems, such as heavily industrialized river basins.
- *Restrictions on Energy Development in Areas of High Water Quality.* Most states' water quality standards contain antidegradation provisions that require

that existing use (e.g., drinking water supply) be maintained and protected. Antidegradation provisions could, if used, decrease the attractiveness of an area for development. Such impacts would be felt primarily in areas of high water quality.

- *Restrictions on Development Arising from Section 208 of the Clean Water Act.* Section 208 requires the preparation of area-wide waste treatment management plans. In principle, such plans could have the same impact on future development as zoning ordinances. However, conditions will vary from area to area and controls on development will only be as stringent as is desired locally.
- *Restrictions Associated With Protection of Drinking Water Supplies.* The primary impact of the Safe Drinking Water Act on the location of energy developments will be through the provision in the act for designation of sole source aquifers. The Safe Drinking Water Act allows the EPA to designate an aquifer that is the sole or principal source of drinking water for an area and that, if contaminated, would create a significant public health hazard as a sole source aquifer. The possibility of contamination of aquifers depends on the soil's leachate quality below an energy activity's waste disposal site. Following sole source designation, no commitment for federal financial assistance may be made for any project that may contaminate the aquifer so as to create a significant public health hazard. Numerous petitions for such designations are being received by EPA. The current sole source aquifers are:
  - Edwards Underground Reservoir, San Antonio, TX;
  - Fresno County, CA;
  - Buried Valley, NJ (East Orange);
  - Nassau and Suffolk Counties, Long Island, NY;
  - Biscayne, FL; and
  - Spokane and Rathrun Valley, WA.

Given the current public concern over the contamination of public water supplies, further restrictions on activities that impact water supplies, both above and below ground, seem likely. These restrictions will further control land use change.

Water Use Legislation and Conflicts

The issues of water availability and water allocation for energy activities are resolved at the state level. Water laws vary from state to state, and it is beyond the scope of this discussion to review conditions in each state. Water allocation law in the East is generally based on the riparian doctrine, in which a water right depends upon ownership of land along a body of water and in which each owner of such land has equal right to make reasonable use of water. In the West the basis for water law is generally the appropriation doctrine, for which the beneficial use of water is the basis of a right to water and for which seniority of use is the basis for dividing water among users when the supply is limited.

In certain areas of the West, water supplies are completely appropriated and the use of water for new activities will require transfer of water rights, which may be purchased. Arizona, North Dakota, and South Dakota have laws which restrict or possibly prevent transfer of water rights from irrigation to energy use. Montana has provisions that inhibit transfer to energy use. However, even where transfer of water rights is permitted, such transfer may not always be straightforward. Most of the appropriation doctrine states allow appropriation permits to be refused if the associated use is not within state and local guidelines. Also, the laws of some states contain provisions involving the maintenance of instream flows for protection of aquatic habitat and recreational and aesthetic values. All western states have some regulation in one or both areas. New industrial users of water will be facing increasing conflicts concerning water use in the West.

Federal legislation that impacts the utilization of water resources for energy development includes:

- *Rivers and Harbors Act.* Section 10 of this Act, which was enacted in 1899, requires the Army Corps of Engineers to issue a permit for any construction taking place in a navigable waterway. Power plants generally need such a permit in order to construct circulating water intake or discharge structures. The Act requires that the energy development's impacts on wetlands, historic resources, wildlife habitat, and coastal zones be considered prior to granting a permit for activities in navigable waters.
- *Wild and Scenic Rivers Act.* This Act vests in Congress the authority to designate certain rivers as wild and scenic. Once a portion of a river is so designated, it must be preserved in its natural state.

Development is generally prohibited on the shorelines of designated river beaches, and Section 1278(a) prohibits licensing of any hydroelectric facility that would affect such a river.

- *Coastal Zone Management Act.* This Act of 1973 creates a national policy dedicated to "preserve, protect, develop, and, where possible, improve coastal resources."[3] Coastal resources (which include both seacoast and Great Lakes shoreline) are generally defined as adjacent lands which directly affect or are affected by the coastal waters. Thirty states are included in this program, but their participation is strictly voluntary. Participating states may use federal funds to formulate a long-range management program for their coastal zones. Any utility that applies for a federal permit for a proposed facility in the coastal zone must demonstrate compliance with the state management plan. The construction of receiving terminals and other coastline facilities for off-shore, outer continental shelf oil and gas developments must also show compliance. Approximately 20 states now regulate development in certain coastal areas, especially in environmentally sensitive wetlands and estuaries. California, for example, has essentially banned all new power plants in coastal zones.[3] (Section 4 delineates programs by state).

The following executive orders also affect the energy-related uses to which a specified area may be allocated.

- *Floodplain Management Executive Order.* This Order prohibits federal agencies and businesses from building in the 100-year flood plain unless alternatives are unavailable.
- *Protection of Wetlands Executive Order.* This Order requires federal agencies to avoid construction activities on wetlands. In addition to the above legislation, federal control of water usage is extended to water allocation on federally owned lands. On Indian owned lands, the water is owned and allocated by the ruling tribe.

Air Quality Legislation and Energy Development

Air quality management policies in the United States have been established by statute, beginning with the Air Pollution Act of 1955 through the most recent amendments to the Clean Air Act, passed in August 1977.[4] The legislation and subsequent interpretations by the Environmental Protection Agency have set up a comprehensive scheme for management of national air resources. The pursuit of air quality can have significant impacts on industrial and utility siting patterns, on energy development, and on the use of land.

In accordance with congressional statute, EPA established National Ambient Air Quality Standards (NAAQS) for seven criteria pollutants—sulfur dioxide (SO_2), total suspended particulate (TSP), nitrogen oxide (NO_x), carbon monoxide (CO), photochemical oxidants or ozone (O_x, O_3), hydrocarbons (HC), and lead. States were required to prepare State Implementation Plans (SIPs) outlining proposed strategies for the attainment and maintenance of the NAAQS. The SIPs were to include a New Source Review program, permittng construction of only those new major sources where emissions would not cause or exacerbate a violation of the NAAQS. In areas where the ambient air is dirtier than the standards (nonattainment areas), the SIPs must include plans to clean up existing sources of emissions in order to achieve attainment, as well as restrictions on new sources. Nonattainment areas for five criteria pollutants are shown in Section 4.

Nonattainment will likely have minimal effect on utility siting, but more significant impacts on industrial development and major fuel-burning installations. Nonattainment areas for TSP, SO_2, and NO_x, the pollutants of primary concern to fossil-fuel combustion facilities, are typically small and localized in urban areas and/or existing industrial areas. Locating new industries or expanding existing plants in such areas may be difficult, depending on the ability of other sources to reduce emissions and make room for a new source of emissions. Utilities have more mobility and can more easily avoid locations in urban nonattainment areas.

In areas where the air is cleaner than the NAAQS, a set of standards has been established to prevent the significant deterioration (PSD) of air quality. Additional pollutants in these PSD areas are to be limited to specified amounts (or increments), calculated relative to a baseline air quality. Increments are a total addition to the pollutant load and cannot be exceeded. Increments have only been established for TSP and SO_2. PSD standards are required to be set for the remaining criteria pollutants, but they have not yet been proposed and might not use an increment approach.

Three classes of PSD areas are defined: an area can be Class I, or "pristine," with a minimal increment allotted (Class I areas are mapped in Section 4), Class II, with increments large enough to accommodate moderate economic growth (e.g., a 1000-MW coal-fired power plant with 85 percent reduction in SO_2 emissions could be built in a Class II area), and Class III, with increments for maximum growth. States have the legal right to reclassify areas, while Indian tribes retain the same reclassification rights for tribal lands.

PSD standards have been described as land use controls in disguise[6] because they have the potential for precluding some sites from use for energy development. Certain scenic areas (150 national parks and wilderness areas) are set aside as mandatory Class I, to be preserved as national treasures for future generations. In addition, the Clean Air Act Amendments declared the protection of visibility in 148 of these areas to be a national goal. An energy facility which is a major new source of airborne effluents could not locate within a Class I area or on the border of such a pristine area without violating the latter's increment.

Class II increments may limit the scale and co-location of new energy facilities. Energy activities that generate TSP or SO_2 may locate only in Class II areas that have PSD increments available for such development.

The designation of an area as in nonattainment or in attainment, governed by PSD rules, is made on a pollutant-specific basis. Thus, a new source of emissions might be reviewed under nonattainment rules for TSP and PSD regulations for SO_2. Although the determination of the attainment status of all states has been officially promulgated in the Federal Register,[5] as required by the 1977 Clean Air Act Amendments, the actual air quality in much of the country is unknown. For example, in Colorado, 90 percent of the counties have no valid data for SO_2 and 40 percent lack TSP data. Even in industrialized Ohio just under 50 percent of the counties are without SO_2 data and 30 percent lack valid TSP values. New sources may be unaware of the air quality status of an area chosen for a construction site.

State Siting Authority

Air quality management is particularly important in power plant siting decisions. In addition to the federal legislation on air quality, 25 states have adopted some form of power siting legislation.[7] These efforts focus almost exclusively on electric power plants, and have generally been limited to coal-fired electric generating and transmission facilities. As a result, a more detailed discussion of state siting laws, state mechanisms for implementing these laws and other state land use programs is presented in the third part of this section, which focuses on land use issues concerning the various fuel cycles associated with energy development.

Federal Lands and Energy Development

The federal government owns and administers 760 million acres of land, one-third of the land area of the United States. Most of this land is concentrated in the western states and Alaska (see map, Section 4), where 30 percent to 90 percent of the land area in each state is under federal control. The Bureau of Land Management (BLM) and the National Forest Service (NFS) are responsible for the bulk of the federal lands, with jurisdiction over 62 percent and 25 percent of the total, respectively.[8]

It has been estimated that 40 percent of the nation's coal reserves, 50 percent of the oil and gas fields, 80 percent of the oil fields, 40 percent of the uranium deposits,[9] 60 percent of the geothermal fields[10] and 70 percent of the oil shale deposits[11] lie beneath federal land. The recovery of these resources is directly dependent on federal land management policies. Additional reserves are indirectly affected due to problems of access or because of inability to conduct an economically viable mining operation without the inclusion of federally owned parcels of land. These problems may be especially acute in the West. For example, in the six western states that account for almost half the nation's coal reserves (North Dakota, Montana, Wyoming, Colorado, Utah, and New Mexico), 72 percent of the coal reserves in Known Recoverable Coal Resource Areas are federally owned. By comparison, the Federal Government owns the coal rights to less than 3 percent of the coal east of the Mississippi.[12] Ownership patterns in the West make if difficult to develop the 18 percent of the reserves that are nonfederal without requiring some federal land to make a mining unit that can be efficiently developed. In 1977, only 9 percent of the total 1977 coal production from these six western states came from mines that involved no federal coal.[12]

In addition to the control of resources on land, the 1953 Outer Continental Shelf Lands Act and its 1978 amendments grant the Federal Government jurisdiction over the lands in the Outer Continental Shelf (OCS) area of U.S. waters and the authority to lease those lands for resource development purposes. Thus, the Federal Government controls all of the resources of the OCS, which may include up to 60 percent of the nation's undiscovered oil and gas reserves.[13]

The large amount of energy resources effectively controlled by federal government is of concern for two reasons: (1) the timetable for development of these resources is directly dependent on federal leasing schedules; and (2) large amounts of federal land are being withdrawn from mineral development in the interest of preserving their wilderness values.

Federal Leasing

The leasing programs of chief concern for energy development are those involving coal and OCS oil and gas. Both programs are administered by the Department of Interior (DOI). Land use planning for energy development on the public domain is a cooperative effort between DOI and the Department of Energy (DOE). The coal leasing program has been recently (June 1979) reinstated as the Federal Coal Management Program, after a moratorium on new long-term leasing which lasted nearly ten years. Prior to 1970, DOI processed permit and lease requests for mineral exploration and mining (under the authority of the Mining Law of 1892 and the Minerals Leasing Act of 1920) on a case-by-case basis. Little consideration was given to the need for additional leasing or the potential environmental impacts of mining on the land to be leased,[12] possibly according to the historic precedent that minerals, which can only be mined where they are found, had priority over all other uses of the land.[14] By 1970, about 788,000 acres of federal lands were leased for coal production, but less than 10 percent of that land was producing coal. In order to allow DOI to develop a comprehensive planning system to determine the size, timing, and location of future coal leasing, a moratorium on new long-term leasing was announced. After several major revisions, the plan was accepted, with leasing to resume in January 1981. The new Federal Coal Management Program, as described in the final EIS, makes the decision to lease federal coal,

> "an integral part of the federal land planning process. Federal lands would be considered for leasing which have not been found unsuitable for coal mining or more valuable for resource protection or other development activities in the land use planning process of the federal land management agencies. In the activity planning process, tracts would be delineated, ranked on the basis of coal quality, cost, and environmental, social, and economic effects and selected for sale by regional coal teams. Regional leasing targets, derived from production goals submitted biennially by the Department of Energy and comments received from the states, industry, and the public, would be applied during the activity planning process to ensure that sufficient tracts would be ranked and selected to meet national energy needs."[12]

Selection of specific tracts of coal to be offered for lease and the administration of the lease sales are to be managed by BLM. Tract selection will probably proceed without the benefit of completed land use plans until 1985 or even later,[15] a necessary compromise if further expansion of production from federal coal leases is to continue past 1986. Since it generally takes 10-15 years lead time to bring a mineral deposit into production,[16] it is probable that coal from new leasing areas will not be available at least until 1990.

The assumptions implicit in timing lease sales to ensure achieving projected regional production goals are that the regional demand/production pattern used is the most desirable alternative of the vast array of demand/production patterns possible, and that a failure to meet the regional goals could result in a decrease in national coal production levels. However, as was pointed out in the final EIS for the coal management program, the most likely result of not attaining the projected regional goals would be that the patterns of coal development in the United States would be altered, and that, "on the basis of computer projection, it appears improbable that total national coal production would be greatly reduced."[12] It can be concluded, therefore, that the federal coal management program, though it may have local and regional impacts on coal development, could pose only a minor constraint to achieving mid-term national energy goals related to coal.

This may not be the case, however, for oil and gas development on the OCS, since it seems that the opportunity to shift the pattern of demand/production away from federally controlled deposits is smaller than with coal. Since as much as 60 percent of the nation's undiscovered oil and gas may occur in the OCS area, there are fewer domestic alternative sources available if OCS development is curtailed. On the other hand, mid-term OCS energy production is expected to be small compared to demand.[13] The real impact of delayed federal leasing of OCS lands is thus hard to determine.

The Example of Oil Shale[11]

The oil shale lands of Colorado, Utah, and Wyoming are largely owned by the United States, about 8 million acres (72 percent of the area considered to be suitable for commercial development) being public lands (Figure 2.1). These lands, which are administered mainly by the BLM, contain 80 percent of national oil shale reserves and 81 percent of the higher grade deposits. The remaining oil shale lands are owned by private interests, by Indian tribes, and by the states. The privately owned lands consist partly of patented mining claims, chiefly along outcropping oil shale deposits, and partly of valley lands acquired under the homestead laws.

In Utah, ownership of the oil shale lands is complicated by a decision on August 8, 1978, by the United States Court of Appeals, Tenth Circuit, to award to the state of Utah 157,256 acres of public lands "in lieu" of grants for school lands that had been denied to Utah because of acquisition of federal reservations or by private entry under the homestead laws. For this award, Utah selected parcels of land in Uintah County that include the U-a and U-b Prototype Oil Shale Lease tracts. A petition for a rehearing on this decision was denied on 6 December 1978, but the Justice Department has further petitioned the Supreme Court to review the decision. In 1979, the state of Colorado made a similar claim to public lands in the Piceance Creek Basin.

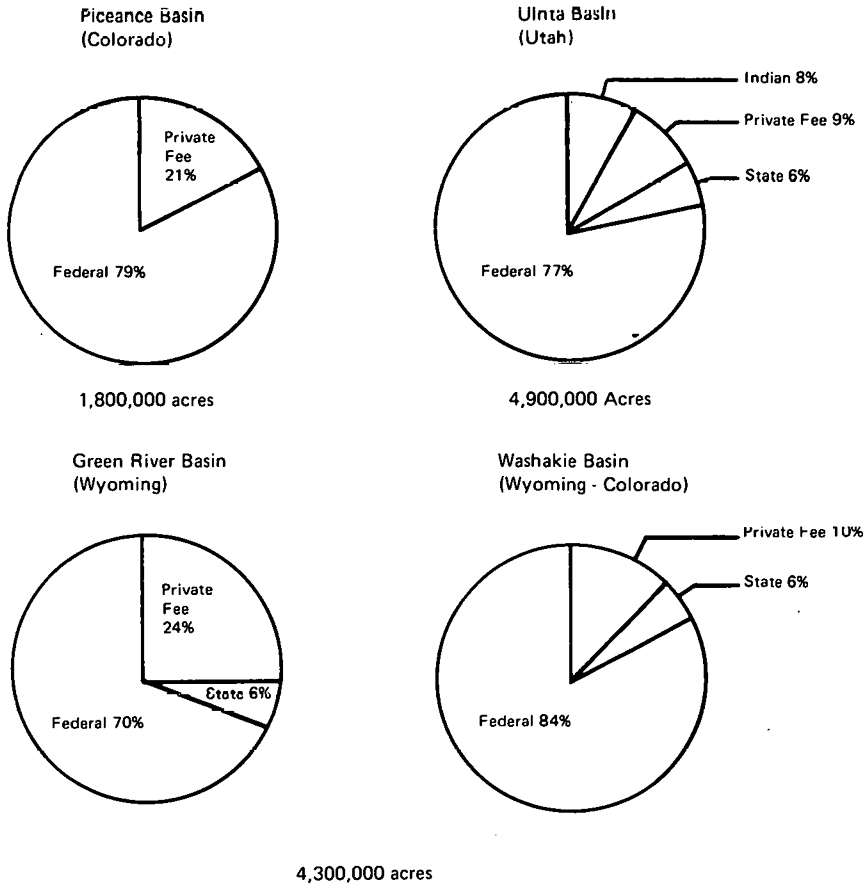
The complexity of oil shale development and management is increased by the existing patchwork of federal, state, and private ownership. Because surface rights are necessary in planning for roads, building sites, and other development activities of a regional character, consolidation of holdings in some areas may be desirable in order to delineate economic blocks of oil shale resources. In this circumstance, equitable exchange of private and public lands has been suggested as a means of consolidating some commercially sized tracts, possibly through exercise of Section 206 of the Federal Land Policy and Management Act of 1976, P.L. 94-579. The BLM in 1979 implemented procedures to make such exchanges.

Public Lands Withdrawals

The prospects of closing large amounts of land to mineral development—areas being considered for wilderness designation by NFS and BLM and the designation of 15 large new national monuments in Alaska, for example—have made the potential energy consequences of public land withdrawals a topic of great concern. In early 1979, NFS, which already had 12.9 million acres in wilderness areas,[17] was nearing the end of the first stage of their review of 62 million acres of RARE II lands (Roadless Acres Review and Evaluation, Survey II) for possible designation as wilderness. BLM had nearly 175 million acres under study for the same purpose. President Carter had just created 56 million acres of new national monuments (closed to mineral development) in Alaska, and the 96th Congress was considering legislative proposals that would withdraw 100-125 million acres of Alaskan land from mineral exploration and development. In addition, BLM's responsibility is to identify areas unsuitable for coal mining, which could have removed yet more acreage from production. If all this land was withdrawn from development it would have nearly doubled the amount of federal land closed to the exploration and development of energy resources. A number of reports issued at that time estimated that 60 to 65 percent of the public lands were totally or partially closed to development.[14,16,18,19] Further, these estimates did not take into account the fact that the designation of a number of offshore sites as marine sanctuaries to protect them from OCS leasing was also being considered. Returning to the figures listed in the introduction to this section, this could mean that 24 percent of the nation's coal, 30 to 48 percent of the oil, 24 percent of the uranium, and 36 percent of the geothermal resources could not be recovered unless the wilderness designations were repealed.

Figure 2.1

Federal Ownership of Oil Shale Lands in Colorado, Utah, and Wyoming as of 1968



Source: *Surface Mining of Non-Coal Minerals,* "Appendix II: Mining and Processing of Oil Shale and Tar Sands," National Academy of Sciences, 1980.

By June 1980, the initial phases of the NFS and BLM studies were completed and a large proportion of the areas originally under study were determined to be nonwilderness, thus opening those lands to mineral development. Congress is debating the Alaskan lands bills, and BLM has modified its unsuitability criteria for coal development deleting the prime farmland and reclaimability criteria because of potential difficulties in application. However, a large number of acres are still under study or have been recommended for wilderness designation. The amount of land presently withdrawn from development, excluding the acreage covered by the Alaskan Lands Bill now under debate, is summarized in Table 2.1. The 282 million acres indicated in the table represent 37 percent of the nation's public lands. The simplistic assumption that 37 percent of the federally controlled resources would thus be rendered unavailable would lead to estimates that about 15 percent of the nation's coal, 19 percent to 30 percent of the oil, 15 percent of the uranium, and 22 percent of the geothermal fields are locked up on withdrawn lands.

RARE II

In January of 1979, NFS recommended that 15.5 million of the 62 million acres of RARE II lands be designated as wilderness, while 10.5 million acres were to be studied further for possible wilderness designation by 1985, and 36 million acres were released for non-wilderness use.[20] Areas recommended for wilderness are closed to energy resource exploration and extraction unless those activities exist under some prior right. The 10.5 million acres of further study areas are open to oil and gas exploration, but no resource development is permitted until studies are completed. The impact of these withdrawals on energy resource availability was of particular concern in the oil and gas rich Rocky Mountain Overthrust Belt. However, though reserves of 1.5 to 8.8 million barrels of oil and 6 billion to 51.5 trillion cubic feet of natural gas are estimated to occur under RARE II lands in the area, 95 percent of the area is still open for resource exploration and extraction.[20]

BLM Wilderness Area

By mid-1979, BLM had completed its initial inventory of more than 175 million

Table 2.1

Federal Acreage Withdrawn from Mineral Uses as of June 1, 1980 (millions of acres)

Government facilities and installations not open to public entry	34.4[a]
National park service lands	25.1[b]
Fish and wildlife refuges	30.3[b]
Wilderness areas in national forests	12.9[c]
Wild and scenic rivers in national forests	0.3[c,d]
RARE II lands recommended for designation as wilderness	15.5[e]
RARE II lands under further study	10.5[e]
BLM potential wilderness study areas	57.0[e]
1978 designation of Alaskan national monuments	56.0[e]
20-year withdrawal of Alaskan lands	40.0[e]
TOTAL	282.0

[a]Source: *Federal Register,* Vol. 45, No. 98, Monday, May 19, 1980.
[b]as of June 30, 1975.
Source: U.S. DOI, Bureau of Land Management, *Public Land Statistics 1976,* U.S. GPO, Washington, D.C. (no date).
[c]As of Sept. 30, 1977.
Source: USDA, Forest Service, *Land Areas of the National Forest System as of September 30, 1977,* File 1380 (54]]), February, 1978.
[d]Additional wild and scenic river acerage can be found outside of national forest lands.
[e]See text.

acres of roadless areas under its jurisdiction and released 113 million acres that "clearly and obviously" lack wilderness values to multiple use management. By December, over 117 million acres had been dropped from the study.[21] These decisions drastically reduced the amount of public land withdrawn from development. Some of the remaining 57 million acres of potential wilderness study areas may also be released after a more intensive inventory that is due to be completed in the western states by October of 1980. As of June 1979, this second inventory stage involved 21.8 million acres in Nevada, 9.3 million in Utah, 8 million in California (including the 6 million acre California Desert Conservation Area on which the intensive inventory has already been completed), 6.8 million in Oregon, 5.6 million in Arizona, 3.7 million in Idaho, 2.7 million in Montana, 1.9 million in New Mexico, 1.2 million in Colorado, 1 million in Wyoming, and 0.14 million in Washington.[22] This acreage represents 30 percent of the BLM lands and 13 percent of the federal lands in the seven western states with major energy resources (Arizona, California, Colorado, Montana, New Mexico, Utah, and Wyoming).[23] Land assessment in other areas has been delayed by ownership questions, particularly in the Northeast and Minnesota.[24]

The management policy for the areas still under study is to "continue existing uses or allow new uses wherever possible and to conclude the period of study and uncertainty as rapidly as possible."[25] Activities causing long lasting or permanent effects are prohibited in the study areas, though mineral uses and mining claims that existed as of October, 1975 may continue even if they cause permanent impacts that impair wilderness suitability.[18] Oil, gas, and mineral exploration are allowed if the areas disturbed by these activities, including access routes, are reclaimed.[25]

The potential effect of the BLM land withdrawals on the future availability of energy resources is not known, though the figures cited above indicate the potential magnitude of the impact. Top priority is being given to the review of areas where there are potentially major conflicts between wilderness and other uses, particularly energy development. DOI expects that the total review will be done before the 1981 deadline set by Congress.[18]

Alaskan Lands Bill

As of June, 1975, the Federal Government owned 352.4 million acres of land in Alaska, more than 96 percent of the state.[23] At that time most of the land was under the jurisdiction of BLM, and thus, was probably open to mineral exploration and development subject to existing native claims. Since that time, 5.2 million acres were included in a three-year emergency withdrawal in late 1978 and 56 million acres were withdrawn by President Carter's 1978 action creating 15 new national monuments in Alaska. The Congress has been debating for three years over legislation to balance the preservation of this fragile frontier through inclusion in the National Forest, Park, Wildlife Refuge and Wild and Scenic River systems with the right of Alaskans to control a substantial part of their own state and the national need for some of Alaska's oil, mineral, and timber reserves. Faced with Congressional inaction, Interior Secretary Andrus withdrew from state selection 40 million acres in November, 1978 by invoking the authority granted him by the Federal Lands Policy Management Act of 1976.[1] This acreage is preserved from development until legislative guidance is provided.

On May 15, 1979, the House bill set aside 110 million acres of land[26] (other sources report 125 million[24] and 127 million[18]), of which 67 million acres would be designated wilderness, precluding energy development. The Senate, on August 19, 1980, amended the House bill, now titled the Alaska National Interest Lands Conservation Act. This measure would put more than 56 million acres under wilderness protection, prohibiting any kind of mineral or other development, and another 49 million acres would receive lesser degrees of protection that would allow limited oil and gas extraction and mining. A compromise has not yet been reached to manage land use changes in this vast area of public domain.

Indian Lands and Coal Production

The largest contiguous blocks of nonfederal coal found in the West are those owned by the Indian tribes (see maps in Section 4). Approximately 70 billion tons of coal, 30 billion tons of which are surface-minable, are found under Indian lands. This represents one-third of the western coal reserve base, although production from Indian coal land in 1977 accounted for only 14 percent of total western production. Of the 22.9 billion tons of Indian coal mined in 1977, 80 percent came from the Navajo lands in Arizona and New Mexico. The remaining 20 percent came from the Crow and Cheyenne reservations.

The most important Indian coal owners are the Navajo tribes in New Mexico and Arizona (5 billion tons), the Crow and Cheyenne tribes in Montana (15 billion tons; individual tribe ownership data not available), and the Three Affiliated Tribes in North Dakota (3 billion tons). The Southern Ute, Ute Mountain, Jicarilla, Flathead, and Blackfeet tribes control another 5 billion to 7 billion tons of reserves. The Navajo, Crow, and Three Affiliated Tribes have all indicated an interest in developing their coal reserves. The largest uncertainties about future development of Indian coal center on the 15 billion tons of reserves in Crow and Cheyenne lands. The Cheyenne do not wish to develop their coal reserves at this time, and legal battles between the Crow tribe and previous purchasers of leases and holders of prospecting permits make the future development of this coal uncertain.

State and Local Control of Energy Development on Federal Lands[27]

In anticipation of the potential adverse impacts of energy development on federal lands in the western U.S., traditionally pro-development western state and local governments have demanded a greater role in the federal policymaking process[28] and have passed laws which place greater restrictions on mineral development than have federal controls. For example, in addition to federal legislation designed to control the environmental effects of strip mining, several states have enacted considerably more stringent laws which purportedly apply to federal lands.[29] Similarly, state and local governments have actively asserted their authority to impose land use controls on federal lands. And in *Ventura County v. Gulf Oil Corporation,* recently decided by the Ninth Circuit Court of Appeals and currently on appeal to the U.S. Supreme Court, a local government sought to enforce its zoning ordinances against an energy developer using federal lands.

The property clause of the Constitution gives Congress the power to pass laws affecting territory owned by the Federal Government.[30] Although the states can also pass laws which restrict activities on federal lands,[31] federal laws will preempt conflicting state regulations where Congress has supplied a "clear manifestation" of its desire to supersede state law.[32] Relying on the property clause, Congress has passed several statutes authorizing the development of energy resources on federal lands.

In *Ventura County v. Gulf Oil Corporation,* the Ninth Circuit Court of Appeals held that energy development policy, as codified by the Minerals Lands Leasing Act, prohibits a county from requiring a private energy developer on federal land to obtain a use permit before engaging in energy development under a federal lease. The defendant, Gulf Oil, had obtained a federal lease executed by the BLM to drill for oil on national forest land and had received the necessary permits for the NFS and the Geological Survey. After drilling had begun, the county advised Gulf that its zoning ordinance required Gulf to obtain a conditional use permit by 11 conditons before Gulf could continue drilling on the site. When Gulf refused to obtain a permit, the county sued for a declaratory judgement that Gulf was subject to the ordinance, and for an injunction suspending operations until Gulf obtained the permit from the county planning commission. The district court denied both requests and the Ninth Circuit affirmed, holding the imposition of the county permit requirement on a federal lessee would impermissably substitute local policy for the extensive federal scheme for energy development emobdied in the Mineral Lands Leasing Act, rejecting the county's argument that Section 32 of the Act saved its land use ordinances from pre-emption.

The court's conclusion, however, avoided the question of whether the use of federal lands by private energy developers in ways that violate state and local laws has actually been sanctioned by federal legislation. The Federal Land Policy and Management Act of 1976 (FLPMA), which was superimposed on the basic procedural mechanism of the Mineral Lands Leasing Act, may show increased deference to non-federal regulation.

FLPMA consolidated hundreds of public land statutes previously scattered throughout the United States Code. It represents the first time the powers and duties of the BLM have been spelled out by legislation, requiring the Secretary of Interior to develop, maintain and revise land use plans for public lands and instructing the Secretary to manage the public lands according to these plans. FLPMA directly affects two kinds of state and local restrictions of energy development on federal lands—pollution control and land use requirements.

Pollution control laws and restrictions, as described previously in this report, are important direct controls that state and local governments may wish to impose on energy developers using federal lands. FLPMA stipulates that the push for energy development on federal lands may not interfere with nonfederal pollution control efforts. Section 202(c)(8) of the Act declares that "in the development and revision of land use plans, the Secretary shall...provide for compliance with applicable pollution control laws, including State and Federal air, water, noise, or other pollution standards or implementation plans."[33] By this language, FLPMA appears to demand application of state and local pollution control laws to federal lessees.

By contrast, the enactment of FLPMA does not require federal planning to follow all state and local use plans. Land use requirements enforceable against federal lessees would give state and local governments more control over the location, size, and operation of energy developments on federal lands than would the narrower tools of pollution control—ambient pollution standards and effluent limitations. But while Section 202(c)(9) requires the Secretary of the Interior to provide for "meaningful" involvement by state and local officials, BLM plans need only be "consistent with State and local plans to the maximum extent the Secretary finds consistent with Federal law and the purposes of the FLPMA."[34] Thus, the possibility of conflict between federal and nonfederal plans was recognized, and the Secretary of Interior was given the discretion to preempt state and local land use plans inconsistent with federal energy development schemes. But Section 202(c)(8)'s mandatory incorporation of nonfederal pollution control laws limits the Secretary's discretion.

Consequently, state and local land use laws will more clearly be enforceable against federal lessees if they are drafted to explicitly identify pollution control as one of their major goals. For example, the county in the Ventura case might have had more success in court had it stressed the pollution control motivations of the land use restrictions it sought to enforce against Gulf. Although the ordinance imposed pollution conditons relating to soundproofing, waste disposal, and runoff protection,[35] these provisions were submerged in a zoning ordinance which contained other more general land use provisions probably inapplicable to federal lands.

Additional Federal Regulations Affecting Energy-Related Land Use

National Environmental Policy Act (NEPA)

NEPA, which became law in 1970, is considered landmark legislation because it introduced environmental considerations into the governmental decision-making process. One of the many mandates of this far-reaching law is the preparation and review of EISs for all proposed projects that will utilize federal funds. The EIS must assess all aspects of the proposed action, including:

- environmental characteristics of the site;
- description of the facilities;
- environmental impacts of the activity;
- socioeconomic impacts;
- alternatives; and
- unavoidable adverse impacts.

The draft EIS must be reviewed by several state and federal agencies and finalized through a series of hearings. Through the EIS process, NEPA has provided a statutory basis for opposition to the development of energy facilities. It also affects the facility siting process by enjoining a proposed project until all requirements of the Act have been fulfilled. These requirements include an analysis of the impacts on land resources and require that environmentally preferable alternatives must be identified and discussed.

Endangered Species Act

Under the Endangered Species Act of 1973 (Public Law 93-205), all federal agencies are required to cooperate in the conservation of endangered and threatened species. Section 7 of the Act states that:

> "The Secretary (of Interior) shall review other programs administered by him and utilize such programs in furtherance of the purposes of this Act. All other Federal departments and agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance

of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to Section 4 of this Act, and by taking such action necessary to insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of such endangered and threatened species or result in the destruction or modification of the habitat of such species which is determined by the Secretary, after consultation as appropriate with the affected States, to be critical."[36]

Mechanisms have been implemented for determining land occupied by "critical habitats"; modification of a critical habitat has been redefined to "adverse modification"; and these concepts have been qualified and quantified for enactment of this legislation.

Resource Conservation and Recovery Act

This legislation, enacted in 1976, provides for the control and management of solid and hazardous waste disposal. It mandates the EPA to promulgate standards relating to the generation, transportation, treatment, storage and disposal of hazardous wastes in order to protect health and the environment.

Recently, the EPA classified fly ash, bottom ash, slag, and flue gas emission control wastes resulting from the combustion of fossil fuels as nonhazardous. Utility wastes, therefore, are currently exempt from RCRA hazardous waste regulations.[37] In light of the characteristics for identifying hazardous wastes, however, this nonhazardous classification of utility waste may be subject to future change.

The RCRA specifies four criteria for identifying hazardous waste: ignitability, corrosiveness, reactivity, and toxicity.[37] Some portions of utility solid wastes may exhibit one or more of these characteristics, particularly toxicity. If the classification of these wastes is changed to hazardous, they will be subject to the provisions relating to hazardous waste disposal facilities. The land use effects of reclassification of energy-related wastes from nonhazardous to hazardous would be increased land consumption for permanent waste disposal sites and the possible prohibition on using certain lands for disposal that have high leachate qualities. Additional locational restrictions in RCRA are that hazardous waste disposal sites shall be located on land with a low alternative use value, must be more than 200 feet from public roads, and shall not be located in "critical habitat areas" of endangered species, unless it can be ascertained that the species will not be further endangered.

RCRA seems to have a contradictory influence on energy siting decisions. Remote sites (especially those in the semi-arid West) look attractive in view of the site exclusionary criteria listed above. However, to successfully satisfy Section 5003, which deals with the recovery of waste materials, disposal facilities must be located near their markets, since major waste products are heavy and, therefore, expensive to transport and yet bring a small return in dollars.[38] RCRA may increase the cost of siting energy facilities on sandy soils as opposed to those on or near clay soils due to the potential leachate migration from waste facilities. RCRA may also increase the attractiveness of western coal which has lower sulfur and ash contents and thus less waste handling problems.

Atomic Energy Act/Energy Reorganization Act

The Atomic Energy Act established the Nuclear Regulatory Commission (NRC) to license and promulgate guidelines for locating and operating nuclear power plants. The Energy Reorganization Act gave the NRC sole responsibility for regulating the nuclear energy industry. It requires a two-step licensing procedure for nuclear power plants, consisting of a construction permit and an operating license, both to be obtained through the NRC. These license guidelines affect land use by this industry both in land requirements and site suitability as discussed in the next section.

TOPICS ASSOCIATED WITH FUEL CYCLES

The first subsection of the issue report discussed land use topics which tend to impact energy development in a generic sense. That is, the issues identified can be related to most any energy technology and most any phase of the fuel cycle associated with a specific technology. For example, the discussion of state and local participation in energy developments on federal lands is relevant regardless of the type of energy development that may occur on these lands. However, it is obvious that particular energy technologies will have, or have had, a greater impact on land use than others. And, more specifically, different phases of the fuel cycle associated with a particular technology will have, or have had, greater impact on land use than other phases.

The purpose of this subsection is to identify and assess land use topics associated with specific energy resources and specific cycles associated with developing these resources. Essentially, an analytical approach is presented in which several energy systems are broken down into their parts, i.e., extraction, conversion, combustion, etc. These subsystems are then analyzed to determine the major land use impacts that have been experienced in the past and may be expected to occur in the future as products of alternative DOE energy supply and demand scenarios.

The result of this analysis are summarized in Tables 2.2 and 2.3 and discussed in detail below. For each fuel or energy source in each part of the fuel cycle, the discussion describes the kinds of direct and indirect land use impacts caused by development activity and quantifies the area of land required per unit of resource extracted, converted, or burned, and per unit of waste generated. Finally, the amount of land impacted by each activity in the past and potential land requirements in the mid-future (1990) are estimated and discussed.

Coal Systems

Extraction: Surface and Deep Mining

Land Requirements

The amount of land disturbed by coal mining depends on the mining method used, the thickness of the coal seam, and the density of the coal. The mining method, either surface or underground, determines the recovery efficiency, which ranges from 50 percent for underground room and pillar mines to 80 or 90 percent for surface mines. Extraction of thick seams disturbs less land

Table 2.2

Estimated Area Occupied by Energy Activities in 1975, as Calculated in Text

Fuel Cycle Element	Estimated Area (acres)	Comments
Extraction[a]		
Coal	51,400	Disturbed by surface mining in 1975
Oil	196,700	
Natural Gas	179,000	
Uranium	2,700	Disturbed in 1975
Geothermal	3,600	
Conversion[a]		
Uranium	154,300	Milling, conversion, enrichment, fuel fabrication, and nuclear power plants
Oil Refineries	327,400	
Hydro	not estimated	
Synfuels	300	Pilot plants
Combustion		
Utilities	175,000	Coal- and oil-fired power plants
Solid Waste		
Utilities	30,900	Lifetime disposal area requirement
Industrial	6,300	Lifetime disposal area requirement
Total	1,127,600	Does not include land requiring or undergoing reclamation; land covered by hydroelectric reservoirs; land devoted to activities not listed here.

[a]Assume no land devoted to oil shale, biomass.

Table 2.3

Estimated Additional Area Required for Energy Activities by 1990, Assuming High Level of Production in Each Element

Fuel Cycle Element	Estimated Additional Area (acres)	Comments
Extraction		
Coal	1,007,400	Surface mining only; cumulative requirements 1975-1990
Oil	23,000	
Oil Shale	4,000-16,500	For shale disposal; assume 0 in 1980, with linear increase to 1990
Natural Gas	3,000	
Uranium	18,100-36,000	Cumulative requirements 1975-1990
Geothermal	60,000-241,000	Extrapolate 1990 estimate from 1985 and 2000 estimates
Biomass	16,880,000-55,740,000	Grain for ethanol; 17 state central region only
Conversion		
Uranium	353,500-363,300	New mills, fuel fabrication facility, power plants
Oil Refineries	10,330	
Hydroelectric	not estimated	
Synfuels	24,000	Coal to gas or liquids
Oil Shale retorts	1,200	
Biomass	21,000	Ethanol from grain; to produce 5.4 billion gallons/year
Combustion		
Utilities	110,400	New coal- and oil-fired power plants
Solid Waste		
Utilities	103,300	Lifetime disposal area requirements
Industrial	24,500	Lifetime disposal area requirements
Total	18,647,000-57,719,000	Worst case estimate: assumes attainment of highest projected energy production levels
(without biomass)	(1,767,000-1,979,000)	Reported for each fuel and stage of fuel cycle

per ton of coal mined, than does the mining of dense deposits. Surface mines will disturb 21 to 86 acres per million tons of extracted coal in the West where seams are thick and recovery is high, 131 to 277 acres per million tons in the Appalachians and the Midwest, where seams are thinner, and up to 400 acres per million tons in the central states. All surface mines will require additional acreage for storage of topsoil and of overburden from the initial cut, for facilities, and for haul roads. Where traditional contour mining is practiced (i.e., the Appalachians), casting the overburden soil downslope can disturb one acre for every acre mined. The more stringent reclamation laws now in effect will probably ensure that most overburden will be replaced in previous cuts in the future. In underground mining, head-of-hollow fills (filling small, natural valleys creating flat land) are often used for disposing of excess overburden where topographic conditions are favorable.

The 50 percent recovery ratio given for underground mines reflects the fact that large amounts of coal must be left in place ("sterilized") to prevent collapse of the mine roof and an associated subsidence of the surface. Although numerous precautions are taken, and mandated, to prevent subsidence, the corrosion of mine pillars over time may weaken the support and cause subsidence many years after mining has ceased. The timing and likelihood of subsidence is hard to predict. It has been estimated by the Bureau of Mines that 23 percent of the land undermined for coal has subsided. Thus, the actual amount of land affected by subsidence is only a small fraction of the area undermined using conventional methods. If longwall mining methods are used, however, almost all of the area undermined will subside, but the greater recovery efficiency of this method (80-85 percent)[10,42] means that less area is undermined. Subsidence has the potential for causing the greatest land impacts in highly developed areas but may also affect agricultural land uses by altering drainage patterns.

The cleaning of coal mined underground generates large quantities of waste rock and coal. Wastes from cleaning surface-mined coal are often returned to the open pit, but wastes from cleaning underground coal are usually not returned to the mine workings. Little coal is cleaned in the West, where coal sulfur content is lower, but in the Appalachians 50 to 99 percent of the coal mined underground is cleaned, and almost half a ton of refuse is generated for each ton of clean coal. In the past, these wastes were deposited in unsightly refuse banks which were usually not revegetated. Present restrictions require planned disposal of these wastes, which may be deposited in head-of-hollow fills or other designated sites. The amount of land required for waste disposal is determined in large part by the type of disposal method used and the height of the waste pile. A 1972 Bureau of Mines study[40] on coal refuse fires tabulated data on waste pile size and volume, and determined that 214.6 million cubic yards of refuse were contained in waste piles covering a total of 2584 acres throughout the U.S. At an average refuse density of 100 lbs/cu ft,[41] this converts to a land requirement of 8.9 acres per million tons of refuse. It is doubtful that this estimate will apply to refuse dumped in head-of-hollow fills, where topographical considerations make area estimates very difficult.

Estimates of the acreage potentially disturbed by coal surface mining in 1990 range from 61,700 to 100,000 acres under different scenarios. In all cases, the greatest amount of land disturbed occurs in the Appalachians, the Central West, and the Great Plains. Deep mining may undermine an additional 118,000 to 149,00 acres of land, in that year, with the greatest areas affected in the Appalachians and the Midwest.[1]

Estimates of the acreage disturbed over the period 1975 to 1990 can be based on assuming a linear increase in production from 1975, when the national production was 648.4 million tons, to 1990. Assuming the same patterns throughout the period as are predicted in 1990, estimates of the amount of land potentially affected by mining range from 732,000 to one million acres for surface mining, and 1.4 to 1.5 million acres undermined. Table 2.4 provides regional projections for surface mining and their associated land use impacts.

Potential Land Use Conflicts

The kinds of land uses likely to be affected by surface mining are estimated in the preliminary results of a DOE-funded land use study being performed at Argonne National Laboratory using a scenario that projects an annual production of 2 billion tons by the year 2000.[43] About 1.4 million acres of land would be surface-mined between 1975 and 2000 nationwide under this scenario; 2.5 million acres may be undermined; and about 25,000 acres (almost all of it east of the Mississippi) would be required for coal cleaning waste disposal.[43]

Forest is most likely to be disturbed in the Appalachians and parts of the Midwest; cropland is most likely to be disturbed in the Midwest, North Dakota, and parts of the Central West; and rangeland will probably be most heavily affected in the West. The greatest impacts due to underground mining may occur in the Midwest, where land uses sensitive to subsidence, i.e., cropland, are likely to be undermined.

Legal Topics

Surface mining activities remove surface vegetation, disturb the soil, and change existing topography and surface and subsurface drainage patterns. Adjacent lands not directly disturbed by the mining may be affected by sedimentation, acid or alkaline drainage from dust and noise from mining equipment and blasting, and/or a disruption of groundwater supplies. The Surface Mining Control and Reclamation Act which regulates surface mining on private and public lands and prohibits mining on critical lands is designed to minimize the potential adverse effects of surface mining by requiring reclamation and imposing stringent pollution control requirements. Additionally many states have more stringent state reclamation laws. Thus, mining should be a temporary use of the land. Reclamation of croplands will probably take 5-6 years; rangelands, since they occur in the more arid regions of the country, may require more than 10 years for reclamation; and forests will take 20-30 years or longer to develop after mining and revegetation.[43] The likelihood of restoring premining pro-

Table 2.4

Estimates of Acreage Disturbed By Surface Mining - 1990 and 1975 - 1990

		LPDO Scenario[b]				EIA Scenario[a]	
		Low		High			
	Acres Mine per 10^6 tons[a]	Production[b] (10^6 tons)	Area Mined (acres)	Production[b] (10^6 tons)	Area Mined (acres)	Production[b] (10^6 tons)	Area Mined (acres)
Appalachia	184	96.4	17,738	101.0	18,584	137.2	25,245
Midwest	148	44.6	6,660	45.5	6,734	39.4	5,831
Central West	323	65.9	21,285	107.7	34,787	78.9	25,485
Great Plains	41	291.1	11,935	799.6	32,784	527.8	21,640
Rest of West	66	62.7	4,138	100.9	6,659	31.8	2,099
National Total		560.4	61,696	1154.6	99,548	815.1	80,300
Estimated Cumulative, 1975 - 1990		6,648	731,715	11,684	1,007,426	8,819	868,846

[a]Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.
[b]DOE/RA-0009, October, 1978

ductivity levels is still under question, and not all surface-mined lands are returned to their original use. Forests, for example, have often been replaced by pasture lands in the Midwest,[44] and flat lands suitable for urban and industrial development are often preferred over the original wooded mountainous topography in the Appalachians.

In addition to surface mining reclamation laws, states also may have strict underground mining regulations. For instance, extensive urbanization has often occurred over abandoned underground mines in Pennsylvania which now has strict mining controls and an active backfilling program to alleviate the potential damage caused by subsidence.[45]

The 1976 Resource Conservation and Recovery Act (RCRA) restricts the disposal of solid and hazardous wastes. Presently, the solid waste produced by coal cleaning is classified by EPA as nonhazardous. Coal cleaning wastes are now being landfilled rather than deposited in huge refuse banks. RCRA siting criteria stipulates that these landfills may not be in environmentally sensitive areas or pose a hazard to the environment or public health.

Coal Combustion

Land Requirements

In 1975, there were approximately 1.95 x 10^5 megawatts of coal-fired power plant capacity in the U.S. Assuming existing coal-fired power plant sites use an average of 0.5 acre/MW, there were a total of about 97,620 acres of land consumed by coal-fired power plants in 1975 (see Table 2.5).

The permanent, physical structures—the powerhouse, fuel handling system, air and water pollution control systems, stacks, and administration and laboratory buildings—occupy only a fraction of the total plant area. Coal storage piles, access roads, landscaping, etc., comprise most of the site. Cooling systems can be a major consumer of land; mechanical draft and natural draft cooling towers only require about 28 acres per 1000 MW generated; however, cooling lakes require about 1000-3000 acres of pond per 1000 MW.[46] Some utilities may prefer larger sites to allow for future expansion in generation capacity or have a buffer zone around the plant. The spatial distribution of structures on the site may also be influenced by the site terrain or by a need to maximize plume dispersion.

Table 2.5

Estimated Direct Land Use by Existing Coal-Fired Power Plants, 1975

Regions	MW	Acres
1	2,224	1,130
2	4,630	2,310
3	32.968	16.480
4	56,464	28,220
5	66,219	33,360
6	4,945	2,470
7	14,304	7,160
8	8,195	4,110
9	3,414	1,710
10	1,335	670

Source: K. Robeck, et al., *Land Use and Energy,* Argonne National Laboratory ANL/AA-19, September 1980.

In general, the amount of land required per megawatt of plant capacity is not necessarily linear with plant capacity. Also, older plants, particularly those located in urban areas, tend to maximize their usage of the site area. The actual amount of land required per facility is highly variable. Table 2.6 illustrates the range of acreage occupied by coal-fired power plants and was used to develop the 0.5 acre/MW figure used earlier.

Practically all coal-fired utility and industrial combustion facilities require land for disposal of solid wastes, including fly ash, bottom ash, scrubber waste, and

Table 2.6

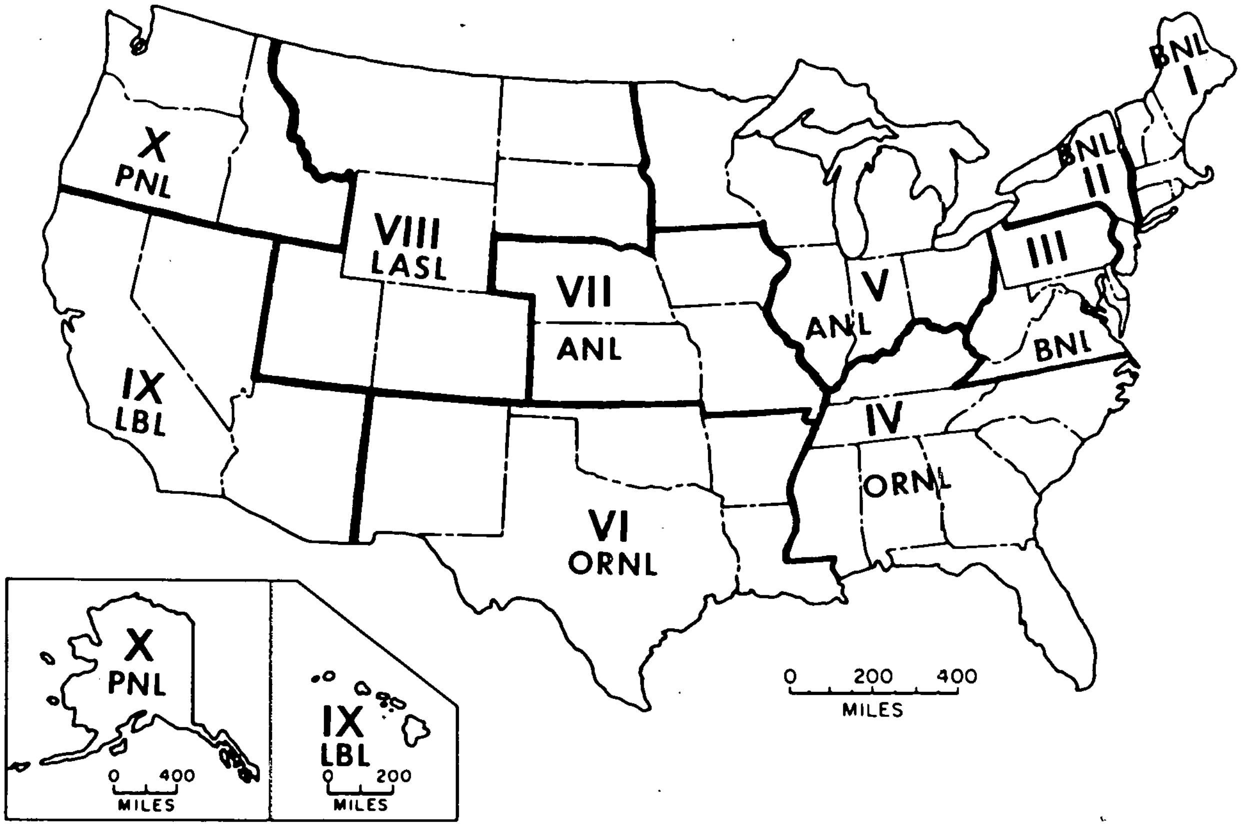
Range of Land Use by Coal-Fired Power Plants

MW	Acres
500	500 - 1,000
1,000	475 - 1,000
1,000	330
3,000	220 - 1,200

Source: K. Robeck, et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September 1980

Figure 2.2

Department of Energy Federal Regions



sludge from water treatment. Since the amount of waste from water treatment processes is much smaller than the wastes from the other three streams, only solid wastes from fly ash and bottom ash removal and flue gas scrubbers are discussed here.

There is little uniformity in the acreage of land required for sludge and ash disposal, because of variability in disposal practices, topography, and climate. Available figures are mostly based on theoretical calculations rather than actual experience. According to one study, land requirements for waste disposal of a typical utility plant varied, on a 10^{12} Btu per year output basis, from 12.8 acres for eastern coal to 5.9 acres for western coal.

For a 1000-MW coal-fired power plant equipped with lime/limestone FGD systems, the production of solid waste, on a national average basis, was estimated at 0.406×10^6 tons/year of sludge. Assuming all solid wastes produced are to be disposed of on land, the lifetime (30 years) land requirement for solid waste disposal for the average power plant (1000 MW) is estimated at 310 acres, of which 158 acres are for ash disposal and 152 acres for sludge disposal.

A recent survey indicated that all of the planned facilities had adequate acreage to accommodate on-site waste disposal. Even in the Northeast, where one might expect the greatest difficulties in site selection in view of high population densities, the utilities have been able to assemble 1000 to 3000 acres to accommodate solid waste disposal on sites where planned units will be built. These results indicate that assembly of large land areas for coal-burning plants seem well within the capabilities of the utilities. The conclusion is, therefore, that availability of waste disposal sites will be unlikely to constrain increased coal utilization in the electric utility sector.

In summary, a hypothetical average power plant (1000 MW) would require 740 acres for plant operation, 28 acres for a cooling tower or 1000 acres for a cooling lake, and 310 acres for solid waste disposal.

To estimate the amount of future lands that will be directly impacted by coal-fired electric utilities, an energy scenario currently used by DOE for its impact assessments was considered as a basis. The scenario chosen was the high world oil price scenario from the Regional Issues Identification and Assessments (RIIA-II) program. According to this scenario, there will be a total of about 141,600 MW of new coal-fired capacity in 1990 occupying 106,350 acres, as delineated by region in Table 2.7, excluding solid waste disposal and cooling requirements.

Adding to the 1990 acreage the 1975 acreage of approximately 97,500 for existing facilities yields a total of 203,500 acres to be occupied by coal-fired power plants, excluding land used for cooling and waste disposal. Only four states—Indiana, Oklahoma, Pennsylvania, and Texas—are expected to have additional direct land consumption of more than 5000 acres by 1990. Power plant siting in Texas would require the largest amount of land, approximately 15,000 acres (0.01 percent of the land area).

Total land commitments for utility waste disposal (e.g., over the 30-year lifetime of all plants) will increase from 30,850 acres in 1975, to 134,100 acres in 1990. The 1990 total land requirement will consume 0.0059 percent of the total land area of the U.S. The regions of the country with the largest total land requirement for utility solid waste disposal are Federal Regions 3, 4, 5, 6, and 7.

In 1990, a hypothetical coal-fired electricity generating plant will be 70 miles from the nearest urbanized area, will be 2000 MW and will use 1000 acres for operation, use a 56 acre cooling tower or a 2000 acre lake and require 600 acres of solid waste disposal area.

Potential Land Use Conflicts

The major land use topics affecting siting of coal-fired plants are applicable PSD requirements for the proposed area, local, rural zoning restrictions, water availability, and possible displacement of a small, but significant, agricultural area. Impacts on agricultural production caused by effluents generated by rurally based power plants are discussed in the third part of this section.

If all of the land occupied by fossil fuel facilities in each region was cropland, the percent of total cropland used by 1990 would be small for each region. Nationally, coal-fired facilities would replace, under worst conditions, 203,500 acres of cropland which represents 0.03 percent of the total 1977 cropland. The topic concerning the potential conflict between coal-fired power plants and agricultural production is discussed in detail in the next subsection.

Legal Topics

The Resource Conservation and Recovery Act (RCRA) mandates EPA to regu-

Table 2.7

Projected Coal-Fired Power Plants and Land Requirements, 1990

New Facilities, 1990

Region	MW	Acres	Plant Size (MW)	Site Size (Acres)
1	2,645	1,500		
2	3,573	2,500	under 500	300
3	11,490	8,900	500 - 1,000	500
4	25,869	17,700	1,000 - 2,000	1,000
5	25,629	19,700		
6	36,947	26,900	Average: 0.05 Acres/MW	
7	13,314	11,150		
8	16,908	13,200		
9	5,687	4,300		
10	500	500		

Source: K. Robeck et al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

late the handling and disposal of solid and hazardous wastes. Wastes generated by coal combustion have been recently classified as nonhazardous, a classification which is subject to change should these wastes be shown to exhibit toxicity. Such a change in classification would impact land use decisions on facility siting in terms of balancing such variables as maximizing use of low-sulfur Western coal, the soil leachate properties of the proposed site and distance to urban areas or to critical habitats of endangered species.

RCRA also specifies certain restrictions on site location, in addition to land requirements, for landfills and ponds, even for nonhazardous wastes. Landfills and ponds are not to be located in certain "enviromentally sensitive areas" (ESAs) unless the disposal facility is designed, constructed, and operated so that it does not pose a threat to the environment or to public health. Most of the utility plants have been and will continue to be sited in non-urban areas. As a result, land availability for waste disposal may not be a problem for utilities in most areas of the country. Waste disposal does, however, pose significant problems for industrial conversions to coal combustion. Many industires are or will be located in urban areas where competing land uses and the inability to meet RCRA siting criteria will require these industries to haul their wastes to distant landfills. The exorbitant costs which could be involved with transporation of these wastes may allow industries to obtain exemptions from requirements to convert to coal. It is presently too early to tell how serious the potential conflict may be between the requirements of waste disposal and increased coal use.

In addition to the increased land requirements and the constraints of siting provided by RCRA, the Clean Air and Clean Water Acts have substantial impacts on coal combustion facility land use patterns. These acts were discussed in detail in the Legal Topics Issue portion of this study.

The majority of state land use legislation relative to energy development concerns the siting of coal-fired power plants. Twenty-five states have adopted some form of power siting legislation. However, in most states, the private sector still makes all siting decisions, with only incremental review by governmental authorities. State agencies review proposed coal-fired electric generating facilities for violations of state environmental protection restrictions. These restrictions relate to such federal acts as the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act. Thus, state reviews tend to be fragmental in nature, being directed toward separate air quality, water quality, and waste disposal concerns, rather than to overall compatibility and suitability.

A summary of the provisions of state power plant siting laws is presented in Section 4. All but one of the states which have adopted a power siting law use a one-stop provision. This means that these states have one agency which has final authority to approve power plant sites and to issue construction permits.[3]

Seventeen states require an investigation of alternatives, ranging from sites and routes to equipment and technologies. Minnesota and North Dakota, for example, require that alternate primary corridor options, as well as transmission line routes, be considered. Montana requires an assessment of alternative energy sources and uses (including joint industrial use) of the proposed site. California and Wisconsin are among the states which require consideration of conservation plans as reasonable alternatives to capacity expansion.[3]

Synthetic Fuels

Land use impacts induced by the construction and operation of a synthetic fuels plant are expected to be very similar to those caused by conventional coal-fired power plants. Approximately the same land area is required for direct and indirect liquefaction and high Btu coal gasification plants as is necessary for coal-fueled electrical generating units. Other similarities between these processes include requirements for a railroad spur, close proximity to a water source, adequate coal supply and a coal storage pile. In terms of a conversion process, direct and indirect coal liquefaction and coal gasification technologies closely resemble the equipment, plant configuration and chemical effluents associated with a crude oil refinery.

As demonstration and/or commercial scale facilities are constructed, greater knowledge of the potential impacts on land use and the environment will be acquired. Until that time, or when more detailed data relative to each process are available, the land use impact correlations identified above will have to suffice.

The coal liquid processes closest to commercialization and, thereby, providing the greatest economic, technological and environmental information, are Fischer-Tropsch, Mobil-M, Exxon Donor Solvent, H-COAL, and SRC-I and II. The first three processes convert coal indirectly (i.e., by first processing methanol) whereas the latter three are direct processes. The typical land requirements for a 50,000 bbl/d coal liquids plant is approximately 500 acres. The same amount of area is assumed to be necessary for a 250 MM scf/d high-Btu coal gasification complex. As with all other energy developments, the amount of land which the plant occupies depends upon ownership, topography, economics, process noise, availability, expansion and the technology configuration itself.

To date, there has been very little land devoted to synthetic fuels production from coal. There are pilot plants in: Wilsonville, Alabama; Cattlesburg, Kentucky; Ft. Lewis, Washington; and Baytown, Texas; which occupy less than 300 acres combined. The next stage to commercialization is demonstration plants; there are seven plants planned, located in: Memphis, Tennessee; Baskett, Kentucky; Perry County, Ohio; Morgantown, West Virginia; Newmank, Kentucky; Muscle Shoals, Alabama; and Buela, Mercer County, North Dakota. These seven plants will utilize approximately 2000 acres for their plant processes, coal piles and auxiliary equipment. The draft Environmental Impact Statements on several of these facilities identify significant variability in land area with ranges between 100 acres to 700 acres.

For the commercial scale facilities, approximately 40 plants will be necessary to satisfy the 1979 Presidential directive for producing 2.5 million oil equivalent barrels/day. This industry size would, therefore, require greater than 22,000 acres of land for the direct conversion of coal to liquids and synthetic gas. If the sites identified in the DOE Feasibility/Cooperative Agreements are any indication of the types of lands the synthetic fuels industry will impact, then the areas will be principally rural, coal rich, semi-industrialized, transshipment-linked locations.

Oil Systems

Oil production in the United States has, until recently, supplied well over half of the domestic oil demand. A maximum production level of 11.3 million barrels a day was reached in 1970 and contributed to 75 percent of the total U.S. consumption.[47] During 1970, however, the U.S. excess capacity disappeared and production in subsequent years declined. Crude oil contains many organic compounds, making its end-use consumption flexible and diverse. This wide variety of oil-based products will continue to make oil valuable and ensure its continued production in future years.

Oil reserves in the U.S. are estimated at 57 billion barrels of identified resources, and from 50 to 127 billion barrels of undiscovered resources[48]. Most of these reserves are located throughout the Central Plains states, southern California, and the Central Gulf states. Significant reserves are also found in Alaska and offshore. Reserves in the lower 48 states will provide oil additives from wells in previously undrilled areas, deeper wells, and from additional recovery from known fields.[10]

Oil resource development for energy production requires a sequence of activities, including exploration, development, processing (or refining), and combustion for electricity generation. This portion discusses the land use patterns associated with each of these phases in the oil utilization fuel cycle.

Exploration and Development (Extraction)

Land Requirements

Before exploratory drilling takes place, the site must be prepared by clearing the land, digging small holding ponds for circulating fluids and brine, and constructing access roads. Wells are dug at those locations identified by regional and detailed geologic surveys as sites with potential oil resources. Exploratory drilling is done to search for a geologic strata containing enough oil to economically justify recovery. For reference, a 100,000 bpd oil field will typically require 300 successful holes that will produce oil, and 300 dry holes.[49] Land requirements for this exploratory phase are minimal and include about 2 acres per exploratory well. After drilling, the land can be restored to its original condition.

Development drilling is done in the same manner as exploratory drilling, except that well spacing and the location of the bottom of the holes are more carefully controlled.[49] Estimates of the amount of land used for oil production vary and are not well documented. Hittman and Associates (1974) estimate that 3.03 - 6.9 acres/10^{12} Btu/year are disturbed.[50] These figures are based on onshore land use ranging from 1/4 acre to 1 acre per well and offshore land use of 0-1 acre/well. Land use from offshore wells is much less than onshore wells because the only land required for offshore wells is for the onshore processing facilities.[10] A more recent study has estimated land use from oil production to be 2,000 acres/100,000 barrels per day (9.45 acres/10^{12} Btu/year).[49] These figures are based on 5 acres/well for cleared areas around the producing well, pipeline right-of-ways, separation facilities, and roads.

Domestic oil production in 1975 was 3.59 billion barrels with an energy equivalent of 20.09 quadrillion Btus (using 5.8 x 10^6 Btu/barrel).[49] Assuming that 2000 acres of land are used for the production of 100,000 bpd of oil, then total land used in 1975 for oil production was 196,712 acres (307 square miles), or 60,872 to 138,621 acres (95-217 square miles) if Hittman's figures are used. Land use for oil production in 1985 and

Table 2.8

Oil Production and Estimated Land Use Under Alternative Oil Production Scenarios

		1985		1990	
	1975	NEP	NEA	NEP	NEA
Domestic Production (10^{15})	20.09	21.8	20.35	19.48	22.48
Equivalent Barrels (billion barrels)	3.59	3.89	3.63	3.48	4.01
Land Area Requirements (10^3 acres)	197	213	199	190	220
(square miles)	307	333	311	298	343
Hittman Estimates (10^3 acres)	60 - 139	66 - 150	62 - 140	59 - 134	68 - 155

Source: DOE/EIA, *Annual Environmental Analysis Report,* December, 1977.

1990 has been estimated and comparisons made for two moderate, but different, oil production scenarios. For this study, projections from the National Energy Plan I (NEP) and the National Energy Supply System (NESS) were compared.

Table 2.8 indicates that production levels, and the subsequent land uses, vary little between the two scenarios. Land use in 1990 ranges from 298 square miles to 343 square miles (190,000 to 220,000 acres), and considerably less than that if the Hittman estimates are used. Comparing 1985 and 1990, the trend under the NEP is for a reduction in land use by 35 square miles between 1985 and 1990 while, under the NESS the land use would increase through 1990 because of projected increases in oil production.

Potential Land Use Conflicts

The predominant kind of land use likely to be affected by oil extraction over the mid-term is rangeland in the West and Southwest. Oil exploration and development may also displace smaller amounts of cropland in the Great Lakes and Mississippi River delta.

Oil production disturbs a very small amount of land in comparison to other fuel extraction cycles. Also, once production has ended, a site can be returned to rangeland or cropland in a relatively short period of time. Reclamation of cropland will probably take 5-6 years; rangelands may require 10 years, depending on water availability.

Legal Topics

In terms of legal topics, environmental management programs associated with laws such as the Coastal Zone Management Act affect oil production siting decisions. In addition, as exemplified by the *Ventura County v. Gulf Oil Corp.* case, state and local participation in oil developments on federal lands will continue to be an issue as new oil exploration leases are granted by the BLM.

Oil Refining

Refineries are by nature very complex systems with many component parts. As such, it is difficult to characterize a 'typical' configuration, size and product mix. Generally, complexity and associated resource requirements increase with product mix diversity. Refineries specializing in one or more of the four standard products (gasoline, jet fuel, diesel fuel, and fuel oil) are relatively simple and require less land area than a diversified refinery producing a wide range of products and petrochemical feedstocks. As refineries diversify into additional products requiring more processing, supplemental units must be incorporated into the plant structure. These units and the associated storage tanks required to handle the intermittent products demand expansion of the land acreage.

Land Requirements

The long-term land use impacts related to a refinery can be associated with: (1) crude oil receiving and storage; (2) plant operation; and (3) product storage and shipping. There are aspects within each of these activities which may result in a significant change in the land use and general environment surrounding the plant. The initial direct and indirect impacts of these three activities coincide with construction of the refinery, especially:

- *Ground cleaning and reshaping*—those operations involving the physical disruption of the ground surface, including stripping of vegetation, grading, excavation, road building and site restoration.
- *Land committed to facility*—the impact of the lost opportunities for potential uses of the land committed to the development of the refinery.

During the operation phase of the plant, the important effects influencing land use can be categorized by activitiy.[51]

- *Receiving, Storing, and Shipping*
  - Hydrocarbon emissions
  - Leaks and spills
  - Visual intrusion
  - Accidents
- *Plant Operation*
  - All those listed under Crude Oil Receiving and Storage
  - Air pollution effluents (SO_x, NO_x, etc.)
  - Solid wastes
  - Cooling/process water consumption and discharge

Historically, refineries occupied land areas ranging from 1500 to 2000 acres per 100,000 barrels of oil produced. These plants were constructed in remote areas where land was relatively inexpensive and the plant layout could be spaciously arranged. Currently, only 500 acres per 100,000 barrels are assumed to be required when assessing the site of a "grassroots" refinery. Approximately 10 to 20 percent of the total site is specified for process units, 20 to 35 percent for tankage, 10 percent for planned expansion and the remaining 15 to 20 percent is designated for uses such as a structural buffer, sound barrier, sludge storage area or greenbelt perimeter.

The location of oil refineries is a function of two countervailing forces. One is the necessity of being located close to the finished product market or distribution system to reduce transportation costs. The second is to meet environmental criteria related to reduced air quality, aesthetic and noise impacts, etc. The final site selection, though, has become increasingly determined by public acceptance. Therefore, it has been and will be important that public opinions and attitudes be incorporated into the site selection process, especially with regard to relevant air and water quality issues, aesthetics, conflicting land uses and the economic impacts on property values and taxes.

Refineries are located in 41 states, but are principally concentrated in California, Illinois, Kansas, Louisiana, Oklahoma, Pennsylvania, Texas, and Wyoming (see Section 4). It is not a coincidence that these same states are either very large producers of crude oil, have favorable deep water port facilities, and/or are principal market distribution areas. Those states that have the greatest number of refineries also have 70 percent of the total crude capacity presently available in the United States.

The amount of land currently occupied by existing refineries is summarized by Federal Region in Table 2.9 below. The total area within the country which is supporting oil refinery structures, tankage, greenbelt perimeters, sound barriers, environmental controls and transportation networks approaches 328,000 acres. Approximately 45 percent of this area is concentrated in Region 6, the South Central Region, particularly the states of Texas and Louisiana.

Table 2.10 exhibits the projected land area to be occupied by oil refineries by region, using 500 acres/100,000 barrels of crude (also see Section 4). The table illustrates the dominance of the capacity additions and corresponding land acreage to be affected by prospective refineries in Region 6. Regions 1 and 2 also have large land areas, but only as a result of a 250,000 and 175,000 barrel per day refinery being constructed in each area, respectively. Given this distribution of land impacts, Region 6 will be expected to absorb the greatest number of refineries and many of the largest, and subsequently, will have the greatest expansion in land area utilized for crude oil processing. Since many of the areas where the prospective plants are to be constructed are within close proximity to other refineries and probably already classified for in-

Table 2.9

Land Area Occupied by Refinery Complexes Within Federal Regions

Region	Number of Plants	Crude Capacity (b/sd)	Refinery Occupied Land Area (acres)
1	1	13,000	228
2	8	878,978	15,382
3	17	1,105,494	19,346
4	22	863,079	15,104
5	34	2,949,464	51,616
6	111	8,337,448	145,905
7	13	603,291	10,558
8	32	668,952	11,707
9	43	2,629,362	46,014
10	14	659,460	11,541

Source: Great Lakes Basin Commission, *Energy Facility Siting in the Great Lakes Coastal Zone: Analysis and Policy Options, for the Office of Coastal Zone Management,* NOAA, DOC, January, 1977.

Table 2.10

Potential Region Land Area to be Impacted by the Construction of a Refinery Complex

Region	Acres
1	1,250
3	1,025
4	1,500
6	4,290
8	750
9	765
10	750
National Total:	10,330

Source: Calculated from *Oil and Gas Journal,* 19 May 1980.

dustrial use, the impact on alternative land use should be dampened. Alternatively, many of the other refineries proposed will be sited in more relatively populated areas adjacent to a water body (either a channel, major river, or ocean port), and thereby induce additional ecosystem and coastal zone management impacts. One final point to be made is that both within Region 6 and the other regions, there are numerous 3,000 to 4,000 barrel per day plants planned. The construction and operation land use impacts of these diversified plants and corresponding site areas may precipitate more widespread land use conflicts than those caused by several large (150,000-250,000 bpd) processing facilities. The land use consequences/impacts of such a tradeoff is too site-specific to generalize.

Potential Land Use Conflicts

A potential conflict of substantial public interest associated with oil processing is over the use of land for disposal of the Class I hazardous solid wastes produced by refineries. Generalizations about land consumption for refinery wastes are difficult to develop because land requirements are dependent upon two types of management decisions - the method chosen for waste water treatment, and whether the solid wastes remaining are disposed of at the plant or at a centralized treatment facility.

Through a variety of waste water treatment technologies, refineries separate oil and iron-toxic water from waste streams and concentrate all toxic materials in a wet sludge. This waste accumulates at the rate of 30.7 tons per 10^{12} Btu produced, or per 189,500 barrels of crude consumed.[52] Disposal of hazardous waste, either in-plant or by a waste treatment facility, is accomplished by one of three methods: surface impoundments, burial in secure landfills, or incineration.

The secondary impacts associated with land use allocations for solid waste disposal relate to the issue of public concern over contaminants migrating to groundwater in a given locality. EPA continues to upgrade and monitor its regulations over this issue through the avenues provided by RCRA, as implemented by state water and waste control agencies. Optimistically, this continuing interrelationship of legal control serves to ameliorate this land use topic.

Legal Issues

The process of oil refining produces other effluents controlled by the federal legislation discussed previously in this report; these are RCRA, the Clean Air Act, the Federal Water Pollution Control Act, the Safe Drinking Water Act and the Coastal Zone Management Act.

At the state level, California's hazardous waste control system has been operated by the California Department of Health Service since 1974; California's controls are more stringent than those of EPA, and Health Services tracks the movement of hazardous wastes. The Illinois Pollution Control Board implements waste handling controls described by the Illinois governor as the toughest in the United States; these controls exceed RCRA in many respects. Texas' legislation, rewritten in 1979, addresses most areas of EPA restrictions, but the Texas Department of Water Resources does not control carriers nor control transportation of hazardous wastes.

Oil Combustion

Land Requirements

As in the case for coal-fired power plants, the physical structures for oil-fired utilities occupy only a fraction of the total plant site area. For oil-fired utilities, access roads, landscaping, buffer zones or greenbelts and room for future expansion

Table 2.11

Land Requirements for Oil-Fired Power Plants, 1975

Region	MW	Acres
1	11,004	890
2	5,995	480
3	11,556	930
4	13,400	1,075
5	7,647	620
6	2,663	215
7	484	45
8	330	60
9	24,434	1,955
10	126	20
National Total:	77,639	6,290

Source: K. Robeck, et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Table 2.12

Estimated Direct Land Use by New Oil-Fired Power Plants, 1990

Regions	MW	Acres
1	1,160	95
2	2,837	230
3	1,220	95
4	4,572	380
5	3,621	295
6	3,344	250
7	0	0
8	0	0
9	292	25
10	175	20
National Total:	17,221	1,390

Source: K. Robeck, et al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September 1980.

comprise most of the site. The spatial distribution of structures of the site may also be influenced by the site terrain or by a need to maximize plume dispersion (i.e., prevent plume building downwash, interaction with cooling tower plumes, etc.).

In 1975, there were approximately 0.78×10^5 MW of oil-fired capacity in the United States, concentrated mostly in the Northeast. The amount of land required per MW of plant capacity is not necessarily linear with plant capacity. Older plants and urban area plants tend to maximize the usage of their acreage. Site size has been estimated to be approximately 80 acres for a 1000 MW oil burning plant and range between 150-350 acres for a 3000 MW plant (excluding cooling requirements). This estimate is based on the assumption of 0.08 acre/MW. Using this figure, it can be calculated that oil-fired power plants occupied 6,300 acres in 1975.[1] Table 2.11 summarizes the land occupied by oil-fired power plants by federal region.

To estimate the amount of future lands that will be directly impacted by oil-fired electric utilities, an energy scenario currently used by DOE for its impacts assessments was considered as a basis. The scenario chosen was the high world oil price scenario from the Regional Issues Identification and Assessment (RIIA-II) program. According to this scenario, there will be a total of about 17,200 MW of new oil-fired capacity in 1990.

The calculations shown in Table 2.12 indicate that the new oil-fired power plants may require approximately 1400 acres in 1990 based on an average land requirement of 0.08 acre/MW. Added to the 1975 acreage estimates, the total land devoted to oil power plants may be more than 7,500 acres. This does not include land required for cooling ponds, which could double the land measurement in some parts of the country. Four regions, South Central, Great Lakes, New York-New Jersey, and Southeast, expect to increase their capacity by more than 30 percent. All of these areas have either substantial refining capabilities or are in close proximity to major refined oil sources. The largest expected regional increase in land consumption is only about 400 acres in the increasingly populated Southeast. This region is also projected to increase its coal-fired utility land requirements by 17,700 acres by 1990.

Potential Land Use Conflicts

The potential conflicts of allocating land to oil-fired plants are essentially those already discussed regarding coal-fired power plants. As with coal combustion, the land use conflict of greatest concern is the displaced cropland in rural areas. For oil-fired power plants, the ratio of facility site to cropland is very small. Even if all of the oil combustion generating facilities in 1990 are on cropland, these facilities would displace only 7,680 acres or .002 percent of tota cropland.

Oil Shale

According to DOE projections and research, the major oil shale deposits in the U.S. will likely be recovered in two forms: liquid from the Green River Formation and gas from deep Devonian shale. Any product recovery from oil shale resources in the mid-future will most likely be liquids from the deposits of Colorado and Utah.

The Western oil shale region is still largely an undeveloped area of deserts, canyons, and gulches, and there is considerable public concern that an oil shale industry will adversely affect this natural environment. Oil shale development will produce physical and chemical changes on the surface and subsurface both during and after mining and processing. The principal impacts to the land will result from the disposal of solid waste, construction of the surface processing facilities, and (for some methods of extraction) subsidence. The existing landforms, soils, and vegetative cover will be temporarily or permanently altered by the various processing steps.

Land Requirements

Oil shale processes present a unique problem with regard to land use since in particular instances the retort process is integrated with shale extraction. Due to this situation, most estimates of land area associated with shale oil production processes include in the total acreage the amount of land needed for extraction.

Land alterations from oil shale development will be caused by surface support facilities, subsidence, and solid waste disposal sites. Surface facilities will vary with the type of process. At a surface plant, the facilities would include access roads, retorts, upgrading structures, warehouses, crushing and screening areas, storage tanks, conveyors, drainage ditches, catchment basins, and office space. At a modified in situ plant, the facilities would include access roads, mine shafts, headframes, hoist houses, storage tanks, power generators, warehouses, a gas treatment plant, and office space. The area needed for these facilities is more related to the production capacity than to the process used. However, an in situ operation may require large areas for evaporation ponds. For surface mining and processing of oil shale, the area occupied by surface facilities for an operation that would handle 500,000 tons per day has been estimated to be 5,400 acres.[11]

Subsidence of the shale extraction area may be initiated by underground mining or by dewatering of local aquifers. The detrimental physical effects of land subsidence include ground rupture, cracking and displacement of surface structures, failure of well casings, loss of aquifer storage capacity, derangement of surface drainage, and the initiation of gully erosion.

Surface subsidence in an area of modified in situ retorts is possible some time after the burn because of the porosity created by mining and blasting and the loss in strength of the burned retorts and their supporting pillars.[11] These factors may result in creep and subsidence of large blocks of retorts. Further, shrinkage of the rublized oil shale within the retorts is possible and could cause several lines of pillars to fail. Possible control strategies include modifying the mine design, backfilling abandoned retorts, and establishing criteria for selecting suitable sites for modified in situ processing.

The immediate effects of oil shale development on land use are caused by spent shale disposal (see Section 4). Because the volume of the shale increases by as much as 30 percent during the retort process, all of the shale cannot be returned to the mine for disposal. The excess may be disposed of by filling in canyons or building up into mesas.[53] About 20 million tons of spent shale per year are generated by 50,000 bb/d surface retorting facility.[54] To provide a perspective on the volume of spent shale for the oil shale development shown in the table below, the following assumptions are made:

- 1.1 tons of spent shale is produced in surface retort per barrel of oil produced;
- Compaction of the spent shale produces a material density of 90 pounds per cubic foot;[55]
- 30 percent of shale from a modified in situ would be mined.

If all mined shale were to be disposed of above ground, which is the most likely case since oil shale will probably be mined underground and little backfilling of deep

Table 2.13

Oil Shale Site Size

Tract	Process or Location	Size by 1990 (10000's of barrels/day)
I. **Surface Retort**		
1. Long Ridge (Union)	TOSCO II	50
2. DOW (Colony Development Operation)	TOSCO II	47
3. Uintah (White River) U-a and U-b	Phillips-SOHIO-SONOCO	50
4. Naval Oil Shale Reserve #1	Carfield Country, CO.	50
5. Uintah-Rio Blanco	SONOCO, Phillips, SOHIO Cleveland-Cliffs	50
6. TOSCO Sandwash	TOSCO II	50
Subtotal		297
II. **Modified In-Situ**		
7. Tract C-a (Rio Blanco)		60
8. Tract C-b (Occidental-Tenneco)		40
Subtotal		100
TOTAL		397

Source: DOE, "Oil Shale R&D Program Management Plan," June, 1979.

mines is presently practiced in the U.S., projections of the volume of spent shale would be:

360,000 tons per day
296,000 cubic yards/day
3300 acres/year at 20 ft. average depth
1700 acres/year at 40 ft. average depth
800 acres/year at 80 ft. average depth

If 70 percent of the mined shale (except that from modified in situ) were to be returned to the ground, then data on the spent shale would be:

131,000 tons per day
108,000 cubic yards per day
1200 acres/year at 20 ft. average depth
600 acres/year at 40 ft. average depth
300 acres/year at 80 ft. average depth

By considering the conservative estimate of 40 foot average spent shale depth, the amount of land required for spent shale disposal is not trivial, especially considering the relatively small area in which oil shale production will take place.

The topic, however, is not only the amount of area covered, but also the ability of the spent shale to be reclaimed. Methods to revegetate the shale piles have been studied for several years.[33] The vegetation must sustain itself on a thin mantle of soil covering the piles or on the pile itself (without soil). It is likely that the revegetation process will require irrigation to initiate the revegetation of the large areas. However, the local water supply may not be adequate for the irrigation requirements and the vegetation may not be able to sustain itself without irrigation. In addition, waste disposal in canyons would significantly alter existing land uses, the natural topography, drainage patterns, and the ecology of the region.

Currently, the impacts of oil shale development are limited to the area of an experimental modified in situ facility in Colorado. The sizes of projected facilities are listed for both modified in situ mining and above ground retort in Table 2.13.

Potential Land Use Conflicts

If a mature oil shale industry were operating by 1990, it would be centralized in the Piceance Basin of western Colorado with some devleopment in the adjacent area of Utah. This area is arid and sparsely populated, and the land is often steeply sloping from mesas. One of the nation's largest migratory deer herds, endangered bald eagles, and a wild horse population are found in the area.

Land use in this region consists mostly of small non-intensive uses such as grazing, wildlife production, hunting, fishing, and other dispersed outdoor recreation, together with scattered production of oil and gas. Agricultural activities follow the familiar western pattern of livestock production on privately owned alluvial valleys (hay and winter pasture) in company with grazing on public lands through the granting of grazing permits and leases. Such permits presumably could be cancelled in favor of oil shale development (see Sec. 402 of P.L. 94-579, The Federal Land Policy & Management Act of 1976), but such a decision would entail changes in the existing ranching economy and probably would be resisted by organized livestock interests. Intensive land uses such as for cultivated crops, transportation, and municipal and industrial development occupy only limited areas, mostly in the major valleys.

Legal Topics

Oil shale development will produce unique environmental and socioeconomic impacts which may not be adequately controlled under present laws. This section will address the current acts and orders which affect oil shale facility siting and briefly discuss local and state controlled growth programs that may be developed relative to land management under rapidly changing conditions.

The Federal Government owns most of the oil shale lands in Colorado, Utah, and Wyoming, which comprise 80 percent of commercially developable resources. This land is currently managed by the Bureau of Land Management. The remaining oil shale lands are owned by private interests, Indian tribes, and the states. The Bureau of Land Management is implementing procedures for an equitable exchange of public and private lands to provide a consolidation of holdings necessary for direct and secondary construction activities associated with large oil shale mining and processing.

Control and reclamation of the huge amounts of spent shale generated by oil shale facilities are the most serious regulatory issues pertinent to land use for this fuel type. Since these solid wastes have not been classified as hazardous, their disposal would be controlled under the auspices of SMCRA.

Environmental and aesthetic considertions will require that the disposal piles of processed shale be revegetated. On the drier sites, as in the Uinta Basin, water harvesting practices would be beneficial. On wetter sites, such as the Piceance Creek Basin, it is generally agreed that the following minimum steps would be required where plants are to be grown on processed shale:

- Leach salts from the top layer of the shale pile;
- Apply a soil layer for plants with additives;
- Select a mixture of native and imported plants;
- Protect surface with mulches, and install fences to ward off grazing animals during the early period of growth; and
- Irrigate the planted areas for two years or more to establish a viable root system.

The crucial issue facing land reclamation for an oil shale industry is the long-term effectiveness of the selected control strategies. Whatever practices are selected, they must be able to withstand natural processes that accelerate erosion. A high rate of erosion would destroy the vegetative cover and expose the processed shale. Plants grown on the processed shale may accumulate toxic trace metals that may be damaging to wildlife and livestock. Thus, long-term management of disposal piles apears to be necessary. Periodic maintenance also would be needed to remove accumulated sediment and salts from impoundments. In summary, it is uncertain that disposal piles of processed shale could ever be truly abandoned without risking some hazard from undesirable runoff.

Natural Gas

Natural gas has been used as a source of fuel in the U.S. for over 150 years, although early use was localized. A rapid increase in end use consumption of natural gas has occurred over the past 30 years due to increased pipeline construction, (increased from 218,000 miles in 1945 to 980,000 miles by 1975),[56] development of new markets, such as petrochemicals and fertilizers, and, more recently, a demand for low-sulfur fuels.[49]

Unlike oil, 85 percent of the natural gas consumption in the United States has been domestically produced.[47] Nineteen trillion cubic feet (tcf) of natural gas were pro-

Table 2.14

Natural Gas Production and Estimated Land Use Under Alternative Natural Gas Production Scenarios

	1975	1985		1990	
		NEP	NEA	NEP	NEA
Domestic Production (10^{15} Btu)	19.8	17.61	18.8	16.68	19.45
Land Area Requirements* (10^3 Acres)	179	159	170	151	176
(sq. mi.)	279	248	265	235	274

*Assumes 1.032 Btu per cu ft measured at 14.7 psia and 60 °F and 850 acres for each 250,000,000 cu ft per day natural gas field.

Source: K. Robeck, et al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September 1980.

duced in 1975, but peak production levels were reached two years earlier. Production generally is found in the same areas where oil drilling occurs.[57] By 1978, gas production had fallen 12 percent while the level of proven reserves fell 25 percent between 1967 and 1978.[47] While new discoveries have not replaced what has been consumed, it is generally agreed that enough natural gas exists onshore and offshore in the U.S. to sustain a yearly consumption rate of 20 tcf for 25 to 35 years.[47,56] Natural gas is expected to play a diminishing energy role in the United States, such a decline is a result of complex economic and regulation issues and not necessarily due to limited near-term supplies.

Exploration of natural gas is similar to that described for oil. For a 250 mmcf/d gas field, it has been assumed that, for every 10 producing wells, 8 dry holes will have been drilled.[49] Permanent land usage for the exploratory phase of this reference plant is 30 acres for drilling and roads.

Land required for the development of natural gas is estimated at 850 acres for a gas field and processing plant with a capacity of 250 mmcf/d.[49] This figure is based on 7 acres/well for cleared area around the well, pipeline right-of-ways, and roads, and 250 acres for the plant site.

Using the two scenarios described in the Oil Production Section of this report, estimated gas production levels in the United States are projected to decline by 1990 from the 1975 levels. Land use requirements in 1975 were 279 square miles (179,000 acres), but this level may decline to 235 square miles (151,000 acres) under the NEP scenarios (Table 2.14). As with oil, unless major changes in natural gas production occur, changes in land use by 1990 will likely be minimal.

Uranium Systems

One ton of uranium ore contains, on the average, only about four pounds of uranium oxide, which is delivered to nuclear reactors as "yellowcake," a milling product that is 90 percent uranium oxide.[58] A 1000 MW reactor requires 250 tons of yellowcake per year,[58] which in turn requires about 112,500 tons of ore. Uranium ore deposits are found mainly in the western United States. The Colorado Plateau, which includes parts of Utah, Colorado, Arizona and New Mexico, and the Wyoming Basin contain the majority of the nation's proven reserves and potential resources. Two states alone, New Mexico and Wyoming (including the Powder River Basin, which is also a major coal producing area), contain 87 percent of the proven economically recoverable reserves of uranium oxide,[58] and they provided 74 percent of the uranium oxide produced in 1978.[59]

Extraction

Land Requirements

Uranium ore deposits are found in highly irregular seams, and the uranium oxide content of the ore in different deposits ranges from 0.11 percent to 0.30 percent.[58] It is difficult, therefore, to make a generalized

Table 2.15

Estimated Land Requirements for Three Uranium Mining Methods[a]

Method	Acres/1000 Tons U_3O_8	Acres/Mine
Open-pit mining	158 - 316[b]	-
Underground mining	-	2 - 5[c]
Solution mining	111 - 222[d]	-

[a]Derived in Section 2.
[b]Lower number is for pit alone; higher number includes topsoil storge, haul roads and other associated uses.
[c]Average mine size = 30 tons U_3O_8/year.
[d]Based on 25 - 50 acres of well field/year to produce 250 tons/year of yellowcake.

Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

estimate of the amount of land disturbed per unit of ore or uranium oxide extracted by surface mining methods. The potential magnitude of the disturbance can be indicated by using empirical data on land requirements of planned or existing mines. For example, a 1000 ton/day operation in Converse County, Wyoming, is expected to mine 575 acres of land over a five-year period.[58] This converts to 0.3 acres per thousand tons of ore (315 acres per million tons, to put it in the same units as presented earlier for coal) and 158 acres per thousand tons of uranium oxide (assuming a uranium oxide content of 0.20 percent, the average in New Mexico and Wyoming, the major ore producing states).[59]

Additional land is required at a surface mine for support facilities, haul roads, and topsoil and overburden storge. At the proposed Converse County mine it is estimated that the mine shop will require 40 acres, haul roads and settling ponds will cover 130 acres, 880 acres will be required for overburden piles, and 148 acres for topsoil storage.[59] These values present total requirements over five years. In some cases the same land will be used for several different purposes over the five-year period, thus the total acreage of 1773 acres (including 575 acres of open pit) represented by this estimate is probably high. It can be assumed that the total acreage disturbed at a surface mine at any one time may be as much as twice the area of the pit. Areas mined in previous years that are still undergoing reclamation also will contribute to the total acreage devoted to mining uses.

An underground mine carries relatively little surface disturbance; one source estimated that about 10 acres of surface land would be required for a 1500 ton/day (547,000 ton/year) underground mine.[58] The average production of the 305 underground uranium mines operating in 1978 was 30 tons/year of uranium oxide[59] which converts to approximately 15,000 tons/year of ore. It will be assumed that 2-5 acres of land will be required for surface activities associated with the average deep uranium mine, since some facilities (e.g., access roads, mine offices, etc.) are not proportional in size to the size of the mine. A general estimate of the area undermined cannot be made because of the variability of the deposits, as discussed earlier.

An in-situ, or solution, mine requires the construction of a number of wells throughout the area of the deposit. A leaching solution is introduced into the ore deposit through injection wells and is removed, along with the dissolved uranium oxide, at associated production wells. The wells themselves cause a relatively small surface disruption, but the entire well field is closed to other uses during production. An in-situ operation producing 250 tons/year of yellowcake requires 25-50 acres of well field area per year.[58] Estimated land requirements for the three mining methods discussed above are summarized in Table 2.15.

About 12,300 tons of uranium oxide were produced in 1975; 55 percent of that amount came from surface mines, and 43 percent came from 121 underground mines. It has been calculated that 1300-2700 acres of land

Table 2.16

Estimated Land Required 1980 - 1990 for Projected U_3O_8 Extraction

Scenario[a]	Mine Type	Cumulative U_3O_8 Production[b] (tons)	No. Mines[c]	Land Requirements (acres)
Low	deep	113,120	377	754 - 1885
	surface	58,580	NC[f]	9256 - 18511
	solution	14,140	NC	1570 - 3139
	Total	202,000[d]	NC	11580 - 23535[e]
Medium	deep	143,920	680	1360 - 3400
	surface	74,530	NC	11775 - 23551
	solution	17,990		1997 - 3994
	Total	257,000[d]	NC	15,132 - 30,945[e]
High	deep	173,600	754	1508 - 3770
	surface	89,900	NC	14204 - 28408
	solution	21,700	NC	2409 - 4817
	Total	310,000[d]	NC	18121 - 35995[e]

[a]See text, Section 2
[b]Values for different mining methods calculated on the basis of 56% contribution from underground mines, 29% from open pit, and 7% from solution mines.
[c]Based on 30 ton/year per mine
[d]Includes production from other sources.
[e]Assumes no additional land requirement for production of uranium as a by-product.
[f]Not calculated.

may have been disturbed by uranium mining in 1975.

The RIIA II scenario projects a U.S. nuclear generating capacity of 12.2 GW by 1990. Assuming that a 1000 MW reactor requires 250 tons/year of yellowcake (90 percent uranium oxide), this amount of generating capacity would require an annual production of 36,500 tons of uranium oxide, and a cumulative production[59] from 1980 to 1990 of about 257,000. Another projection[58] estimates an annual 1990 production of 40,400 tons of uranium oxide, and a cumulative production between 1980 and 1990 of approximately 310,000 tons. Maintaining the 1978 level of production until 1990 (assumes no new reactors will come online after 1978) would place the 1990 annual production at 20,200 tons[59] and the cumulative 1980 to 1990 production at 202,000 tons.

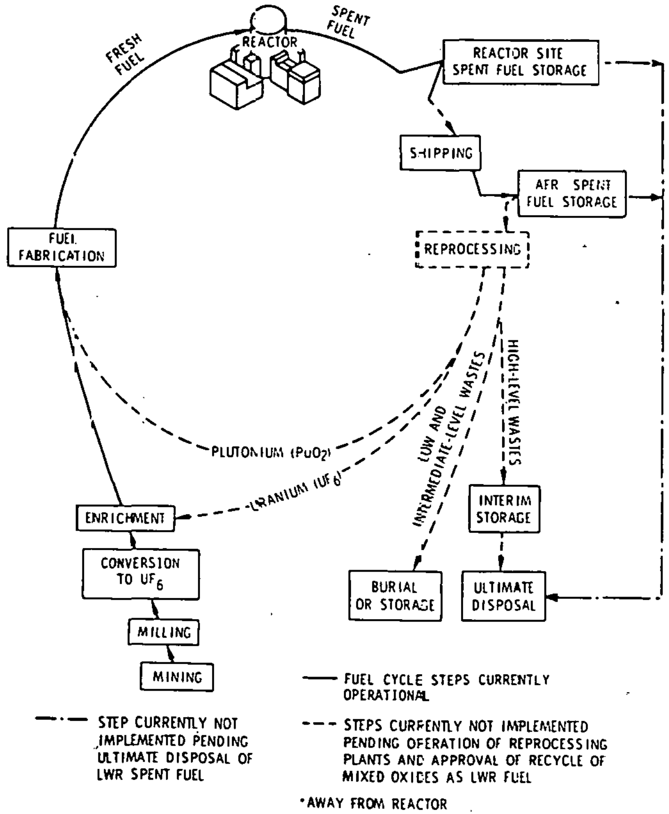
The calculations in Table 2.16 indicate that 1990 land requirements for uranium mines range from 1835 - 4049 acres for the low scenario to 3673 - 8100 acres for the high scenario. The open pit of surface mines, the most disruptive uranium-related land use, constitutes 25-50 percent of this total. From 1980 to 1990, 11,580 - 23,535 acres of land might be used under the low scenario and 18,121 - 36,995 acres if the high projections are reached. Approximately 40-80 percent of this total would be due to the creation of open pits.

Potential Land Use Conflicts

If present mining patterns continue, about 75 percent of the land disturbed by uranium mining will be in New Mexico and Wyoming. Most of this arid to semi-arid area is covered by native grassland or rangeland, and any potential land use conflicts arising over uranium extraction will be the displacement of rangeland.

Figure 2.3

Schematic Diagram of Light Water Reactor Fuel Cycle



Source: U.S. NRC Office of Nuclear Material Safety and Safegards, *Final Generic Environmental Impact Statement on Handling and Storege of Spent Light Water Power Reactor Fuel,* NUREG 0575, Vol. 1, August, 1979.

Legal Topics

The Surface Mining Control and Reclamation Act requires that mined land be restored to its original use value or a preferred use value. For arid regions, reclamation of rangeland can require 10 years.

Uranium Processing

The development of a commercial nuclear electricity generating industry in the past two decades has given rise to a number of new industries for processing nuclear fuel. The full cycle of uranium processing includes: milling, conversion, enrichment, fuel fabrication, storage, reprocessing, waste management, and transportation (Figure 2.3).

At present, the fuel cycle is open ended because no spent fuel may be reprocessed commercially to recover usable uranium and plutonium.[60] Consequently, only milling, conversion, enrichment, and fuel fabrication will be addressed in this section.

Land Requirements

The largest part of the land disturbed by a conventional uranium mill is devoted to the disposal of mill tailings, because in effect, nearly the entire mass of ore processed by the mill ends up in the tailings. After mills are shut down, environmental regulations stipulate that the tailing areas be covered with earth and planted to prevent soil erosion and spread of radioactive material by wind and water. The covered and planted areas are reclaimed to resemble the surrounding terrain. Current practice is to withhold such land from future unrestricted use so as to minimize exposure to the uranium and radioactive decay process. This type of disposal is temporary, pending completion of studies directed toward the development of acceptable procedures for ultimate disposal of mill tailings. Mill sites, including the area required for tailings disposal, cover 400 to almost 2000 acres, depending on the capacity of the mill. Approximately 20,000 acres of land, located chiefly in Regions 6 and 8, are presently devoted to conventional milling facilities. The acreage devoted to uranium mill sites (including tailings disposal) in 1979 is summarized in the table below.

Table 2.17

Acreage for Uranium Mills, 1979

Federal Region 4	10 acres
Federal Region 6	10,237 acres
Federal Region 8	9,266 acres
Federal Region 10	1,200 acres

Source: Dept. of Energy, Office of Technology Impacts, DOE/EV-0061/2, January, 1980.

Table 2.18

Estimated Uranium Mining Expansion

	Construction Commitments	Potential Construction
Region 4	2,250 acres	1,500 acres
Region 6	3,750 acres	2,250 acres
Region 8	3,750 acres	6,000 acres

Source: Dept. of Energy, Office of Technology Impacts, DOE/EV-0061/2, January, 1980.

For uranium milling, the construction or expansion of mill complexes from 1978 to 1990 is expected to remain proportional to what presently exists. States expecting new production capacity include: New Mexico, Texas, Florida, Louisiana, Colorado, Wyoming, Utah, and Arizona. Assuming a nominal capacity range of 1200-3000 tons per day, new mills may require land as illustrated in the table below:

A uranium mill typically is located in an arid, isolated region. The population density, approximately 5-10 people per square mile, is less than the average population density, 11.5 people/square mile, in the four-state mining area of the West. Most of the land in this area of the country is BLM-administered public lands where the principal land use classifications are desert shrubland, subhumid grassland, semiarid grazing land, and rangeland. It is expected that process modifications in future conventional uranium milling operations will be directed at improving operating efficiencies, increasing uranium recoveries, and decreasing impacts on the environment, especially with respect to land reclamation/utilization.

The conversion of uranium ore concentrate to uranium hexafluoride (UF_6) is currently performed at only two plants. The Allied Chemical facility in Illinois produces 13,000 tons per year of UF_6; the Kerr-McGee facility in Oklahoma produces 9000 tons per year. Based on these two facilities, a model uranium conversion plant is expected to occupy 1400 acres.

It is believed that no additional capacity will be required between now and 1990. If a plant were built, it would probably occupy a larger site than those currently under operation and be located near a water source that would provide a reliable supply and permit final discharge of treated liquid wastes and cooling water. Siting near mill sites or enrichment facilities would also be advantageous.

The enrichment of uranium above natural levels can primarily be done by either gaseous diffusion or gas centrifuge. Three gaseous diffusion plants located at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio, are currently owned by the government and operated by private industry under contract.

A gaseous diffusion plant is characterized by a large number of compressors which move UF_6 though large amounts of pipe in separate enrichment stages. The present gaseous diffusion plants are among the largest industrial facilities in the world with respect to land area under roof. The combined acreage of these three plants approaches 2000 acres of which 80 percent is covered by building structures housing the machinery for the 1700 stage enrichment process.[61]

There are two major expansion programs to enlarge enrichment capacity at existing sites. The Cascade Improvement Program will provide a significant improvement in equipment efficiency. The Cascade Upgrading Program will increase throughput of the three gaseous diffusion plants by increasing power capability from 6065 to 7380 MW. Neither of these two programs is expected to affect land use characteristics of the area surrounding the respective sites.[62]

Gas centrifuge enrichment technology is currently undergoing design and development. A gas centrifuge facility is expected to consume less power and acreage than a gaseous diffusion facility but generate more hazardous waste in the form of contaminated machinery parts.[62]

Most of the commercial power reactors in use or under development utilize a fuel fabricated by loading fertile and/or fissile material into fuel rods and assembling these rods into a fuel element. Fuel fabrication facilities will have varying impacts on land use since they process varying radioactive fuel material (by fission content and toxicity). Section 4 gives plant size and demography data for current fabrication plants. Land usage ranges from a few acres to 1650 acres, but plant sites need not be that large, and almost all disturbed land can be reclaimed. These facilities are generally sited in industrial complexes within populated areas. One new fuel fabrication plant is expected to be built before 1990; it will occupy approximately 800 acres in Prattville, Alabama.

Potential Land Use Conflicts

Much public interest has developed around the issue of radioactive waste management of uranium fuel. Of the four commercial processing activities discussed, the greatest magnitude of land consumption for wastes is the disposal of uranium mill tailings in covered revegetated landfills and retention ponds. A typical uranium mill is located in an isolated, thinly populated region of arid grassland or rangeland. Allocation of land for uranium mills must be considered a permanent land use decision, given the current 50-year reclamation statutes.

Potential land use conflicts for conversion enrichment, and fabrication activities are not as severe; these industries together currently occupy 10,000 acres, almost all of which can be reclaimed if enrichment wastes are not ultimately disposed of onsite. Indirect impacts of land use affecting uranium enrichment facility siting focuses on the availability of water for water heat and availability of abundant and inexpensive electric power, 6065 MW consumption. Presently this generation is fossil fueled and these combustion effluents have a much more serious land use impact than the enrichment effluents which include a solid byproduct UF_6 currently stored in cylinders pending further federal legislation. For fabrication facilities, to date, there have been no off-site detrimental environmental effects, and this temporary land use creates no adverse impacts in the industrialized complexes where fabrication plants are currently located.

Nuclear Power Plants

The generation of electrical power by nuclear power plants is similar in technology to that of fossil-fueled combustion

Table 2.19

Cooling System Land Requirements

	Nuclear	Fossil Fuel
Once-Through	1	1
Natural Draft Cooling Towers	15	10
Mechanical Draft Cooling Towers	68	45
Spray Canals	150	100
Cooling Ponds	3000	2000

Source: Environmental Technology Assessment, *State of Illinois, Power Facility Siting in the State of Illinois, Part II - Impacts of Large Energy Conversion Facilities*

plants. A nuclear steam supply system replaces the conventional fossil-fueled boiler, and the nuclear fuel core replaces the fossil fuel supply.

There are many site-dependent factors which determine the land requirements of a facility. The site area is related to local conditions (e.g., topography, land use, zoning, land cost, taxes, etc.) and the size of the exclusionary area required for radiation health and safety purposes. There are several other additional considerations which determine the size of the site required. Some of these include: (1) additional land to provide adequate noise buffering, especially in the case of mechanical draft cooling towers; (2) the necessity to restrict the potential impact of water vapor plumes from the cooling system; (3) multiple use areas for controlled public access to shoreline areas and cooling ponds, farming and grazing and the use of other inactive areas of the site; (4) visual relationships between the facility and the setting, the scenic worth of the setting, types of surrounding topography, and vegetative ground cover and seasonal variations; and (5) transmission line corridors.

As with fossil fueled power generation, the cooling system can occupy a substantial portion of the site area. Land consumption for cooling systems is broken out of nuclear plant site size and displayed, for comparative purposes, in Table 2.19.

A siting decision must examine the social and economic impacts of power plant zoning. NRC specifies a three-tiered system of population-related locational criteria that must be met in siting a nuclear facility. The three criteria are:[51]

- An exclusion area, which is that area surrounding the reactor in which the reactor licensee must have the authority to determine all activities including exclusion or removal of personnel and property from the area. Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, but the licensee must be in a position to clear the area promptly in the event of an emergency.
- A low population zone, immediately surrounding the exclusion area in which the total number of residents and the population density are small enough to provide a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident. NRC's controls do not specify a permissible population density or total population within this zone because the situation varies from case to case.
- A population center distance, which is the distance from the reactor to the nearest boundary of a densely populated center containing more than about 25,000 residents.

The exclusion distances for the 75 existing and planned sites range from 0.13 to 1.32 miles in radius.

An analysis of existing and proposed nuclear power plant sites shows a size range of approximately 100 acres to 30,000 acres. A 1974 report on land use and nuclear power plants found the average size to be 2730 acres with an average station size of 135 acres or roughly 5 percent of the total site area.[63]

The table below shows that of the 36,276 MW of nuclear capacity operating in 1975, 60,124 acres were occupied by the various reactor structures with additional 63,494 acres dedicated to transmission line corridors, exclusion areas, and barrier space.

Table 2.20

Land Area Occupied By Nuclear Reactor Facilities, 1975[a]

Region	Megawatt Capacity	Number of Reactor Sites	Site Area (acres)	Total Area (acres)[b]	Number of Sites Within SMSA
1	5753	6	4307	12322	1
2	3642	4	1987	6801	3
3	5463	5	3863	13253	3
4	5400	4	32470	44794	2
5	10081	10	9931	26201	2
6	836	1	1164	4880	0
7	1733	3	1972	7217	1
9	2506	4	3341	6581	2
10	862	1	1089	1569	0
TOTAL	36,276	38	60,124	123,618	14

[a]Using the RIIA-High scenario megawatt capacities and siting locations.
[b]Includes site area, transmission line corridors and substations, railroad spurs, and water supply facilities.
Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Under the RIIA-High Scenario, the projected nuclear capacity is expected to be 161,421 MW. The distribution of generating capacity is projected in Table 2.21, which illustrates that the greatest number of reactors and megawatt generating capacity may be shared by the Midwest and Southeast. It is evident, when comparing Table 2.20 and 2.21, that all regions experience growth of nuclear power plant sites, but Regions 4 and 5 grow most rapidly by exceeding a 100 percent increase in land area devoted to nuclear power production. Also more nuclear power plants are being sited in rural areas and, moreover, are tending to be larger in megawatt capacity.[64] If this trend is accurate and the historical siting land uses remain stable, more agricultural and grazing lands wil be affected by the growth of this industry.

Potential Land Use Conflicts

Use of land for nuclear power stations, cooling systems, effluent control, transmission lines and transportation systems effectively withdraws it from other uses. The land use in a 5-mile radius of the 75 existing and proposed nuclear power sites is either agriculture, wooded area, or grassland/undeveloped.[63] As indicated above, permanent allocation of land for nuclear sites may reach 290,000 acres by 1990, compared to the 203,500 acres projected for coal-fired utility plants. Use of land for barrier or exclusionary zones may be considered a temporary land use, assuming that monitoring of ambient radiation continues to be minimal and that exclusionary zone restrictions do not become more strict. If exclusionary or buffer zones are judged to be not reclamable by NRC, then land displacement may increase to 470,000 acres by 1990. In a worst case scenario, the allocation of cropland to nuclear sites may displace .12 percent of U.S. cropland.

Indirect land use impacts which may conflict with alternative land uses or adjacent land uses include possible changes in air and water quality, water quantity, and weather conditions. The depletion of water caused by evaporation to cool reactors affects adjacent land uses and can be significant if the water body is incapable of replenishing supply. This situation can cause ecosystem disturbances, water right conflicts and modifications to land uses downstream (or on adjacent waterbody properties) due to depleting reserves and/or lower flow rates.

The topic of concern in air and water quality is radiation exposure. The two principal sources of radiation exposure to humans and/or biota from a normally operating nuclear reactor are: (1) radioac-

Table 2.21

Potential Land Area To Be Occupied By Nuclear Reactor Facilities, 1990

Region	Megawatt Capacity	Number of Reactor Sites	Site Area (acres)	Total Area (acres)	Number of Sites Within SMSA
1	10822	8	5626	19721	2
2	10291	6	2892	12214	5
3	16973	8	24163	39915	4
4	47723	22	136205	196495	4
5	33510	23	42032	76478	7
6	13093	7	30883	46806	0
7	5183	5	13072	36409	1
8	330	1	2238	2551	0
9	9595	4	16709	18749	3
10	13901	5	13793	17261	0
TOTAL	161421	89	287613	466599	26

Source: RIIA-II High Scenario, DOE/EIA.

tive material in gaseous, liquid or solid form in the effluents from the radwaste treatment system; and (2) direct radiation from on-site plant components. Direct radiation from the operating facility on the off-site environment is considered minimal due to highly shielded structures and other design performance characteristics of the facility.[65]

Solid radwastes generated by the liquid radwaste treatment system impose a continuous waste disposal burden for the facility. It has been stated that since the preparation and handling of solid radwastes is a closely supervised internal operation of the facility, the radiation exposure hazard at the site boundary from such material is considered nil.[51]

Geothermal

Land Requirements

Geothermal energy is derived from subsurface occurrences of hot rock and heated water or steam. The only commercial generating plant in the U.S. using a geothermal energy source is The Geysers in Sonoma County, California. Opened in 1960, The Geysers was producing 502 MW of electricity in 1975 from generators powered by dry steam extracted directly from the earth. There is a large potential for expansion in The Geysers area—total production may reach 3000 MW by the year 2000[66] and the area has a maximum production potential of about 5000 MW.[67] The only other potential vapor-dominated geothermal systems in the United States are in Yellowstone and Mt. Lasen Volcanic National Parks, which are excluded from geothermal development under the Geothermal Leasing Act of 1970.[68] Thus, additional geothermal expansion will have to depend on the more common liquid-dominated systems, which extract a mixture of hot water and steam. Hot rock areas without naturally-occurring water can also be exploited by injecting and then recovering water from artifically-induced fractures in the rock. Hot rock systems are not expected to be commercially utilized until the late 1980s,[68] and most geothermal resource development in the next 25 years is expected to depend on the hydrothermal resources. All locations likely to be developed in that time period are located in the western third of the nation,[10,66] including sites in New Mexico, Utah, Nevada, Idaho, Oregon, and several sites in California.[66] There are currently 1.8 million acres of land identified as "Known Geothermal Resource Areas" in the western states and Alaska; and additional 9.6 million acres are defined as having prospective value. All are hydrothermal reservoirs.[10]

Electricity generation from geothermal sources generally depends on a rather large field of noninteracting wells. At The

Geysers, for instance, 75 wells are needed to produce sufficient steam for the 502 MW of electrical power produced, 15 wells per 100 MW.[67,68] For the same amount of electrical output, liquid-dominated systems would require more wells (100 wells per 100 MW) and hot rock systems would require considerably less (11 wells for 100 MW).[67] However, steam production from the vapor-dominated reservoirs decreases with time, and additional wells must be drilled to maintain the supply of steam to the generators; the total requirement over 30 years has been estimated at 35[67] and at 80[68] wells.

Spacing of geothermal wells depends on the porosity and permeability of the reservoir rocks; the density of wells in existing geothermal fields throughout the world ranges from one well per 10 acres to one well per 40 acres.[68] The entire producing field is closed to other land uses. The construction of each well disturbs approximately one acre of land; the operating well consumes only a small fraction of an acre. The land requirement for the pipeline network, service roads, and pumps converts to approximately one-half acre per well.[68] Additional land requirements at a geothermal facility include the generating plant itself. A number of relatively small (e.g., 100 - 110 MW) generating units must be dispersed throughout the resource area to minimize heat loss from the water or steam during transport. The generating plant at each production/generation unit will require about 5 acres of land.[67] It is estimated that generating plants utilizing hot water reservoirs will require about 30 acres and those in hot dry rock systems would require about 15 acres.[68] The land requirements for one production/generation unit, including wellfield and generating plant, are shown in Table 2.22.

All of the land devoted to geothermal energy production has been at The Geysers, where 167 wells have been drilled with an area of over 12,000 acres.[67] Development is scattered within that area, and the producing well fields and generating plants probably cover only 3600 acres.

Projections of U.S. generating capacity from geothermal sources range from 2000-6000 MW for 1985 and 10,000 - 39,000 MW for 2000. The Geysers may have a capacity of about 1700 MW in 1985[69] and 300 MW by 2000.[67] The remainder would have to come from new development of liquid-dominated reservoirs, plus a small amount from hot dry rock systems by 2000. Assuming production/generating units of 100 MW, and using the values in Table 2.22, this converts to a land requirement in 1985 of 13,375 to 22,375 acres for 2000 MW and 54,575 to 183,575 acres for 6000 MW (see Table 2.23). In 2000, 88,440 to 1.4 million acres could be devoted to geothermal energy. The RIIA II scenario projects only 4,125 MW of geothermal generating capacity by 1990, of which 3,250 MW are sited in California, 375 MW in Nevada, and 250 MW each in New Mexico and Utah. According to this scenario, which is at the low end of the ranges discussed earlier, 34,760 to 100,760 acres of land may be used for geothermal energy by 1990.

Table 2.22

Land Requirements for 110 MW Production Generation Units at Geothermal Facilities

Resource Type	Wells/Unit	Acres/Well	Acres/ Generating Unit	Total Acres/Unit
Dry steam (The Geysers)	15[a]	40[c]	5	605[a]
	35 - 80[b]	20[d]	5	705 - 1,605[b]
Hot water	100	10 - 40	30	1,030 - 4,030
Hot dry rock	11	10 - 40	15	125 - 455

[a]Initial requirement.
[b]Over 30-year lifetime of generating unit.
[c]Source: EPA-600/7-79-0607, U.S. GPO, Washington, D.C., March, 1979
[d]Average density over 30 years; derived from data in: Reed, M.J. and G.E. Campbell, *Environmental Impact of Development in The Geysers Geothermal Field, USA,* Second UN Symposium on the Development and Use of Geothermal Resources, San Francisco, California, Vol. II, May 20-29, 1975.

Potential Land Use Conflicts

This temporary land allocation for geothermal conversion will occur in remote areas of the West where population densities average only 3.4 persons per square mile.[66] Geothermal development is most likely to conflict with dispersed wildlife uses, an impact which may be controlled and ameliorated by the requirements of the Endangered and Threatened Species Act. Rangeland may also be affected.

Legal Topics

Other than state land management programs and local zoning ordinances, the major legal control deemed necessary at this time is the implementation of the Surface Mining Control and Reclamation Act which requires that all of the land be returned as nearly as possible to its original condition after the well is plugged.

Biomass

The use of biomass feedstock for energy has received much attention recently. Historically biomass, primarily crop residues, timber, and organic residues from the lumber industry have provided space heat and process heat through direct combustion. Continued use of these materials as a source of fuel, directly by combustion or indirectly from the produciton of alcohol, is viewed as a means of reducing the United States' reliance on fossil fuel. Debate over the role biomass can play in meeting reduced fossil fuel requirements goals centers around whether the various biomass con-

Table 2.23

Calculation of Land Potentially Devoted to Geothermal Energy Production[a]

Year	Source	Capacity (MW)	Land (acres)
1985 - low	The Geysers	1,700[b]	10,285
	Hot-water	300	3,090 - 12,090
	Total	2,000	13,375 - 22,375
1985 - high	The Geysers	1,700[b]	10,285
	Hot-water	4,300	54,575 - 183,375
	Total	6,000	64,860 - 193,660
2000 - low	The Geysers	3,000[c]	18,150
	Hot-water	6,800	70,040 - 274,040
	Hot-dry rock	200[d]	250 - 910
	Total	10,000	88,440 - 293,100
2000 - high	The Geysers	3,000[c]	18,150
	Hot-water	35,800	378,740 - 1,442,740
	Hot-dry rock	200[d]	250 - 910
	Total	39,000	397,140 - 1,461,800
1990 "RIIA"[e]	The Geysers	2,000	12,100
	Hot Water	1,125	22,660 - 88,660
	Total	4,125	34,760 - 100,760

[a]Range of projected capacities from a variety of sources, Ref. 65-69, land estimates from Table 2.22.
[b]Based on units planned for production before 1985, from: Armstead, H.C.H., *Geothermal Energy*, Spon., Ltd., London, Table 7b.
[c]Reed, M.J. and G.E. Campbell, *Environmental Impact of Development in The Geysers Geothermal Field, USA*, Second U.N. Symposium on the Development and Use of Geothermal Resources, San Francisco, California, Vol. II, May 20-29, 1975.
[d]Assume post-1990 development at about the same pace as historical development at The Geysers.
[e]See text.

Source: Robeck, K., et. al., *Land Use and Energy*, Argonne National Laboratory, ANL/AA-19, September, 1980.

version processes provide a favorable net energy balance[70] and, secondly, whether or not sufficient feedstock exists nationally to meet a prescribed energy demand for ethanol from grain or methanol from wood.

Land Requirements

The level at which ethanol can be substituted for gasoline fuels is directly related to the availability of grain feedstocks. Most reviews of feedstock availability assume that competitive uses of grain will be satisfied first and the remainder will be available for ethanol production.[70-73] If, after domestic consumption and export, surplus grain is not available, the common assumption is that set-aside and diverted cropland could be utilized for grain production to produce ethanol. If such a resource base were available, the potential production of ethanol from corn could reach several billion gallons per year, assuming 2.6 gallons ethanol per bushel of corn[72] and 600 to 800 million bushels of corn set-aside.[74] Reliance on the availability of withheld cropland to support an alcohol fuels program is tenuous, however. Between 1961 and 1972, the U.S. averaged 21.7 million acres of corn land that were set aside and diverted (14 million to 27 million acres). Other grains contributed another 9 million set-aside acres during this period. Since 1972, a substantial decline in grain set-aside and diversion programs have occurred with no acreages withheld during 1974-1977.[75] In 1978, only 6.1 million acres of corn land and 8.4 million acres of wheat land were in set-aside or diversion programs.[76]

Current ethanol production in the U.S. is about 21 million gallons per year.[77] A recent statement by Energy Secretary Charles Duncan, supported by President Carter, expressed a desire "to convert 10 percent of unleased gasoline to gasohol within one year."[77] This goal implies an annual ethanol production of 430 million gallons by the end of 1980[77] (based on a 1979 production level of 42.7 billion gallons of unleaded gasoline). Bills introduced in the 96th Congress proposed ethanol production levels up to 920 million gallons/year by 1982.[78] Such levels would require 2 million to 4.4 million acres of corn which could be easily supplied from set-aside cropland (assuming pre-1974 set-aside levels).

To produce enough ethanol to substantially impact the importation of fossil fuel would require more cropland than set-aside or diversion can produce. Soil Conservation Service data indentify pasture, range, forest, and other land, by state, that has a "high" and "medium" potential for conversion to cropland.[79] These figures do not include cropland in set-aside or diversion programs, nor do they include federal lands. Texas, Missouri, and Georgia have the greatest number of acres that are rated as "high potential" for conversion to cropland (Figure 2.4). Eight states have over 5 million acres of "high" and "medium" potential for conversion to cropland (Figure 2.5).

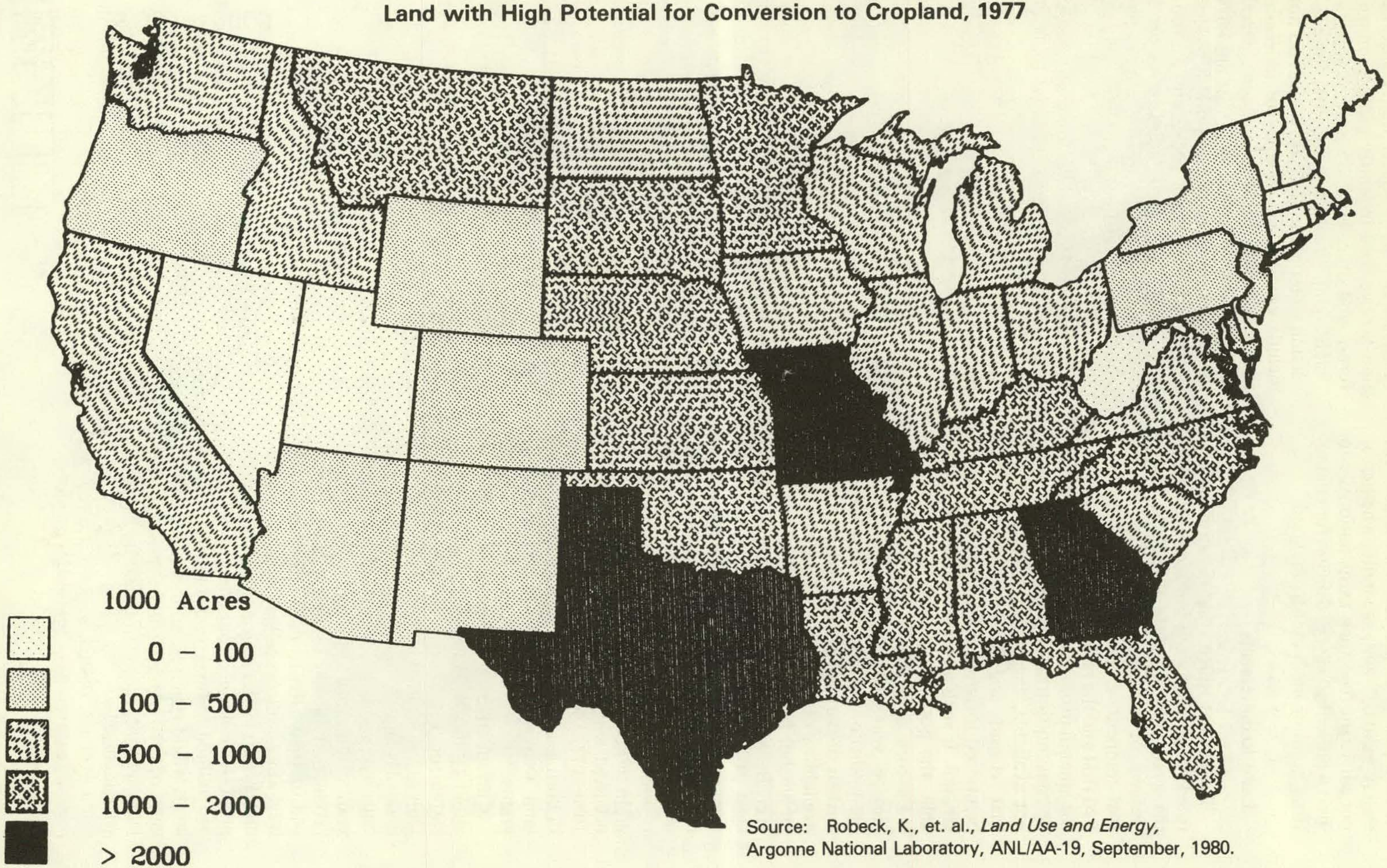
To examine the land required for gasohol programs, a study was conducted for a 17 state region in the central United States examining average requirements for grain under three demand scenarios for ethanol (Table 2.24)[72] A 100 percent gasohol product meant that 10 percent gasoline would be replaced by ethanol; 50 percent gasohol meant 5 percent and 25 percent gasohol meant a 2.5 percent gasoline replacement. Production levels of ethanol under these scenarios ranged from 1.3 billion gallons to 5.4 billion gallons in 1990 in the 17 state region. This region has 19.4 million acres of "high" potential cropland and 52 million acres of "medium" cropland.[79] If corn were grown exclusively on these lands for ethanol production, 17.5 million acres within the 17 state region would be required for a 100 percent gasohol substitution program by 2000 (16.9 million acres by 1990). A mixture of corn, grain sorghum, and wheat would require 26 million acres by 2000 (24.7 million acres by 1990).

National estimates for a 100 percent gasohol replacement program have been 10 billion gallons[80] to 12 billion gallons per year.[81] Such production levels might require all 36 million acres of "high" potential and from 12 to 21 million acres of the "medium" potential cropland in the nation. Such production would result in direct conversion of land use of 40 percent of the reservoir of "high" and "medium" potential cropland. Similar estimates of land requirements have been reported.[82]

The use of methanol in a gasoline substitution program has received attention primarily because of the large resource of woody feedstock that could be used in the conversion process. The nation's standing forests contain an energy equivalent of nearly 300 quadrillion Btus (above ground) with 85 percent of the total in commercial forest.[88] Wood biomass that might be avail-

Figure 2.4

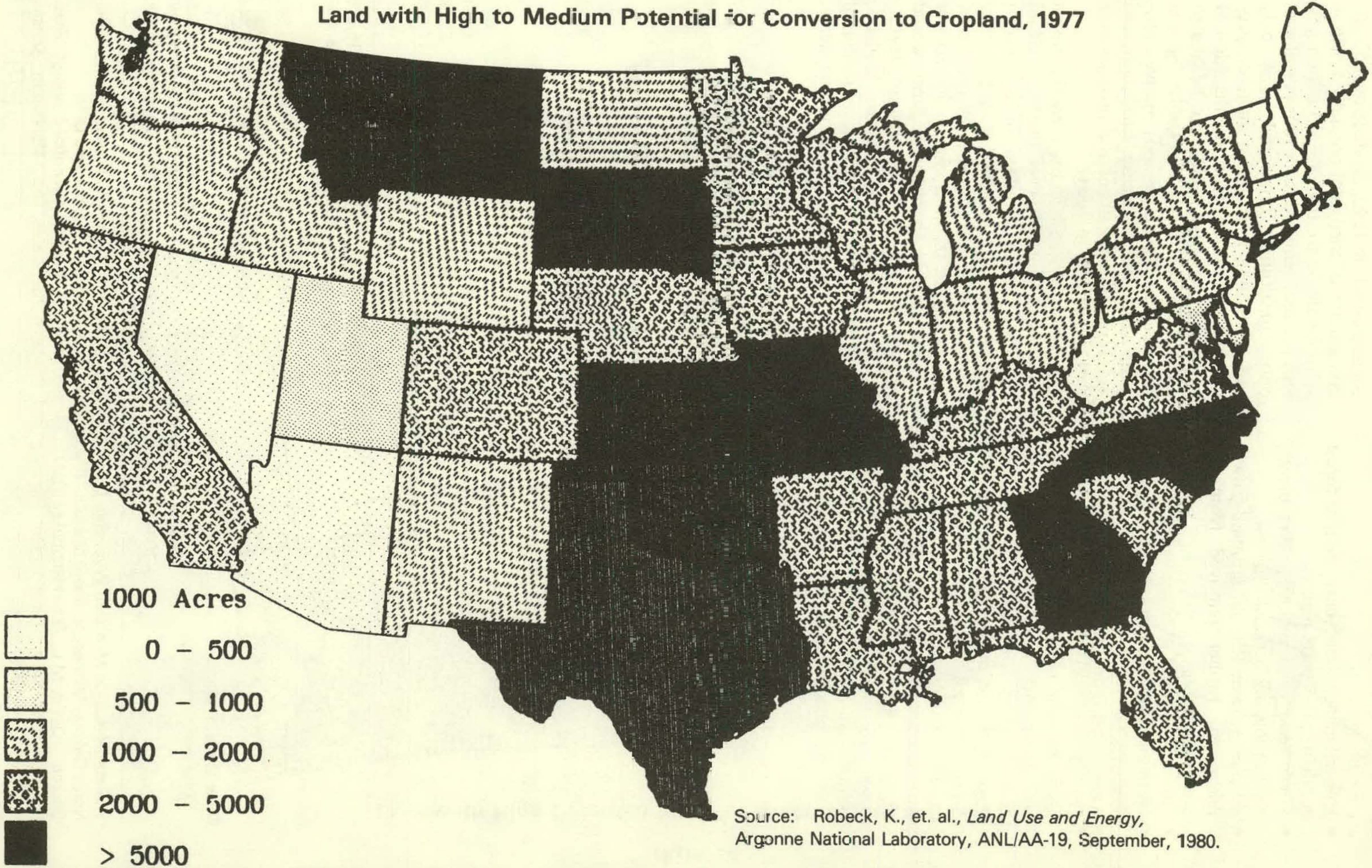
Land with High Potential for Conversion to Cropland, 1977



Source: Robeck, K., et. al., *Land Use and Energy*, Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 2.5

Land with High to Medium Potential for Conversion to Cropland, 1977



Source: Robeck, K., et. al., *Land Use and Energy*, Argonne National Laboratory, ANL/AA-19, September, 1980.

able without causing major impacts on land use include:

- Unused mill residues (bark, etc., at forest products processing plants).
- Forest residues (branches, broken pieces, etc.) at logging sites.
- Surplus growth (the net annual growth minus the timber removed from the growing stock).
- Annual mortality of the growing stock.
- Noncommercial timber (rough, rotten, or dead trees).
- Timber on noncommercial forest land (forest land that cannot yield timber crops because of adverse site conditions and forest land withdrawn from commercial timber use).

Projections of future availability of these resources gives a potential contribution of 7 quadrillion Btus per year in 1990.[80] The decrease in resource availability is due to an increase in timber utilization or decrease in surplus growth. The availability of mill residues may also decrease because of a projected increase demand for these residues for process fuel. The woody biomass resources could, in 1990, produce over 57 billion gallons of methanol annually which is substantially more than the 10 billion gallons per year required for a 100 percent gasohol substitution program.[80] The only waste handling problem in alchohol production is the sludge from the digestion of wood for methanol, which can be treated and used for fertilizer. The major regional contributors to such a woody biomass program would be the Pacific, Mountain, and Southeast regions; all could contribute over a quad per year in 1990.

Beyond 1990, silviculture energy farms could be developed to eventually provide all the wood biomass required for the gasohol program. Such farms could contribute over 4 quads by 2000 with nearly 80 percent of the potential resource from the eastern United States.[80] These energy farms would require the conversion of pasture, forest, range, rotational hay and pasture, hayland, and open land. For a wood to methanol program, approximately 23 million acres,

Table 2.24

Indicative Cropland Requirements In The 17 State Region[a] for Ethanol, 1980-2000[b]

Crop	% Gasohol Use Scenario	1980	1985	1990	1995	2000
		1000 Acres				
Corn						
	25	4,250	4,179	4,217	4,306	4,384
	50	8,503	8,363	8,438	8,612	8,766
	100	17,008	16,727	16,880	17,224	17,536
Grain Sorghum						
	25	6,950	7,023	7,227	7,574	7,841
	50	13,906	14,052	14,459	15,149	15,678
	100	27,811	28,105	28,924	30,297	31,361
Wheat						
	25	13,642	13,727	13,927	14,202	14,963
	50	27,296	27,466	27,865	28,404	29,917
	100	54,593	54,593	55,740	56,808	59,844
Three Crop Production Weighted Average	25	6,210	6,130	6,190	6,340	6,500
	50	12,420	12,270	12,380	12,680	12,990
	100	24,840	24,540	24,720	25,360	25,990

[a]The states include Montana, Wyoming, Colorado, Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Iowa, Missouri, Illinois, Wisconsin, Michigan, Indiana, and Ohio.

[b]Source: David, M.L., G.S. Hammaker, R.J. Buzenberg, and J.P. Wagner, *Gashohol-Economic Feasibility Study,* Development Planning and Research Associates, Inc., Manhattan, Kansas, July, 1978.

Table 2.25

Land Use Requirements for the Conversion of Alternative Feedstocks to Alcohol

Facility	Feedstock Requirements	Alcohol Production (10^6 gal/yr)	Land Requirements Facility (acres)	Land Requirements Feedstock (acres)
Corn Fermentation (ethanol)	25,000 bbl/day	20	80	100,000[a]
Corn and Wheat Residue (ethanol)	1,562 dt/day	25	120[b] 140[c]	-
Wood Methanol	1,000 dt/day	56	210	40,000[d]
Wood Ethanol	1,000 dt/day	33	159	40,000[d]

[a]Assumes 90 bu/acre.
[b]Acid hydrolysis.
[c]Enzymatic hydrolysis.
[d]Feedstock derived from energy farm.

Source: Dale, L., R. Opiela, and J. Surles, *Alcohol Production from Agricultural and Forest Residues,* Argonne National Laboratory, ANL-EES-TM-88, May, 1980.

or about 18 percent of land identified as having "medium" and "high potential" for conversion to croplands would be utilized for silviculture energy farms.

Table 2.25 provides estimates of land used for the operation of model plants that convert grain to ethanol, crop residues to ethanol, wood to methanol, and wood to ethanol.[84]

Potential Land Use Conflicts

This analysis assumes a static reserve base of potential cropland for conversion over the next twenty years, which is unrealistic. Between 1967 and 1975, 24.3 million acres were converted to urban and other nonfarm uses.[81] Thirty-four percent of this total was prime farmland and 5.5 million acres were converted from crop production.[85] The national loss of prime farmland is estimated at 1 million acres per year or about 4 square miles per day. Over half of this acreage is subdivided or placed into residential use. During the 1967-1975 period, 79.2 million acres of pasture and rangeland were added as cropland. However, since 1974, price-cost relationships have made it less economical to convert land to farm use.[79] If the use of farmland continues at this rate, the use of "high potential" cropland for energy purposes will meet increasing competition with its use for food and fiber. The use of crop and lumber residues is not considered by some as a viable source of feedstock to meet large, near-term levels of alcohol production, i.e., levels that would contribute significantly to a national gasoline substitution program.[71,77]

Also, the removal of crop and forest residues both uncovers land, making it susceptible to erosion, and removes the natural decaying process, which may require replacements with chemical fertilizers.

Hydroelectric

Hydroelectric power in the United States has developed rapidly during the twentieth century. Installed capacity doubled between 1921 and 1940, and tripled between 1940 and 1960.[86] Since the late 1960s, however, the rate of expansion of hydroelectric power has declined from these earlier levels for several reasons:

- The most favorable sites were already developed, and undeveloped sites were not as attractive when compared to other energy sources.
- Electrical demand increased rapidly during the 50's and 60's, while concomitant expansion of cheap oil and natural gas, as well as optimistic forecasts concerning nuclear technologies, led to a decreased interest in further development of hydroelectric.

During the past several years, rising costs of fossil fuels and higher costs of meeting tough environmental standards for nuclear facilities has made hydroelectric power more acceptable to both the public and to utilities.[87]

The U.S. Army Corps of Engineers has identified about 50,000 existing small dams in the U.S. of which less than 1000 are currently producing electricity. Many of the dams had, at one time, generated electricity, but had suffered equipment failure or became uneconomical to operate. While the current capacity of the existing hydroplants exceeds 64,000 MW, the Corps suggested that an additional 2,100 MW could be obtained at these existing sites with additional and improved generators. Nearly 34,000 MW could be generated by converting the nonhydropower dams to hydropower.[86,87,88] The total potential hydropower resource base in the United States is, therefore, 119,000 MW (Figures 2.6 and 2.7).

The regional distribution of hydroelectric plants is variable and, generally, reflects both physical and social influences. The largest hydroelectric generating capacity in the United States is found in the Pacific Northwest. The greatest number and density of small scale hydroelectric plants is in the northeast and the Lake Central regions. All three of these regions have the greatest potential for developing small scale hydropower.[87]

Much interest has been directed recently toward using pumped-storage hydroelectric power. Its greatest value lies in reducing peaking costs by using cheap, off-peak power to pump the water from a lower reservoir to a higher reservoir during off peak hours. During peak periods the flow of water from the higher reservoir to the lower is used to generate electricity. Pumped-storage hydroelectric plants currently provide 10,000 MW of electricity in the U.S.[88]

Conventional and pumped-storage hydroelectric plants typically require storage reservoirs, except in those cases where water flow is sufficent ("run-of-river") to contribute a base load. The size of the reservoir created by a dam is extremely variable and depends on the physical characteristics of the area, capacity of the facility, etc. Impoundments typically inundate large areas (often 10,000 to 20,000 acres). Attempts to estimate reservoir area by using published data[87,89] on maximum storage, dam height, or gross static head for individual plants did not correlate with actual reservoir size in reference plants. Valley shape, or excavation configurations are too variable to allow a simple calculation of reservoir area using storage capacity and dam height or head.

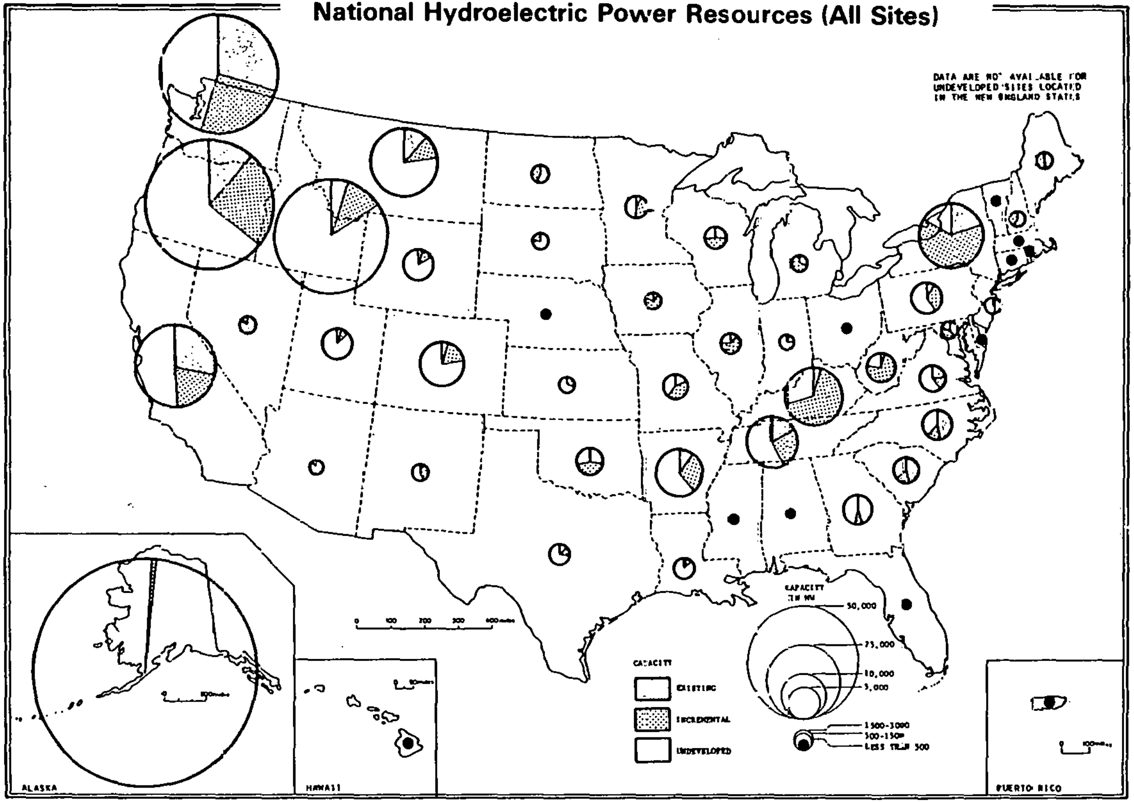
The large amount of area typically inundated by large hydroelectric projects can cause land impacts of some magnitude, but there are a number of positive aspects. In addition to providing electric power, the projects often play an important role in water supply and flood control and provide significant recreational opportunities. Thus, unlike most of the other energy-related facilities discussed in this report, hydroelectric development provides a different range of multiple uses for the land rather than reserving the area for a single use. Some of these new uses may cause secondary land impacts, however. For example, increased recreational activities can damage vegetation, cause increased erosion, or damage wildlife habitat.[10]

Hydroelectric development has, historically, been curtailed by federal legislation. Development in National Parks or Monuments has generally been prohibited. More recently, the Wild and Scenic Rivers Act (1968) has designated segments of rivers to be included in the National Wild and Scenic Rivers systems. These segments are precluded from hydroelectric development. The undeveloped conventional hydropower capacity on these river beaches is estimated to be nearly 4,754 MW at 31 sites, and 1,443 MW of known pumped storage potential.[89] The Wilderness Act of 1964 established a National Wilderness Preservation System on federal lands. Incompatible land and water uses such as hydroelectric facilities are prohibited in these areas unless special authorization is given by the President.

A 34 percent increase in hydroelectric capacity is projected by 1990 over 1975 levels.[90] Most of this increase is projected for Washington and Oregon; however, major increases are expected for California, Colorado, Georgia, Idaho, Montana, Nebraska, New Mexico, Ohio, Pennsylvania, Virginia, and West Virginia. The amount of land that potentially may be impacted by these additions, and the nature of impacts, can be estimted only after a site specific evaluation.

Figure 2.6

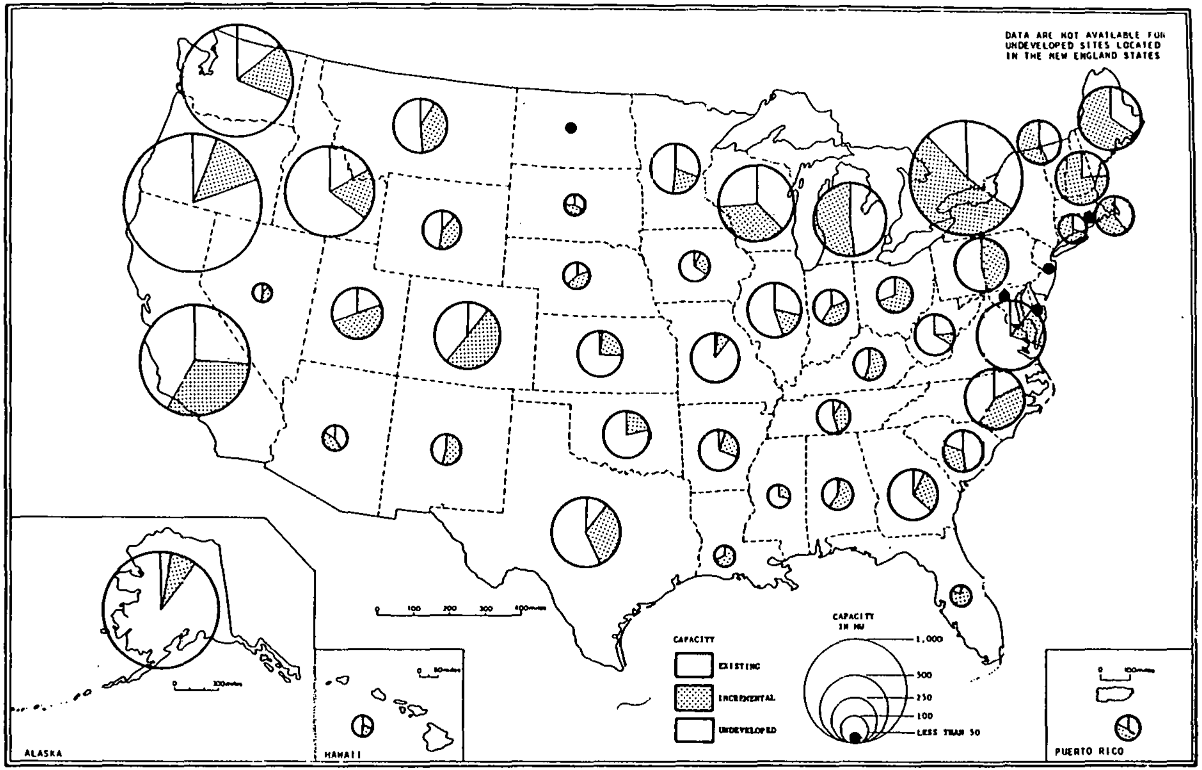
National Hydroelectric Power Resources (All Sites)



Source: U.S. Corps of Engineers. *National Hydroelectric Power Resources Study,* Preliminary Inventory of Hydropower Resources, 1979.

Figure 2.7

National Hydroelectric Power Resources (Small-Scale Sites)



Source: U.S. Corps of Engineers, *National Hydroelecric Power Resources Study,* Preliminary Inventory of Hydropower Resources, 1979.

AGRICULTURAL LAND VS. ENERGY ACTIVITIES

This discussion will address the important topic of energy development competing for land used for growing food and fiber and the need for cognizant energy facility siting decisions which encompass the possible changes in this crucial resource. Included will be direct farmland displacement in terms of permanent and temporary use of land by energy developments, the indirect impacts on adjacent cropland, the regulatory control over use of agricultural lands, and conclusions.

Concern over this topic centers on the possible loss of prime agricultural lands. The Soil Conservation Service in their "capability classes" defines prime agricultural lands as soils on which row crops can be grown using a minimum of conservation practices or special equipment.[79] SCS is currently quantifying this definition so as to complete an inventory of 1200 high priority counties by 1981. This inventory will balance such variables as soil moisture, temperature, humidity, drainage, and slope. Currently, prime agricultural land includes nationally or regionally unique farmlands, such as Michigan's sour cherry orchards or California's vineyards.

This resource is undergoing constant conversion to urban and non-farm uses. The loss of prime farmland is estimated at 1 million acres per year or 4 square miles per day. Over half of this acreage is subdivided or placed into residential use, a non-recoverable, permanent reallocation of land.[85]

Currently agricultural land management and control of agricultural land conversion is the responsibility of local and state agencies. There is no federal legislation for farmland preservation, but bills were introduced into Congress in 1979 for federal agencies to consider agricultural values in decision-making. Some agricultural land may be released either for energy activities or replacement for lost farmland through the leasing structure of federal lands. In addition, an interagency National Agricultural Lands Study was recently announced by the Council on Environmental Quality and USDA. That study, to be completed in 1981, will investigate the causes and extent of the conversion of agricultural land to nonagricultural uses, and assess the role of the Federal Government in influencing this conversion.[91] Their preliminary reports on increasing domestic production of energy and its impact on agricultural uses discusses this topic and stresses the need for conscientious preservation of agricultural resources.[92] The indirect impacts of energy land uses are controlled to minimize detrimental effects by the regulatory legislation discussed in the first part of this section (e.g., Clean Air and Water Acts, SMRCA, and RCRA).

Many states have developed programs aimed at restricting the development of agricultural land. Although the nationwide impact of these programs on energy siting may be slight, in certain states the impact will be significant. The land use programs are listed by type and state in Table 2.26.

Zoning ordinances are used by municipalities to control and restrict land use. These ordinances normally pertain to types of development, size and location of buildings, use of open spaces, etc. Industrial land uses may be further regulated through building codes, permit systems, and air and water pollution controls. Most states, however, may use their power of eminent domain to invalidate zoning ordinances in order to construct energy facilities that are considered to be in the public's general welfare. A municipality may not consider the regional or national impacts of such conversions. Disruption of critical or unique prime farmland may affect food production beyond the local zoning responsibility.

To define the scope of land requirements for energy activities by 1990 in comparison with available cropland, Table 2.27 was developed, and quantifies the issue of cropland consumption for energy development. This is a worst-case scenario since it compares only available cropland to be consumed by energy activities. The earlier part of this section, land use by fuel type and cycle, explained in further detail that most future land requirements will be met by displacement of arid rangeland, pastureland, forestland, or land currently zoned for industrial use. To summarize potential land use conflicts, surface mining is expected to disturb cropland in the Midwest and Central West, forestland in Appalachia, and rangeland in the Great Plains and the remaining West. Although surface mining may disturb only 41,000 acres of cropland in 1990, 40 to 50 percent of the strippable reserves in these regions may be covered by prime agricultural lands. Coal and oil combustion for electric utilities will occur in industrial areas, if PSD increments are available; or in rural, possibly agricultural, areas

Table 2.26

State Programs for Preservation of Farmland, by Type of Program

State	Preferential property tax assessment	Preferential property tax assessment with deferred taxation	Preferential taxation with restrictive agreement	Circuit breaker state income tax credits	Inheritance and estate taxation	Land gains taxation	Agricultural districts	Agricultural zoning	Purchase of development rights	Transfer of development rights	Land use commissions	Land banking
Alabama		s										
Alaska		s							b	s		
Arizona	s											
Arkansas	s											
California			s			b		b				
Colorado	s											
Connecticut	s				s				s			
Delaware	s											
Florida	s											
Georgia												
Hawaii			s					s	b		s	s
Idaho	s											
Illinois		s				b						
Indiana	s											
Iowa	s										s	
Kansas		s			s							
Kentucky		s			s							
Louisiana	s											
Maine		s							s			
Maryland		s,b							s	b		
Massachusetts		s							s			s
Michigan			s	s	s							
Minnesota		s	b	b								
Mississippi												
Missouri	s											
Montana		s				b						
Nebraska		s										
Nevada		s										
New Hampshire			s						b			
New Jersey		s							s, b	b		
New Mexico	s											
New York		s			s		s			b		
North Carolina		s										
North Dakota	s			b								
Ohio		s					b					
Oklahoma	s											
Oregon		s				b		s			s	
Pennsylvania		s	s				b					s
Rhode Island		s										
South Carolina		s										
South Dakota	s											
Tennessee		s			s							s
Texas		s										
Utah		s										
Vermont		s				s						
Virginia		s				b	s		b			
Washington		s, b				b						s
West Virginia	s											
Wisconsin			s	s				s				
Wyoming	s											

Note: s = statute or program
b = bill

Source: Davies, Bob and Joe Belden, *A Survey of State Programs to Preserve Farmland,* (Washington, D.C.: Council on Environmental Quality, 1979).

where local or state zoning for power plants permit the new siting. Synfuels, oil extraction, oil shale, and uranium extraction will be predominantly in the West, displacing rangeland and possibly federal lands with low probability of conversion to cropland. Oil refineries will be sited predominantly near seaports in heavy industrially classified areas such as the coasts of Texas, Louisiana, and New Jersey, and the lakeside of Illinois. For uranium processing, agricultural lands most likely to be impacted are those which will be devoted to milling and mill tailings disposal, an activity which will continue to occur in arid, thinly populated rangeland. Potential geothermal production will also be located in arid western regions.

Thus, the greatest potential impacts to cropland reserves arises from the projected development of nuclear power plants, surface mining in certain regions, coal-fired utility plants in rural areas (which will be much more prevalent than oil-fired plants) and biomass production. These industries can be divided into two land use categories: permanent land allocation and temporary land use.

Nuclear power plants represent a permanent land use; however, the buffer zone or exclusionary zone represents 80 percent of a nuclear plant site. After further study, this

Table 2.27

Estimated Additional Area Required for Energy Activities by 1990[a] and Percentages of Available Cropland, a Scenario

1977 Cropland - 412,619,000[b]
Non-farmland with "high" and "medium" conversion potential - 126,989,000[b]
Loss of prime farmland to urban/residential use - 500,000 ac./yr. - 6,500,000[c]
Remaining available cropland, 1990 - 406,119,000
Remaining available potential cropland - 120,489,000

Fuel Type & Cycle	Energy Activities 1975-1990[d]	% of Remaining Available Cropland	% of Remaining Available Potential Cropland
Coal			
Extraction	1,007,400[e]	0.248	0.836
Combustion	211,000[f]	0.052	0.175
Synfuels	24,000	0.006	0.020
Oil			
Extraction	23,000	0.006	0.019
Processing	10,300	0.002	0.008
Combustion	7,700	0.002	0.006
Oil Shale	5,200 - 17,700[g]	0.001 - 0.004	0.004 - 0.015
Natural Gas	−3,000		
Uranium			
Extraction	18,100 - 36,000	0.004 - 0.009	0.015 - 0.030
Processing	20,300	0.005	0.020
Nuclear Power Plants	343,000[h]	0.080	0.285
Geothermal	69,000 - 241,000	0.016 - 0.059	0.057 - 0.200
Biomass	16,901,000 - 55,761,000[i]	4.162 - 13.730	14.027 - 46.280
National Total	18,639,700 - 57,702,100	4.6 - 14.2	15.5 - 48.0

[a]Assuming high level of production
[b]Source: 1977 Soil Conservations Resources Inventory, USDA, February, 1980
[c]Source: *Environmental Reporter,* May 16, 1980
[d]Derived from text, hydroelectric not estimated, see Table 2.3
[e]Surface mining only
[f]Includes solid waste
[g]Includes retorts
[h]Total site area
[i]Grain for ethanol plus processing requirements, 17 region only

land may be found to be reclaimable or even usable for farming while the plant is operating if it can be evacuated with dispatch. The high scenario projection of 343,000 acres for nuclear power plants is also tenuous, as further development of this energy form is beleaguered with controversy.

Figures 2.8 through 2.11 graphically depict the potential of displacement of cropland by surface coal mining. Table 2.28 identifies counties where specialty crop production may conflict with surface mining. Although surface mining is projected as one of the largest consumers of land for potential energy development, it is to be a temporary use of land. Mining regulations attempt to minimize the short- and long-term impacts of mining on the environment and the land. Federal and state laws are designed to ensure that all lands mined be reclaimed in a manner to reduce water quality impacts and return land to a usable condition. SMCRA requires that lands be restored to at least 90 percent of their original productivity. Pre-mining and post-mining land use need not be the same, and local preferences in land uses may cause a permanent change from the pre-mining use. Wildlife habitats may be altered, and some unique lands for production of specialty crops may not be reclaimable.

When used for coal-fired power plants, agricultural or pasture land will be effectively lost from all future agricultural production. Given a typical power plant lifespan of over 30 years, it is doubtful that reclamation of a used utility site will ever be attempted. Coal ash and flue gas desulfurization disposal ponds will generally need to remain isolated from agricultural use once plant operation is completed because of the potential for trace metals to bioaccumulate in crops and other vegetation. Whether or not these losses can be confined to just the acreage used for a disposal site is a site-specific problem that depends upon many factors in the ambient environment, on how well the disposal site is managed, and on whether ecologically sensitive areas such as animal migration paths or nesting grounds exist. It should be noted, however, that the relative area requirements for fossil power plants are small in comparison to other energy activities such as surface mining.

The use of biomass as an energy source will require that large acreages of land be devoted to crop production for energy uses. Millions of acres may be converted from other rural uses, potentially making biomass the largest energy-related consumer of land. Of the land requirements for energy activities shown in Table 2.27, 90 percent of the projected land requirement is for biomass, a conversion of prime agricultural land. However, the resources are available for development of this temporary land use. The second interim report of the National Agricultural Lands Study gives an interesting analysis of the economics of such conversion:

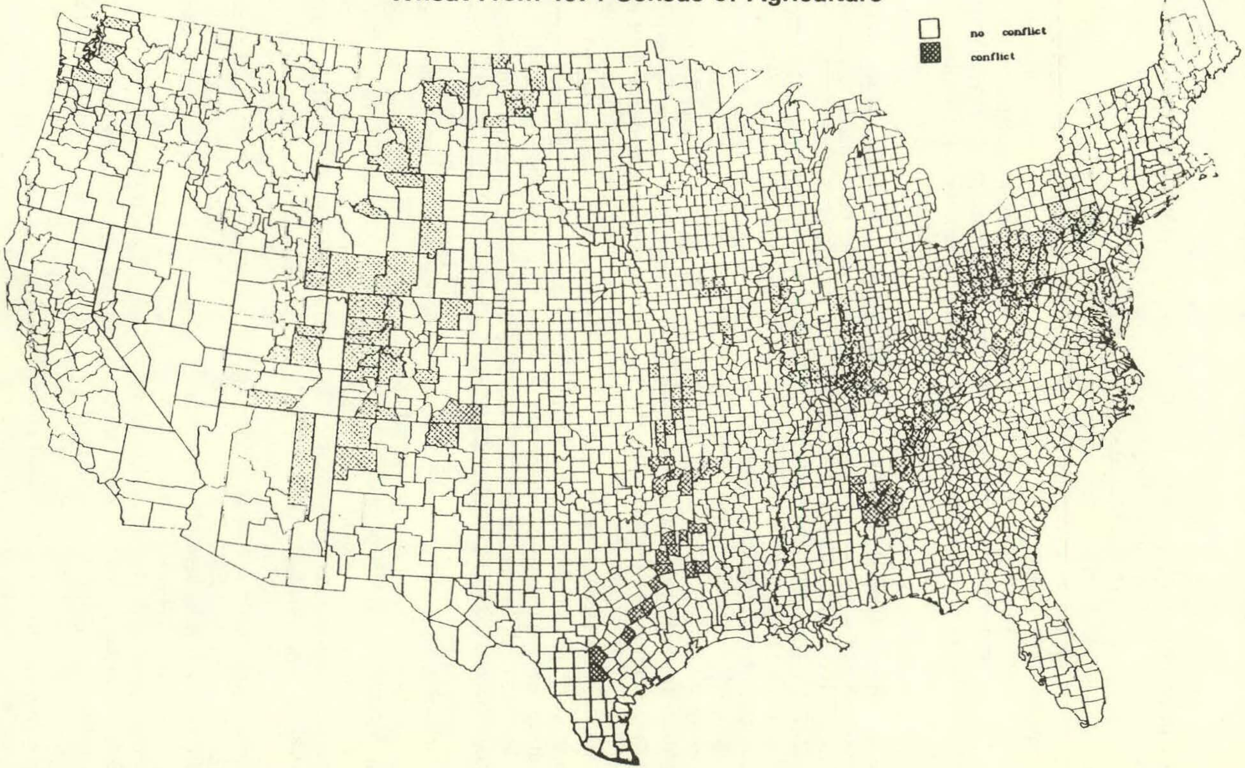
> "If gasohol crops are to be produced by farmers within the structure of U.S. agriculture, energy use of crops simply increases existing demand for these crops, strengthening the market and enhancing profitability of farming. Presumably, this enhances agriculture's ability to compete successfully with non-agricultural uses contending for the same land base. On the other hand, if gasohol crops are produced outside the agricultural structure—for example, by the oil industry—the competing demand would not necessarily enhance the competitive position of farmers producing commodities for food and fiber as traditionally defined. Policy prescriptions that would "protect" agricultural land in the face of national energy initiatives thus are not immediately apparent."[92]

Allocation of cropland to either biomass or food and fiber production is a decision that can be renewed annually for grain to ethanol programs. The use of soil management practices and high yield tree farms, as in the forest industry, should keep soil fertility impacts minimal. Biomass produces very little indirect land use impacts relative to water and air quality, but water availability may cause conflicts between energy farms and other farming and biomass may increase sedimentation in local streams.

The indirect impacts of energy development on farming are more serious for other energy industries. A major concern associated with the refining and combustion of fossil fuels is the possible impact of air pollutant emissions on crops and natural vegetation. Effects of both chronic and acute levels of sulfur dioxide and other gaseous pollutants on crop yields is well documented.[93] Crops and natural vegetation sensitive to sulfur dioxide and reported injury values have been identified and summarized;[94,95] however, the synergistic or antagonistic effects that have been observed from combinations of pollutants make the

Figure 2.8

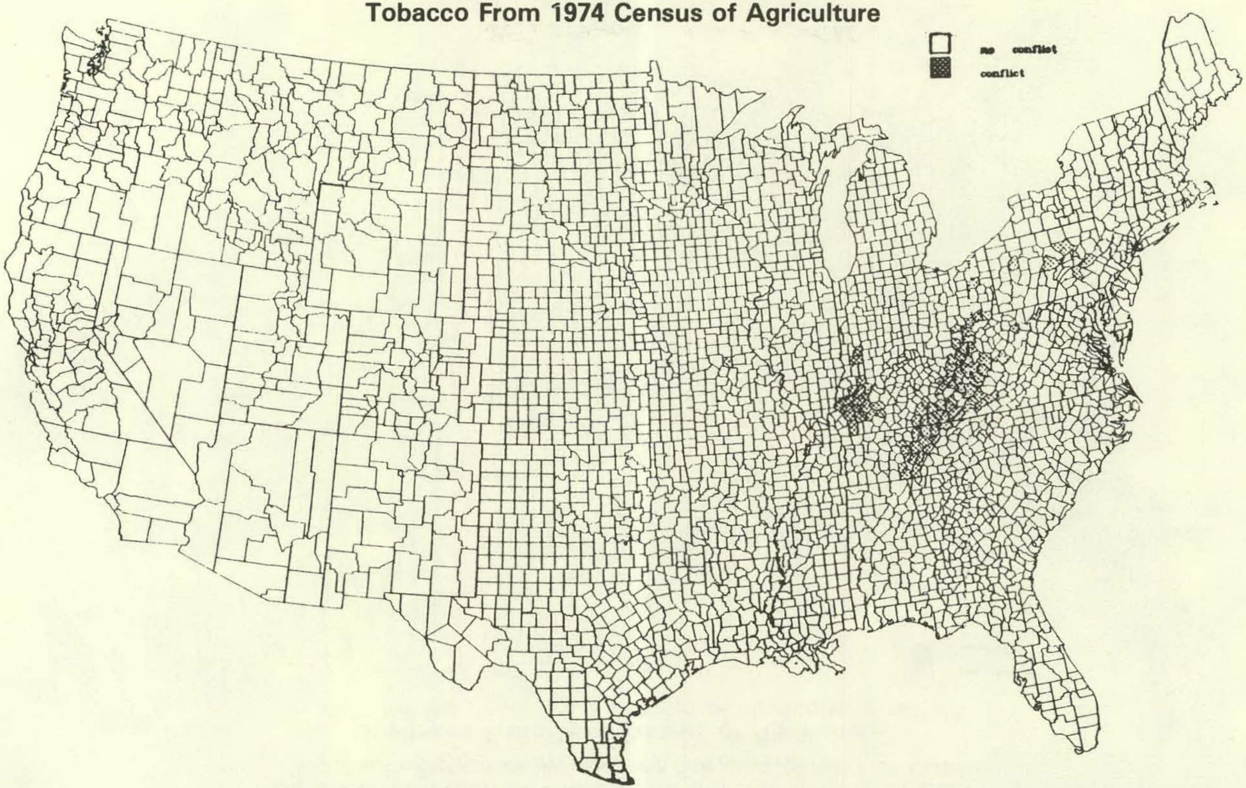
Conflicts Between Wheat and Surface Mining of Coal
Coal From 1990 TAD Scenario
Wheat From 1974 Census of Agriculture



Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 2.9

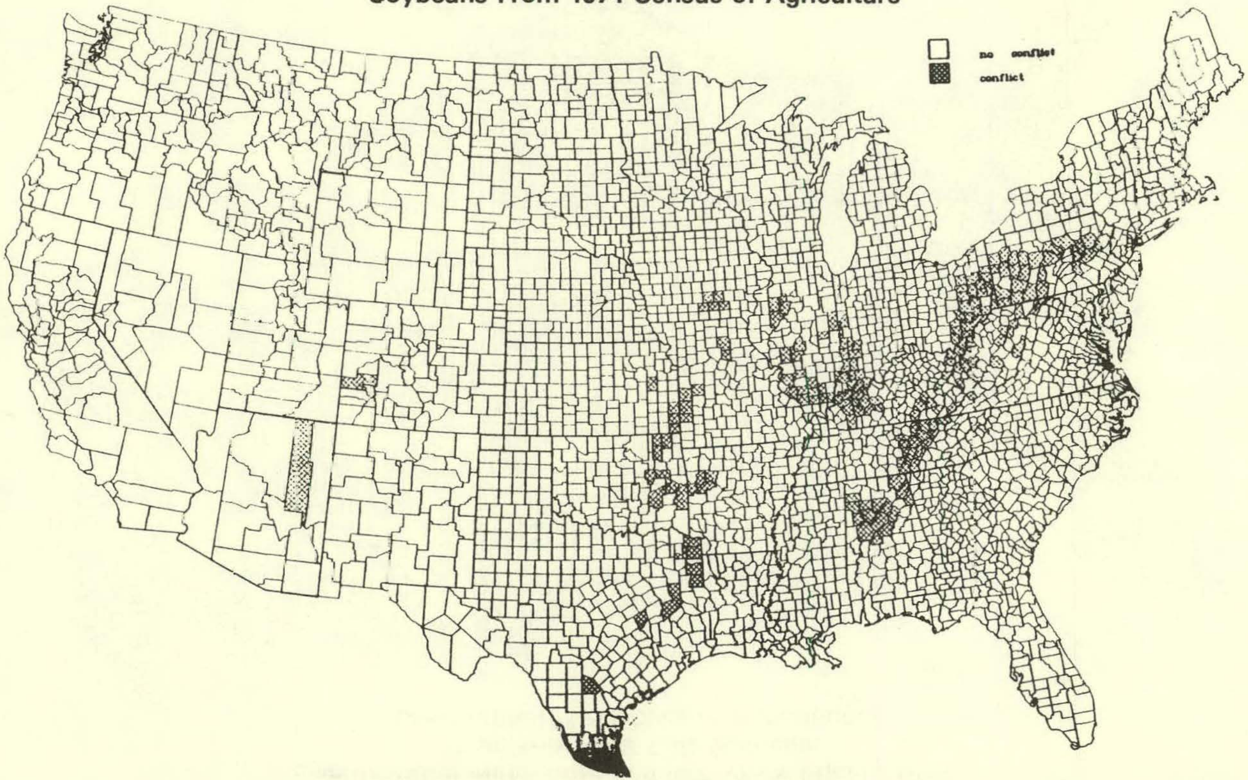
Conflicts Between Tobacco and Surface Mining of Coal
Coal From 1990 TAD Scenario
Tobacco From 1974 Census of Agriculture



Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 2.10

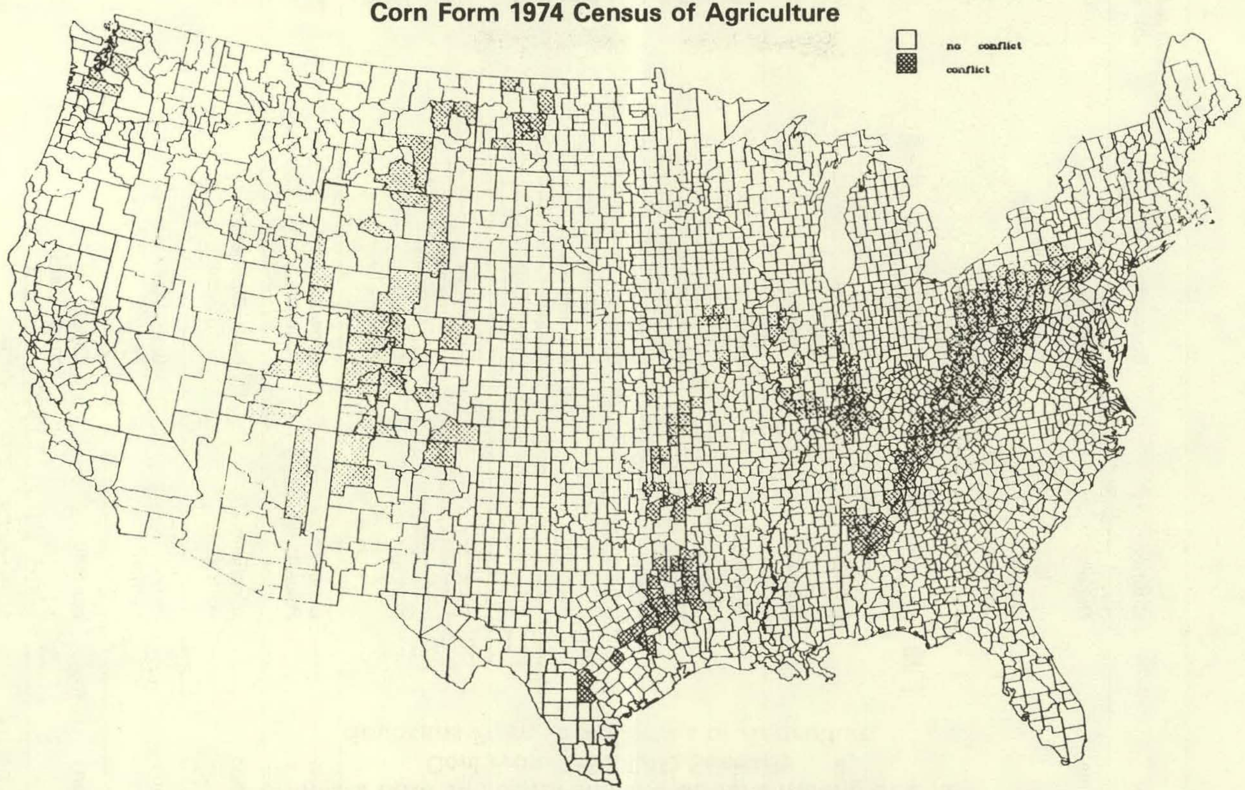
Conflicts Between Soybeans and Surface Mining of Coal
Coal From 1990 TAD Scenario
Soybeans From 1974 Census of Agriculture



Source: Olson, R.J., C.J. Emerscn, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 2.11

Conflicts Between Corn and Surface Mining of Coal
Coal From 1990 TAD Scenario
Corn Form 1974 Census of Agriculture



Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Table 2.28

Conflicts Between Surface Mining And Specialty Crops*

State	County	Specialty Crop	Harvest Acres Rank in Nation
Alabama	DeKalb	Collards	88
		Pimentos	9
		Turnip Greens	59.5
	Franklin	Pimentos	28
	Jefferson	Collards	46.5
		Cowpeas	63
		Okra	42
		Turnip Greens	33
	Walker	Turnip Greens	31
Arkansas	Franklin	Cowpeas	33
		Grapes	51
	Johnson	Peaches	99
Colorado	Montrose	Onion - Dry	58
Illinois	Peoria	Muskmelons	53
		Pumpkins	13
	St. Clair	Eggplant	100
		Okra	79
		Turnips	96
	Vermilio	Asparagus	15
		Pumpkins	11
		Sweet Corn	29
Indiana	Knox	Cantaloupe	22
		Muskmelons	15
		Watermelons	37
	Sullivan	Pumpkins	90.5
		Watermelons	83
Kentucky	Butler	Pimentos	52
	Pulaski	Pimentos	41
Maryland	Allegheny	Black Raspberries	20
	Garrett	Snap Beans	91
Missouri	Henry	Black Walnuts	59.5
	Vernon	Pecans	100
Montana	Richland	Barley	97
		Sugar Beets	61
North Dakota	McHenry	Barley	100
		Oats	41
		Rye	52
	McLean	Oats	84
	Stark	Oats	74

Table 2.28 (Cont'd.)

Conflicts Between Surface Mining And Specialty Crops*

Ohio	Columbia	Black Raspberries	24
		Red Raspberries	41.5
		Strawberries	77
	Holmes	Black Raspberries	68
	Jackson	Black Raspberries	38
	Mahoning	Muskmelons	84.5
	Meigs	Cabbage-Head	90.5
	Muskingom	Black Raspberries	47
	Stark	Beets	57
		Endive	7
		Escarole	8
		Onion-Green	33
		Lettuce	43
		Spinach	72
	Washington	Peppers	89
	Wayne	Black Raspberries	31
		Red Raspberries	80.5
Oklahoma	Le Flore	Cowpeas	19
		Spinach	24
	Okmulgee	Pecans	24
Pennsylvania	Allegheny	Eggplant	92.5
		Endive	55
		Escarole	40.5
		Kale	60.5
		Nectarines	53
	Armstrong	Grapes	96
	Columbia	Broccoli	94.5
		Snap Beans	80
	Luzerne	Broccoli	68
		Cauliflower	80
		Pumpkins	86
	Schuylkill	Cabbage-Head	80
		Nectarines	57
		Other Nut Trees	15
		Pumpkins	43
Tennessee	Cumberland	Snap Beans	21
	Fentress	Snap Beans	62
Texas	Anderson	Watermelons	91
	Atascosa	Cantaloupe	95.5
		Cowpeas	60.5
		Onion-Green	39
		Peppers	75
		Squash	15
		Turnips	55.5
		Watermelons	47
	Bastrop	Blackberries	70

Table 2.28 (Cont'd.)

Conflicts Between Surface Mining And Specialty Crops*

Texas (cont.)	Bexar	Beets	81.5
		Cauliflower	40
		Carrots	86
		Collards	62.5
		Cowpeas	74.5
		Eggplant	35.5
		Endive	39
		Onion-Green	38
		Mustard Greens	17
		Okra	29.5
		Pecans	80
		Peppers	99.5
		Turnips	80
	Milam	Pecans	82
		Watermelons	70
	Robertson	Watermelons	73
	Rusk	Watermelons	48
	Van Zand	Cowpeas	42
	Wood	Watermelons	46
Washington	Lewis	Walnut-Black	59.5
		Filberts and Hazelnuts	13
		Green Peas	78
		Red Raspberries	40
		Strawberries	67.5
	Thurston	Blueberries	42.5
		Red Raspberries	29
		Strawberries	62

*Based upon the TAD coal extraction scenario.

Source: U.S. Department of Agriculture, *1974 Census of Agriculture.*

problem of predicting impacts complex.[96] Decreases in productivity, especially in natural communities, could result in long-term changes in species composition and, consequently, changes in society's perceptions of how the land should be used.

Also of concern is the effect of acid precipitation on crops. A number of air pollutants, including sulfur oxides, nitrogen oxides, and particulates, undergo long-range transport of several hundred kilometers and are further oxidized to more acidic species. Sulfur dioxide is responsible for about two-thirds of the acidity in precipitation. There is substantial evidence that acid rainfall is harmful to crops. While the subject of acid precipitation is currently under extensive study, it is believed that increased coal combustion by electric utilities is a major contributor to the overall increase in rainfall acidity in the Northeast.[97]

Because of their extensive need for cooling water, nuclear and fossil fueled power plants may conflict with availability of water for farming uses. A 1000 MW coal-fired plant with cooling towers operating at 60 percent annual load factor would consume about 7800 - 11,300 acre-feet per year of water. For those using cooling ponds, the consumption would be 9600 - 16,000 acre-feet/year.[98] Use of such large amounts of water may affect the productivity of croplands not directly removed by construction.

In conclusion, the resources are available for increasing domestic energy production and reducing reliance on foreign sources without loss of food production levels, if such development is properly managed according to its land use impacts. Siting decisions become a necessarily complex balancing of alternative land uses, length of reallocations, and impacts on concurrent, adjacent land uses. The introduction of a federal role in this balancing designed to help preserve the availability of cropland for food would be comparable to other legislation which preserves the quality of our environment. Although sometimes time-consuming and complicated, federal control allows national and regional production goals to proceed within parameters that manage and greatly minimize long-term adverse impacts. A national energy program must address the issue of protecting food production, particularly in development policies for biomass, mining, and coal-fired and nuclear electricity generation.

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3. DATA DESCRIPTIONS

As illustrated graphically in Figure 3.1, land use issues associated with energy developments occurs when there is either a conflict between a proposed use for a parcel of land and an existing use or when federal, state or local land management policies or regulations effectively preclude the introduction of energy developments. The data presented in Section 4 have been selected with the intention of providing interested readers with a means by which land use and energy issues can be fully understood and, to some degree, become predictable.

The data in Section 4 are arranged in four categories. The first category consists of national and regional maps and tables that describe the natural physical characteristics of land forms in the United States. The second group of data provides a current baseline description of the major uses of land in terms of agricultural uses, existing energy and minerals development, and urban uses. The data in the third category describes federal and state land management policies as reflected in national maps and in tables while the fourth group consists of tabular data specifying the land requirements for development of future energy fuel resources. None of the data sets contained in any of these categories are all-inclusive. Rather, the data presented represents a compilation of existing data that were available at the time of this printing. New data will be added as this document is updated.

PHYSICAL LAND CHARACTERISTICS

Physical land characteristics include aspects of the environment related to topography, geology, water resources, biota, seismology, and ecology. The data presented in this portion of Section 4 are limited, however, to those characteristics which either have had or may potentially have an impact on energy development, particularly those which affect energy facility siting decisions.

Land Surface Forms

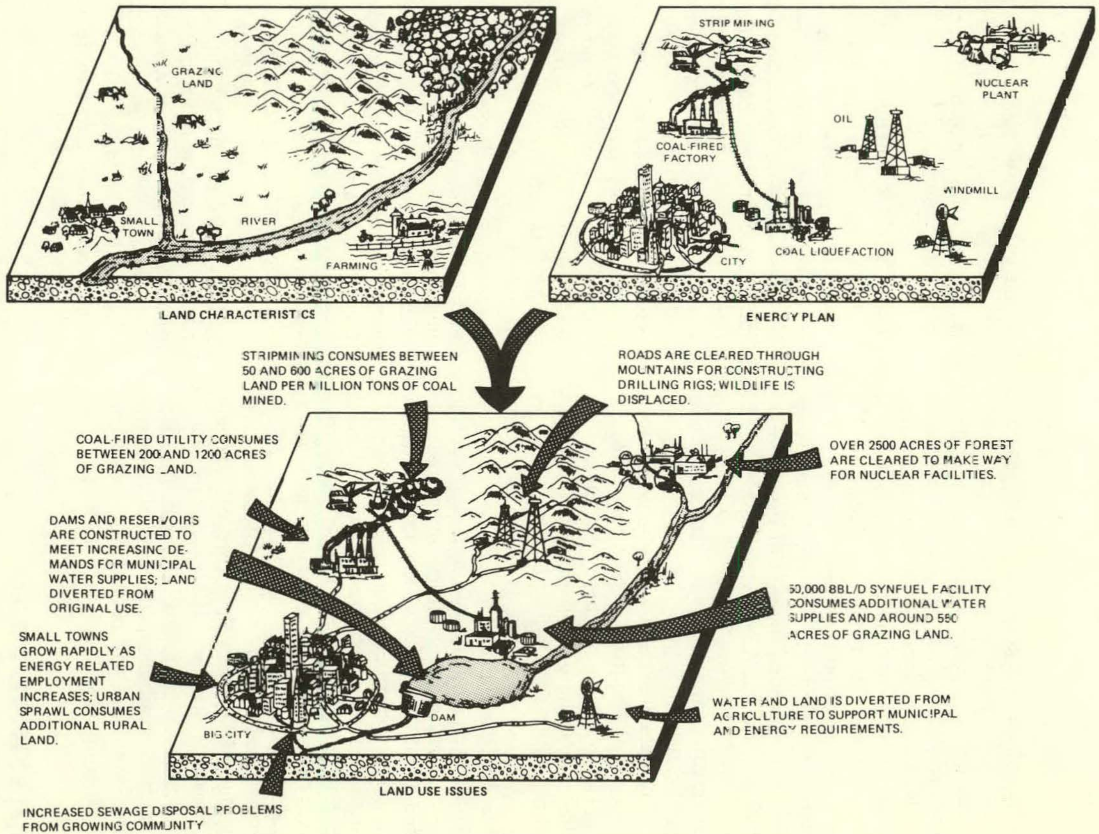
The overall shape and slope of land surface forms are extremely significant factors affecting energy facility siting decisions. While modern transportation, drilling and mining technologies have enabled energy developers to explore for and extract energy resources under the most severe topographical conditions, the development of any energy technology that includes the construction of large physical structures, such as a power plant, requires a uniform and relatively flat land surface.

The data concerning land surface forms include a series of regional and national maps which provide measurements of slope and elevation. A deliberate attempt was made to illustrate the different kinds of data available to measure these factors. As a result, the subsection includes classical relief-type maps, land-surface maps and computer generated elevation maps, which indicate ranges of elevation for every county in the southern United States.

While relief and elevation maps are rather simplistic in nature, land-surface forms maps can be rather difficult to interpret requiring constant consultation with the key. The rather complicated scheme of classification includes distinct symbols for slope, local relief, land profile type, plains, tablelands, plains with hills or mountains, open hills and mountains, sand covering, water covering, irregular peaks and cones, crests, and escarpments and valley sides. Slope, land profile type, sand covering and water covering are measured in terms of percentage while plains, tablelands, plains with hills or mountains, and hills and mountains are measured by adjectives such as, flat, smooth, irregular, moderate, high, low, etc.[1]

Figure 3.1

Conceptualization of the Relationship Between Land Use and Energy Development



Soils

Soil characteristics, such as nutrient content, drainage patterns, and thickness, can be extremely important factors in siting waste disposal sites and in reclaiming land which has been surface mined. In siting waste disposal sites, special care must be taken to ensure that the leaching characteristics of the soils do not permit the contamination of groundwater or surface water supplies. Although regulations promulgated under RCRA often stipulate the disposal method for certain wastes, soil characteristics can be important factors affecting the cost of site preparation.

Although soil characteristics rarely dictate decisions regarding sites for surface mining operations, they are extremely important factors affecting the cost of reclamation. SMCRA requires that overburden removed in surface mining operations be stored according to soil horizons so that it can be replaced in the same configuration that occurred naturally before it was disturbed. In addition, soil characteristics are key factors affecting the rate by which surface mined lands can be revegetated and returned to their original productive capacities.

In addition to the U.S. Geological Survey and the Soil Conservation Service, extensive surveys of soil characteristics and rates of erosion are made by state and county governments.[2] These surveys classify soils according to their color, composition (i.e., clay, oxides, peat, muck, etc.) temperature and moisture content. Section 4 contains a series of regional maps which identify soil characteristics according to the following classifications:[2]

- *Alfisols:* Soils with gray to brown surface horizon, medium to high base supply, and subsurface horizons of clay accumulation. Formative element: *alf.*
- *Aridisols:* soils with pedogenic horizons, low in orgainc matter, usually dry. Formative element: *ent.*
- *Entisols:* Soils without pedogenic horizons. Formative element: *ent.*
- *Histosols:* Organic (peat and muck) soils. Formative element: *ist.*
- *Inceptisols:* Soils with weakly differentiated horizons showing alteration of parent materials. Formative element: *ept.*
- *Mollisols:* soils with nearly black, organic-rich surface horizon and high base supply. Formative element: *oll.*
- *Oxisols:* soils that are mixtures principally of kaolin, hydrated oxides, and quartz. Formative element: *ox.*
- *Spodosols:* Soils that have accumulation of amorphous materials in subsurface horizons. Formative element: *od.*
- *Utisols:* soils with horizons of clay accumulation and low base supply. Formative element: *ult.*
- *Vertisols:* Cracking clay soils. Formative element: *ert.*
- *Miscellaneous land types:* Bare rock, salt flats, ice fields, and some included soils.

The classes of soils can be further disaggregated to the following subclasses:[2]

Class Mollisols

- *Subclass Borolls:* Black surface horizon used for small grain, hay and pasture agriculture in the north-central states, and for range, woodland, and some small grain further west.
- *Subclass Aquolls:* Seasonally wet soils with a thick, nearly black surface horizon. These soils are used for pasture and, where drained, for small grains, corn and potatoes.

Class Entisols

- *Subclass Orthents:* Loamy or clayey soils that rapidly decrease in organic matter with depth. These soils are used for range or irrigated crops in dry regions and for general farming in humid regions.
- *Subclass Psamments:* Loamy fine sand or coarser sand used for woodlands and small grains in warm and moist parts of the region, and for range or irrigated crops in warm and dry areas.

Class Alfisols

- *Subclass Boralfs, Udalfs, Aqualfs, Usalfs:* Contain medium to high base levels and have grey to brown surface horizon.

Class Histosols

- Wet organic soils (swamps and marshes) including peat and muck located in northern portions of the region. While used mostly for woodland, when drained, they become suitable for truck crops.

Class Inceptisols

- *Subclass Aquepts:* Seasonally wet with a light-colored or thin black surface horizon and used for pasture and hay production.

Class Spodosols

- *Subclass Orthods:* with low base composition, but high levels of iron and aluminum, these soils are used for hay, pasture, woodland, and fruit production.

Class Utisols

- *Subclass Udults:* Located in southern Missouri, these soils are basically moist with relatively little soil organic matter in the subsurface horizon. These soils are used for general farming, pasture, woodland, and in some areas, tobacco and cotton production.

Geology

Geologic characteristics, particularly seismic activity, are extremely important factors in siting energy facilities, especially fossil-fired and nuclear power plants. Similarly, rock structures and characteristics are significant determinants of costs involved with fuel resource exploration and extraction. In the case of oil shale, geologic conditions partially dictate the type extraction technology—i.e., surface retorting versus modified in-situ, etc.,—that will be utilized to separate the kerogen from the shale.

Geologic data presented are arranged in two sets. The first set of data consists of several regional maps which categorize sedimentary rocks into classical groupings according to age—pleistocene, pliocene, miocene, cambrian, pre-cambrian, quaternary, upper and lower terciary, cretaceous, the paleozoics, etc. (see Table 3.1). A computer-generated map of the geology of the southern United States is also presented as a means of illustrating different classification and mapping techniques. This map provides county level bedrock informtion classified according to four categories: igneous, metamorphic, consolidated sedimentary, and uconsolidated sedimentary.

The second set of geologic data presented pertains to seismic activity. In order to illustrate the various means by which seismic activity can be exhibited in graphic form, a series of maps have been compiled which demonstrate different aspects of seismic activity. Maps of the Rocky Mountain region and Alaska identify the major seismic faults. A second type of map presented illustrates the Nuclear Regulatory Commission's (NRC) designations of seismic risk -high, medium, or low. Finally, the NRC designations are translated into tabular form indicating the acreage of the three designations by state.

Wetlands and Wildlife

Until recently, water resources planning and management efforts have focused almost exclusively on permanent water resurces, such as rivers, streams, lakes and groundwater aquifers. During the past decade, however, government agencies and the public have given increased attention to protecting the existing natural and economic value of lands periodically flooded or otherwise saturated by surface or groundwater—floodplains and wetlands. Unwise development in such areas has resulted in increasing loss of life and property and in reduction of uses compatible with periodic inundation, such as agriculture and forestry, recreation, fish and wildlife habitiat. In order to discourage federal support of unwise development in floodplains and wetlands, and to provide federal leadership in preserving and enhancing the beneficial use of such areas, President Carter issued executive orders in May 1977 on floodplain management and wetland protection.[3] Similarly, the President has proclaimed numerous additions to the Wildlife Refuge System bringing the total area covered to 46 millin acres. (These acts are discussed in greater detail under the Land Use Management subsection.)

In essence, the growing concern for weltands and floodplains and wildlife habitat has effectively closed these areas to any kind of energy development. The data presented in Section 4 under this category consists of national maps which illustrate the location of natural wetlands, wildlife habit loss, and various biota ecoregions.

Finally a map is presented that describes the potential natural vegetation that would exist today if man were removed from the scene and if the resulting plant succession were telescoped into a single moment. The map reveals the geographical distribution of the types of vegetation in their settings on the continent and in their relation to one another.

LAND USAGE

The purpose of the data presented in the land usage subsection is to provide a baseline scenario of the major uses of land in the U.S. upon which a scenario of future energy development can be overlaid. By consulting this data, one can easily identify the amount of land currently occupied by energy facilities as well as the area where potential conflicts may arise between future energy develoment and existing land use.

The data are divided into two groups. The first group contains generic and crop-specific maps of major agricultural uses, pastureland, and non-federal forest land. In addition, the data in this group inlcude state and regional tables of major uses of land and principal commercial crops cultivated in the U.S. The second group includes tabular data of land area occupied by cx-isting energy facilities, including fossil and nuclear power plants, coal surface mines, uranium mills, oil refineries, etc. In addition, tabular data concerning acreage disturbed by non-fuel minerals development is presented.

Agricultural Land Use

One of the most significant issues concerning energy and land use involves the potential diversion of prime agricultural lands to energy uses. Lands devoted to the cultivation of corn, wheat, tobacco and soybeans are mapped on a county basis. these maps indicate the percentage of a county's area which is currently devoted to the cultivation of each of these crops.

Similar maps are presented for non-federal forest lands which indicate the percentage of the counties' acreage which is devoted to silviculture. Also included in this group are maps of pastureland, forest range and croplands in general. Finally, tables are presented which indicate state and regional land uses (in acres) for:

- cropland - total acreage in crop rotation;
- grassland and other nonforested pasture and range in farms excluding cropland used only for pasture, plus estimates of open or nonforested grazing land not in farms;
- forest land excluding reserved forest land and some unreserved areas;
- urban, transportation, recreational and other special uses of land; and
- miscellaneous areas such as marshes, open swamps, bare rock areas, deserts and special uses not inventoried by the Federal Government.

Energy and Nonfuel Minerals Land Use

The data presented under this heading in Section 4 present a compilation of tables and charts which directly supports the issues delineated in Section 2 under the fuel cycle discussion. The purpose of these tables is to provide the reader with a ready reference from which an understanding of baseline energy land usage can be obtained and to identify areas that contain fuel resources.

In addition to energy land use, a summary of land areas dedicated to the extraction of nonfuel minerals resources is also provided from a historical perspective. The purpose for inclusion of this data is to provide perspective of how energy-related extraction land use relates to the overall mining industry in the United States. It can be seen from these data that while coal extraction is the largest single extraction-related consumer of land, the total area dedicated to the open-pit nonfuel mining industry is far larger than that dedicated to fuel extraction. As a result, it should be noted that future allocation of lands to energy uses (particularly extraction) will represent a small percentage of the land potentially disturbed by the domestic mining industry, particularly as more and more attention is shifted to relieving the nation's dependence on foreign sources of critical minerals and materials.

The data presented in Section 4 includes tables of:

- acres of land utilized for mining selected nonfuel commodities in leading mining states, 1930-71;
- land disturbed by surface and open-pit mining, 1930-71;
- land disturbed by coal surface mining, 1975;
- land occupied by oil refineries by state and region, 1975;
- acreage occupied by uranium mills by state and type, 1979;
- fuel fabrication plant site size and demography;
- land occupied by fossil-fired and nuclear power plants, 1975;

and maps of land with high and medium potential for conversion to cropland for biomass production and of land containing major fuel reserves.

Lands dedicated to energy uses, mineral uses and agriculture, as summarized in this

Table 3.1

Geological History

ERA	PERIOD	EPOCH	Absolute age in years before present	Major geologic events in United States given in order of increasing age	Distinctive features of plant and animal life	
CENOZOIC	QUATERNARY	Recent (HOLOCENE)		Minor changes in land forms by work of streams, waves, wind	Rise of civilizations	Age of Man
			10,000			
		PLEISTOCENE		Four stages of spread of continental ice sheets and mountain glaciers	Development of man; extinction of large mammals	
			1,000,000	Cascadian orogeny: Cascade and Sierra Nevada ranges uplifted; volcanoes built		
	TERTIARY	PLIOCENE			Early evolution of man; dominance of elephants, horses, and large carnivores	Age of Mammals
			13,000,000			
		MIOCENE		Marine sediments deposited on Atlantic and Gulf coastal plain; stream deposits spread over Great Plains and Rocky Mountain basins; thick marine sediments deposited in Pacific coastal region	Development of whales, bats, monkeys	
			25,000,000			
		OLIGOCENE			Rise of anthropoids	
			36,000,000			
		EOCENE			Development of primitive mammals; rise of grasses, cereals, fruits	
			58,000,000			
		PALEOCENE			Earliest horses	
			63,000,000	Laramide orogeny: Rocky Mountains formed		
MESOZOIC	CRETACEOUS			Marine sediment deposition over Atlantic and Gulf coastal plain and in geosyncline of Rocky Mountain region	Extinction of dinosaurs; development of flowering plants	Age of Reptiles
			135,000,000	Nevadian orogeny: Intrusion of batholith of Sierra Nevada region		
	JURASSIC			Marine sediment deposition in seas of western United States; desert sands deposited in Colorado Plateau	Culmination of dinosaurs; first birds appear	
			180,000,000	Palisadian disturbance: Block faulting in eastern United States		
	TRIASSIC			Deposition of red beds in fault basins of eastern United States and in shallow basins of western United States	First dinosaurs; first primitive mammals; spread of cycads and conifers	
			230,000,000	Appalachian orogeny: Folding of Paleozoic strata of Appalachian geosyncline		
PALEOZOIC	PERMIAN			Deposition of red shales and limestones in southwestern United States; much salt and gypsum (glaciation of southern hemisphere continents)	Conifers abundant; reptiles developed; spread of insects and amphibians; trilobites become extinct.	Age of Amphibians
			280,000,000			
	CARBONIFEROUS: PENNSYLVANIAN			Deposition of coal-bearing strata in eastern and central United States	Widespread forests of coal-forming spore-bearing plants; first reptiles; abundant insects	
			310,000,000			
	CARBONIFEROUS: MISSISSIPPIAN			Deposition of limy, shaly sediments in widespread, shallow seas of central and eastern United States	Spread of sharks; culmination of crinoids	
			345,000,000	Acadian orogeny: Folding and igneous rock intrusion in New England		
	DEVONIAN			Deposition of thick marine strata in geosynclines of eastern and western United States	First amphibians; many corals; earliest forests spread over lands	Age of Fishes
			405,000,000			
	SILURIAN				First land plants and air-breathing animals; development of fishes	
			425,000,000	Taconian orogeny: Folding of rocks in eastern United States, Nevada, and Utah		
	ORDOVICIAN				Life only in seas; spread of molluscs; culmination of trilobites	Age of Marine Invertebrates
			500,000,000	Deposition of thick marine strata in geosynclines of eastern and western United States		
	CAMBRIAN				Trilobites predominant; many marine invertebrates	
			600,000,000			
	Precambrian time; age goes back to over four billion years			Many periods of sediment deposition alternating with orogeny	Earliest known forms of life; few fossils known	

Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

report, not only compete among themselves for land resources but also compete with other demands for land, such as residential development, transportation networks, recreation, etc. For example, although birth rates have decreased from the highs of the 1945-1959 "baby boom," the U.S. population increased by almost 2 million people in 1978.[5] Illegal immigrants, not counted in the official census estimates, may add an additional several hundred thousand to population growth each year.[6] All increases in population place additional burdens on the land. The magnitude of these land use impacts depends on many factors, including the rate of growth; the distribution of the new residents across the country; and population characteristics such as age, sex, race, mobility, education, employment, income, and household composition.

In the 1970's, two demographic trends have become particularly important in all parts of country: the trend toward smaller households and population dispersal to rural areas. The Council on Environmental Quality (CEQ) case studies of five rural areas suggest that these growth trends are affecting land use patterns profoundly and are straining local service and critical lands.[7] Although impacts such as these are beyond the scope of this report, it is recommended that the reader consult sources such as CEQ, in order to keep the land use impacts of energy development in a proper perspective with other changes occurring in the U.S.

LAND MANAGEMENT

As noted in the regulatory issue discussion, the federal, state, and local governments possess numerous mechanisms by which land use can be managed and in some cases, planned. These mechanisms consist of direct and indirect controls over land utilization as dictated by numerous laws and regulations. Examples of direct land management controls are those promulgated under the Federal Land Policy and Management Act (FLPMA), the National Parks and Recreation Act, and the Coastal Zone Management Act (CZMA). Indirect land management controls include those implied under environmental legislation and regulations such as the Clean Air Act, the Federal Water Pollution Control Act (Clean Water Act), and the Resource Conservation and Recovery Act (RCRA).

The purpose of land management portion of Section 4 is to provide readers with data concerning the magnitude of these controls and a geographical perspective as to where they are most prevalent. Just how they impact energy development is discussed at length in Section 2.

The data are divided into two parts. The first part deals with federal land management policies and is composed of numerous maps, charts, and tables that indicate the land areas under control of the Federal Government and Indian tribes, the size of these areas and recent trends in their growth. In addition, indirect land management policies stipulated under the nonattainment and prevention of significant deterioration (PSD) provisions of the Clean Air Act are graphically displayed. The second group of data concerns state land management policies and mechanisms, including summaries of state power plant siting laws, state programs to preserve farmland, state protection of significant natural resources under the CZMA, and state laws affecting management of coastal development.

Federal Land Management

The Federal Government owns and administers 760 million acres of land, one-third of the land area of the United States. The Bureau of Land Management (BLM) and the National Forest Service (NFS) have the prime responsibility for managing the bulk of the federal lands, with jurisdiction over 62 percent and 25 percent of the total, respectively.[8] These areas are illustrated on a national map. In addition, a table indicates the amount of land controlled by the BLM and NFS; estimates of lands withdrawn from mineral uses are also provided.

The largest contiguous blocks of non-federal coal found in the western U.S. are those owned by Indian tribes. Section 4 provides a generic map of these Indian lands as well as a map which indicates the amount of strippable coal reserves found on these lands.

Parks, Wilderness Areas and Refuges

In response to public sentiment that more of the nation's especially scenic and wild undeveloped lands be give permanent federal protection, a number of legislative proposals were put before Congress in 1978 and 1979. On November 10, 1978, Congress passed the National Parks and Recreation

Act, which made major additons to the nation's Wild and Scenic River System and the first additions to the Scenic Trails System since the system was created over a decade ago. The Act also created eight new wilderness areas covering almost 2 million acres, and added to the National Park System. Data included in Section 4 graphically describes where these areas are and summarizes in tabular form designated and proposed wilderness and scenic river segments.

The largest and most controversial wilderness issue over the past few years has been the Forest Service's Roadless Area Review and Evaluation Process (RARE II). In June 1977, the NFS initiated a special review of all roadless areas in the National Forest System in order to determine whether some of these lands should become part of the Wilderness System rather than be retained for multiple use. RARE II surveyed 2,919 wild and untouched tracts of National Forest and National Grasslands, totalling 62 million acres. In the RARE II Final Environmental Impact Statement, released January 4, 1979, the Department of Agriculture recommended that 15 million acres of national forest land be designated as wilderness. Of this, 9.5 million acres are in the lower 48 states and Puerto Rico. Additionally, 10.8 million acres were designated to receive further study, and 36.2 million acres were allocated to nonwilderness (28.6 million acres excluding Alaska).[9]

Additions during 1978 brought the National Wildlife Refuge System to 392 refuges covering 46 million acres. Although the system includes several different types of refuges, mammal and bird refuges and national monuments comprise most of the system. Section 4 contains a series of charts which provide an historical perspective of the growth in the refuge system since the early 1900s, the growth in acreage of the system and the numbers, by type, of the nation wildlife refuges in 1978.

Indirect Federal Land Management

Numerous federal laws have been enacted over the past decade that, while intended to protect certain sectors of the physical and human environment, function in effect as land management policies. Of particular concern to energy development are the PSD and nonattainment provisions of the Clean Air Act. As discussed in Section 2, PSD are those areas where the air is cleaner than the National Ambient Air Quality Standards (NAAQS). Additional pollutants in these areas are limited to specified amounts (or increments), calculated relative to a baseline air quality. Three classes of PSD areas are defined: an area can be Class I, or "pristine," with a minimal increment alloted; Class II, with increments large enough to accommodate moderate economic growth; and Class III, with increments for maxium growth. Certain areas, such as the national parks and wilderness areas previously described, are set aside as mandatory Class I. A map which indicates the counties in the U.S. that contain PSD Class I areas is presented in Section 4.

Nonattainment areas are those areas where the air is currently dirtier than the NAAQS. While PSD increments have only been established for two criteria pollutants (TSP and SO_2), nonattainment areas have been designed for five pollutants: SO_2, TSP, NO_2, CO and O_3. Maps illustrating counties containing nonattainment areas are provided in Section 4 for each of these pollutants.

State Land Use Management

As discussed in Section 2, substantial expansion of the legal framework for decision-making concerning the location of energy facilities has occured at the state level only with the last decade. In most states, the private sector still makes all siting decisions, with incremental review by governmental authorities. An assessment of site suitability must consider the physical characteristics, such as soil suitability, flood potential, and air increments, as well as economic and technological variables. Site compatibily generally refers to the site's relationship to a wider geographic area. It takes into account normal site suitability as well as energy needs, public attitudes environmental controls, and legal and political restraints.[10]

Organizational mechanisms used at the state level for utility siting can be broken down into three categories:

1. *Siting authority rests exclusively with the commission which regulates public utilities.* This approach capitalizes on the expertise of an existing regulatory entity. State review of siting decisions is primarily needed only to certify public conve-

nience and necessity and thus to provide the construction permit. This state review may be concerned only with energy needs, as in Virginia and West Virginia, or it may also include an environmental assessment, as in Illinois.

2. *Siting authority is vested in environmental and energy agencies.* In these states, an environmental protection agency is mandated to participate or consult in the review of site permit applications. Generally, then, two certificates are required: one is the construction permit, and the other is a certificate attesting environmental compatibility. This structure exists in Kentucky, where the state environmental agency consults with the utility regulatory agency, which issues both of the necessary certificates.

3. *An independent utility siting agency or an energy planning agency has siting authority.* This agency theoretically exercises total jurisdiction over the utility siting and construction within the state. Normally, however, an interdisciplinary commission, consisting of member from public and state commerce, environmental, health, and energy agencies, certifies the site. Such an organizational structure exists in Ohio.

A matrix is presented which summarizes the provisions of the 25 state power plant siting laws which are currently in effect in the U.S. This table provides a ready reference from which information regarding site certification authorities, the size and composition of siting panels, methods of acquisition, utility forecasting requirements, and alternative site consideration can be obtained.

Many states have developed other land use programs that, while they do not specifically address energy development, may have a significant impact on energy facility siting decisions. Most notable of these programs are those that deal with the preservation of farmland. Although the nationwide impact of these programs on energy development may be slight, in certain states the impact will be significant. A table appears in Section 4 which summarizes these programs as inventoried by the National Conference of State Legislatures (NCSL) for CEQ.[11] The NCSL inventory found that although 48 of the 50 states had adopted farmland preservation measures, most states had dealt with the issue primarily through provisions allowing preferential property tax assessment, that is, taxation of farmlands at a lower rate than land used for residence or other purposes. Among other types of preservation programs highlighted in this survey, three continued to attract the most attention in the states: purchase of development rights, agricultural districting, and transfer of development rights.

In addition to farmland, states are providing an increasing level of protection to critical resource areas. Many of these initiatives have been in direct response to requirements of the Coastal Zone Mangement Act (CZMA).

Thirty-one of the thirty-five eligible states and territories have either adopted new statutes and regulations protecting wetlands or improved implementation of existing laws as part of state coastal zone program planning. Because wetlands are prime floral and fauna habitats, most wetlands statues provide habitat protection as well. In addition, 21 states have special management programs that deal with unique plant and animal species protection. Two tables are presented that summarize the status of state coastal zone management programs and the protection of historic and cultural resources under the CZMA.

States also exercise land use controls through the state implementation planning (SIP) provisions of the Clean Air Act, the Resource Conservation and Recovery Act and the Clean Water Act. Although all of the SIPs could not be summarized in this report, these plans may have significant impacts on energy facility siting decisions.

MEASURING FUTURE LAND USE IMPACTS

Obviously, one unit of measure used for estimating land use impacts of energy development is acres. An acre equals 4,840 square yards or 43,560 square feet. The data which appears under the measurement of land use impacts heading consist of tables designed to provide readers with a reference of values used in calculating the area that can potentialy be affected by different types of energy development. For the most part, these tables are self-explanatory, simply indicating past experience with land areas consumed by various sizes of energy facilities. The facilities for which land use values are provided include:

- Coal surface and deep mining
- Fossil-fueled power plants (ranges and trends)

- Oil refining complexes
- Uranium mining
- Nuclear power plants
- Power plant cooling systems
- Geothermal facilities
- Solid waste disposal from oil shale
- Soild waste disposal from utilities
- Conversion of alternative feedstocks to alcohol.

The variables which affect the land use requirements for the facilities listed above are discussed at length in Section 2. Since it is beyond the scope of this report to explain the specific methodologies used to determine the values presented in these tables, it is suggested that interested readers consult the sources provided for each table for descriptions of these methodologies.

REFERENCES

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3. "Floodplain Management," Executive Order No. 11988, *Federal Register,* Vol. 42, p. 26951, 1977; "Protection of Wetlands," Executive Order No. 11988, *Federal Register,* Vol. 42, p. 26961, 1977.

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8. U.S. General Accounting Office, *Land Use Planning, Management, and Control: Issues and Problems,* CED-77-101, July, 1977.

9. U.S. Dept. of Agriculture, Forest Service, *Final Environmental Impact Statement, Roadless Area Review and Evaluation,* January, 1979.

10. Ohio River Valley Water Sanitation Commission, "Siting of Major Facilities," Cincinnati, May 9, 1979.

11. Davies, B. and J. Belden, *A Survey of State Programs to Preserve Farmland,* U.S. Council on Environmental Quality, Washington, D.C., 1979.

4. LAND USE DATA

The data described in Section 3 are presented here in four parts:

- Physical Land Characteristics
- Land Usage
- Land Management
- Measuring Future Land Use Impacts

Each of these data sets is preceded by a listing of tables and figures.

PHYSICAL LAND CHARACTERISTICS

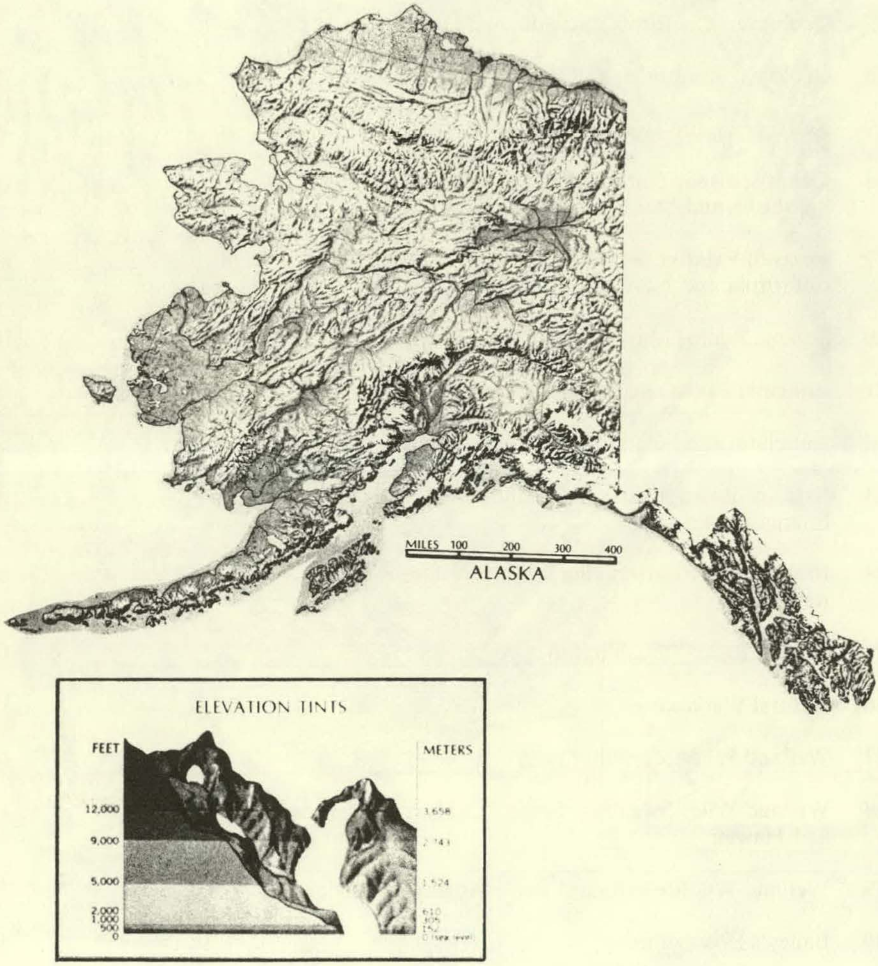
List of Tables

List of Figures

Figure No.		Page

Figure 4.1

Shaded Relief: Physiographic Features of Alaska



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970

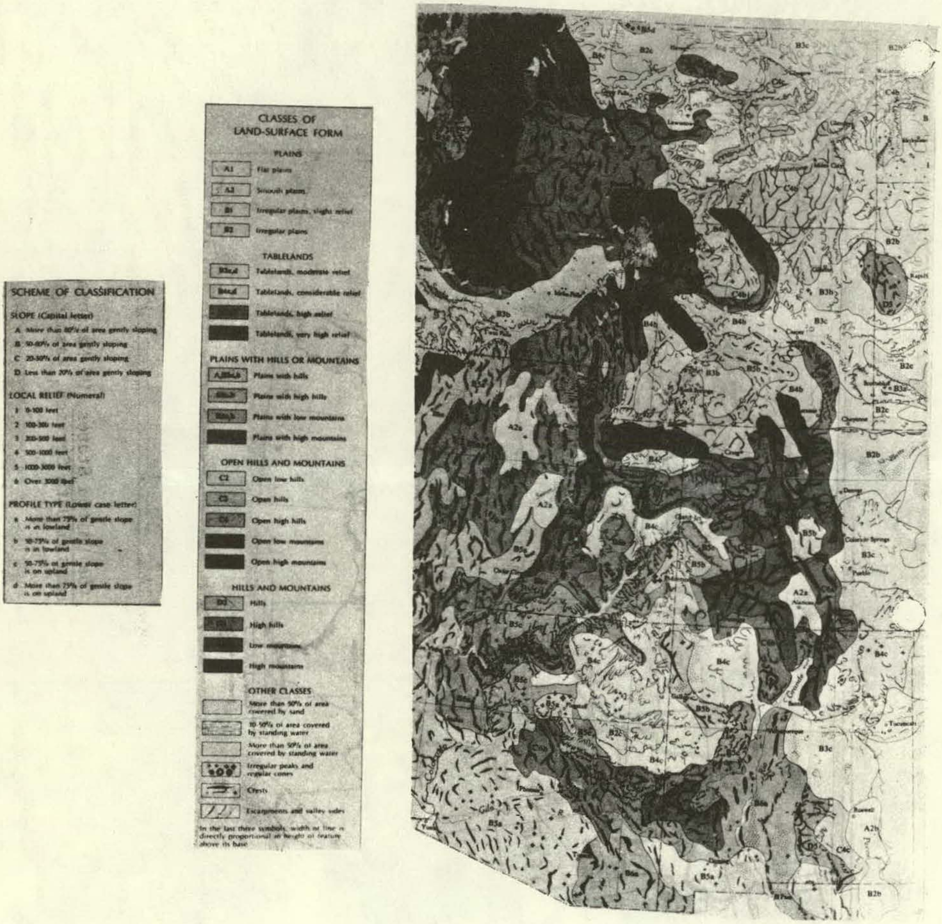
Figure 4.2

Shaded Relief: Physiographic Features of California and Nevada

Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970

Figure 4.3

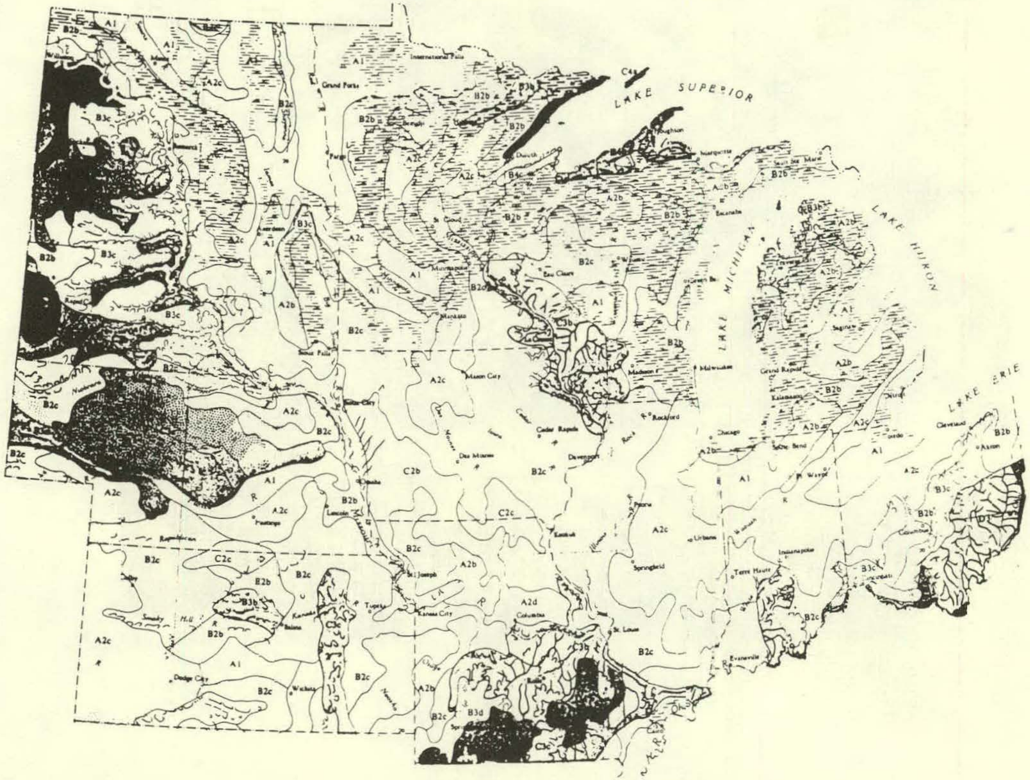
Classes of Land Surface Forms: Rocky Mountain Region



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970

Figure 4.4

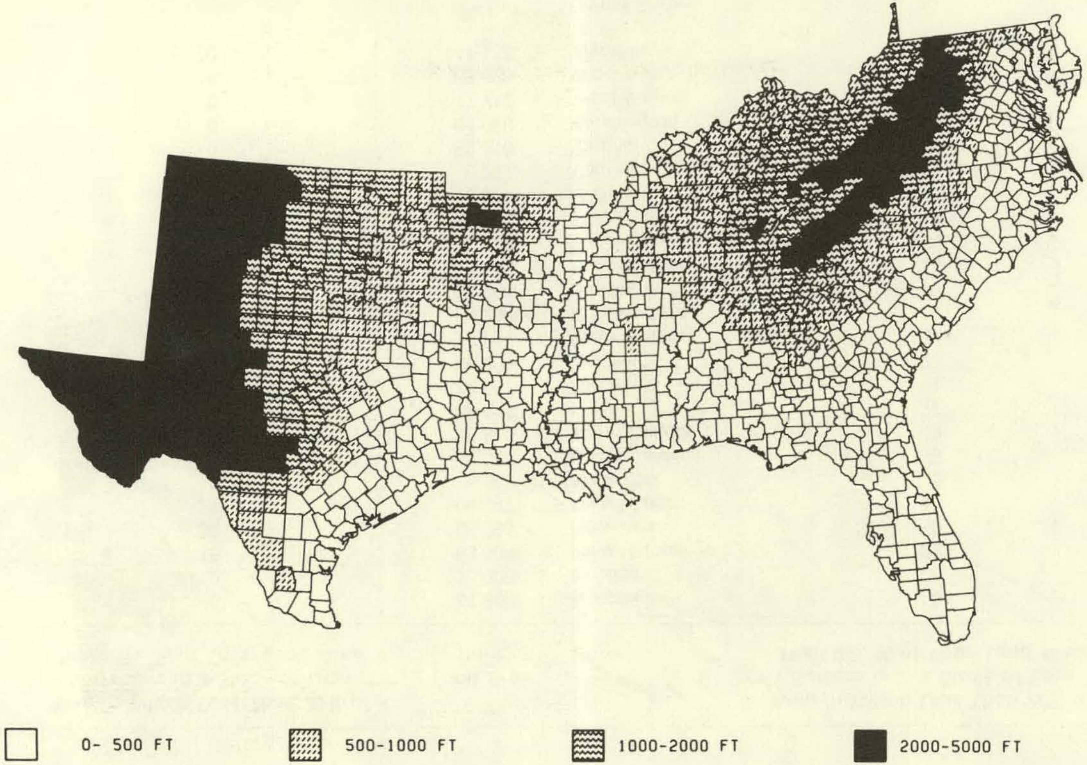
Classes of Land Surface Forms: Great Lakes Region



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.5

County Elevation Classification: Southeast and South Central Regions



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Table 4.1

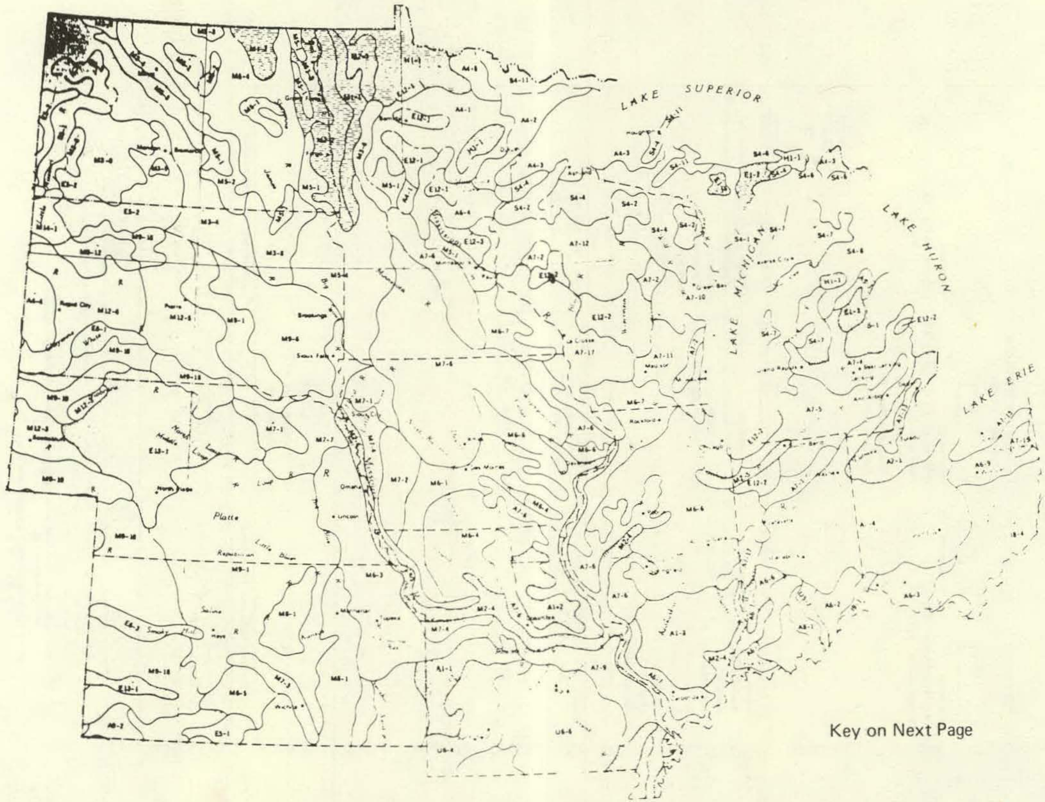
Areas of Excessive Slope By State

State	Area in Which Less Than 20% of Surface is in a Slope of Less Than 8%, % of Total Land Area	Total Area (mi²)	State	Area in Which Less Than 20% of Surface is in a Slope of Less Than 8%, % of Total Land Area	Total Area (mi²)
Alabama	0	51,609	Nebraska	0	77,227
Arizona	2	113,909	Nevada	0	110,540
Arkansas	15	53,104	New Hampshire	22	9,304
California	38	158,693	New Jersey	0	7,836
Colorado	21	104,247	New Mexico	13	121,666
Connecticut	0	5,009	New York	6	49,576
Delaware	0	2,057	North Carolina	8	52,586
Florida	0	58,560	North Dakota	0	70,665
Georgia	2	58,876	Ohio	27	41,222
Idaho	34	83,557	Oklahoma	1	69,919
Illinois	0	56,400	Oregon	27	96,918
Indiana	0	36,291	Pennsylvania	27	45,333
Iowa	0	56,290	Rhode Island	0	1,214
Kansas	0	82,264	South Carolina	0	31,055
Kentucky	40	40,395	South Dakota	5	77,047
Louisiana	0	48,523	Tennessee	14	42,244
Maine	3	33,215	Texas	2	267,339
Maryland	0	10,577	Utah	9	84,916
Massachusetts	0	8,257	Vermont	10	9,609
Michigan	0	58,216	Virginia	5	40,817
Minnesota	0	84,068	Washington	44	68,192
Mississippi	0	47,716	West Virginia	87	24,181
Missouri	16	69,686	Wisconsin	0	56,154
Montana	20	147,138	Wyoming	23	97,914
			United States	12	

Source: Hammond, Edwin H., "Classes of Land Surface Form," University of Wisconsin, 1963.

Figure 4.6

Soils: Great Lakes Region



Key on Next Page

Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.6 (cont.)

Key for Soils: Great Lakes Region

	WARM SOILS Mean annual soil temperature higher than about 47°F			COOL SOILS Mean annual soil temperature lower than about 47°	
	MOIST	WET	DRY	MOIST	WET
ALFISOLS	Udalfs A6[1] A7[1] A8	Aqualfs A1 A2	Ustalfs A9 A10 Xeralfs A11 A12 A13	Boralfs A3 A4 A5	
ARIDISOLS			Argids D1 D2 D3 D4 Orthids D5 D6		
ENTISOLS	Psamments Quartzipsamments E10 Udipsamments E12[1]	Aquents E1	Fluvents E2 Orthents E3 E4 E5 E6 E7 E8 Psamments Torripsamments E11 Ustipsamments E13 Xeropsamments E14	Psamments Cryopsamments E9	
HISTOSOLS		H2			H1
INCEPTISOLS	Andepts Dystrandepts I2 Ochrepts Dystrochrepts I8 Eutrochrepts I9 Fragiochrepts I10 Tropepts I12 Umbrepts Haplumbrepts I14	Aquepts Haplaquepts I5 Humaquepts I6	Andepts Eutrandepts I3 Ochrepts Ustochrepts I11	Andepts Cryandepts I1 Ochrepts Cryochrepts I7 Umbrepts Cryumbrepts I13	Aquepts Cryaquepts I4
MOLLISOLS	Udolls M6 M7 M8	Aquolls M1 M2[1]	Ustolls M9 M10 M11 M12 M13 M14 Xerolls M15 M16	Borolls M3 M4 M5	
OXISOLS	Orthox O1		Ustox O2		
SPODOSOLS		Aquods S1		Orthods S2 S3 S4[2]	
ULTISOLS	Humults U2 U3 Udults U4 U5 U6	Aquults U1	Xerults U7		
VERTISOLS	Uderts V1 V2		Usterts V3 V4 Xererts V5		

[1]Includes some soils that are cool

[2]Includes some soils that are warm

Misc land types	X2 X4		X1 X5	X3	

ALFISOLS: Soils with gray to brown surface horizon, medium to high base supply, and subsurface horizons of clay accumulation
Formative element: alf

ARIDISOLS: Soils with pedogenic horizons, low in organic matter, usually dry
Formative element: id

ENTISOLS: Soils without pedogenic horizons
Formative element: ent

HISTOSOLS: Organic (peat and muck) soils
Formative element: ist

INCEPTISOLS: Soils with weakly differentiated horizons showing alteration of parent materials
Formative element: ept

MOLLISOLS: Soils with nearly black, organic-rich surface horizon and high base supply
Formative element: oll

OXISOLS: Soils that are mixtures principally of kaolin, hydrated oxides, and quartz
Formative element: ox

SPODOSOLS: Soils that have accumulation of amorphous materials in subsurface horizons
Formative element: od

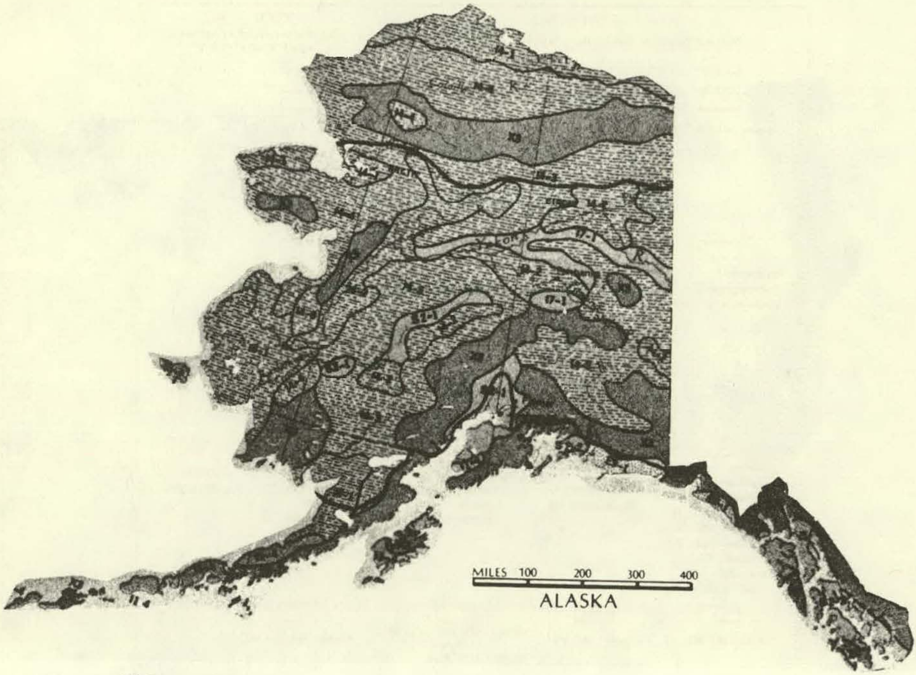
ULTISOLS: Soils with horizons of clay accumulation and low base supply
Formative element: ult

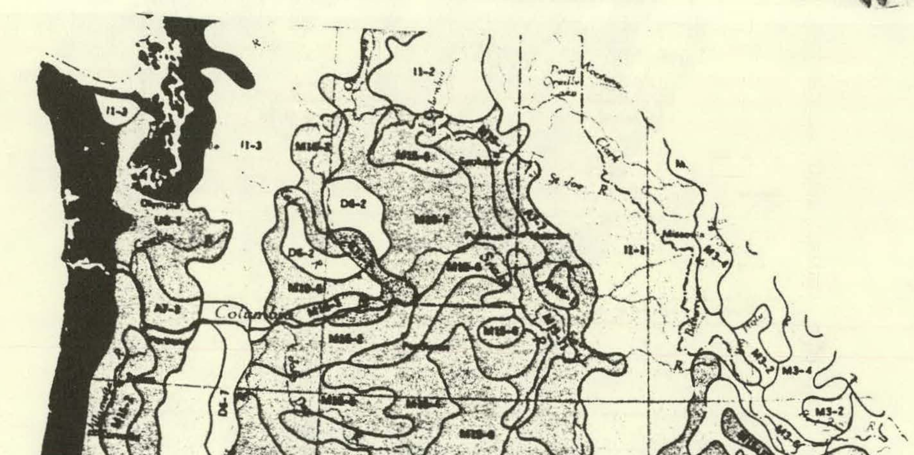
VERTISOLS: Cracking clay soils
Formative element: ert

Miscellaneous land types: Bare rock, salt flats, ice fields, and some included soils

Figure 4.7

Soils: Alaska & Northwest Region

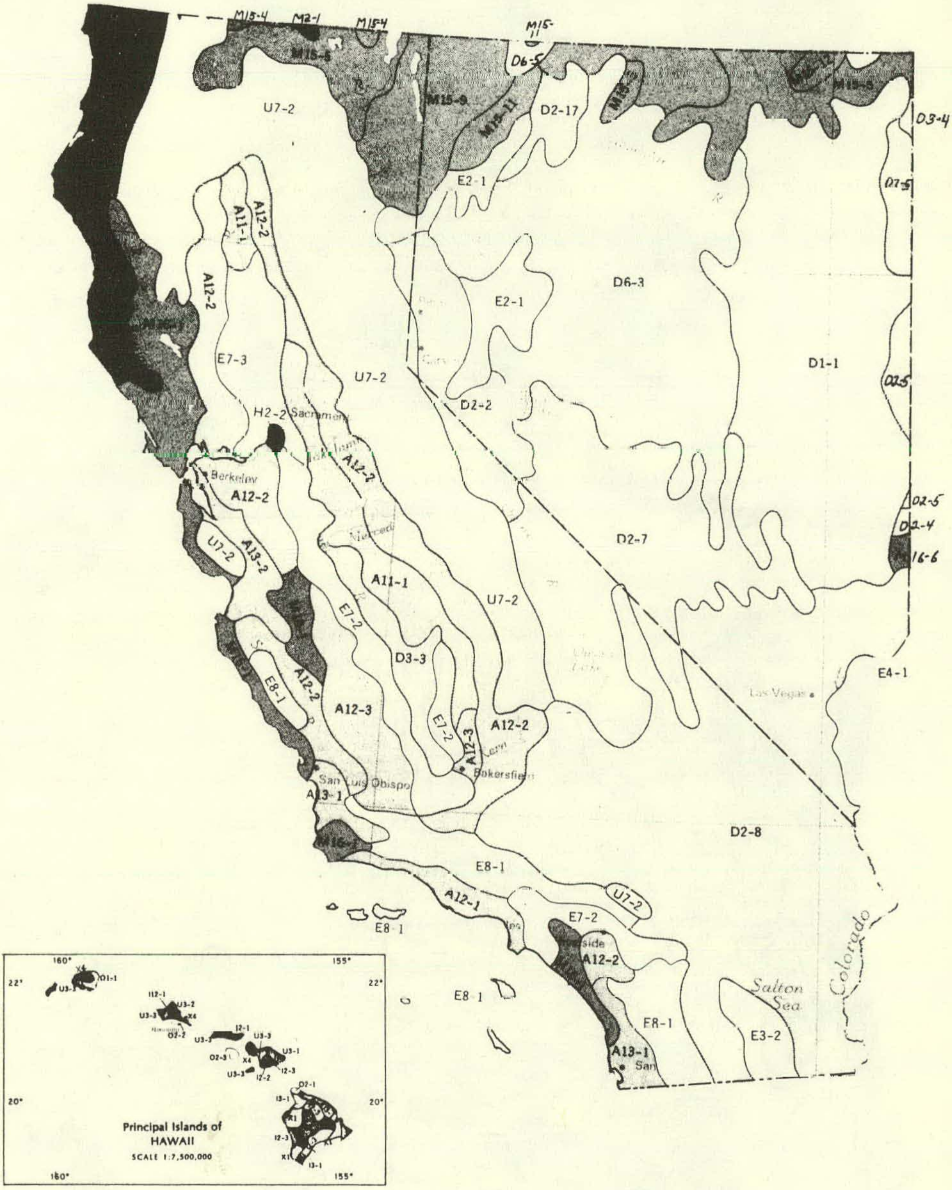




Source: U.S. Geological Survey, *The National Atlas of the United States of America*, Washington, D.C., 1970.

Figure 4.8

Soils: California, Nevada, and Hawaii



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.9

Soils: Rocky Mountain Region

Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.10

Key for Soils: Western United States

	WARM SOILS Mean annual soil temperature higher than about 47°F			COOL SOILS Mean annual soil temperature lower than about 47°	
	MOIST	WET	DRY	MOIST	WET
INCEPTISOLS	Andepts Dystrandepts I2 Ochrepts Dystrochrepts I8 Eutrochrepts I9 Fragiochrepts I10 Tropepts I12 Umbrepts Haplumbrepts I14	Aquepts Haplaquepts I5 Humaquepts I6	Andepts Eutrandepts I3 Ochrepts Ustochrepts I11	Andepts Cryandepts I1 Ochrepts Cryochrepts I7 Umbrepts Cryumbrepts I13	Aquepts Cryaquepts I4
MOLLISOLS	Udolls M6 M7 M8	Aquolls M1 M2[1]	Ustolls M9 M10 M11 M12 M13 M14 Xerolls M15 M16	Borolls M3 M4 M5	
OXISOLS	Orthox O1		Ustox O2		
SPODOSOLS		Aquods S1		Orthods S2 S3 S4[2]	
ULTISOLS	Humults U2 U3 Udults U4 U5 U6	Aquults U1	Xerults U7		
VERTISOLS	Uderts V1 V2		Usterts V3 V4 Xererts V5		
ALFISOLS	Udalfs A6[1] A7[1] A8	Aqualfs A1 A2	Ustalfs A9 A10 Xeralfs A11 A12 A13	Boralfs A3 A4 A5	
ARIDISOLS			Argids D1 D2 D3 D4 Orthids D5 D6		
ENTISOLS	Psamments Quartzipsamments E10 Udipsamments E12[1]	Aquents E1	Fluvents E2 Orthents E3 E4 E5 E6 E7 E8 Psamments Torripsamments E11 Ustipsamments E13 Xeropsamments E14	Psamments Cryopsamments E9	
HISTOSOLS		H2			H1

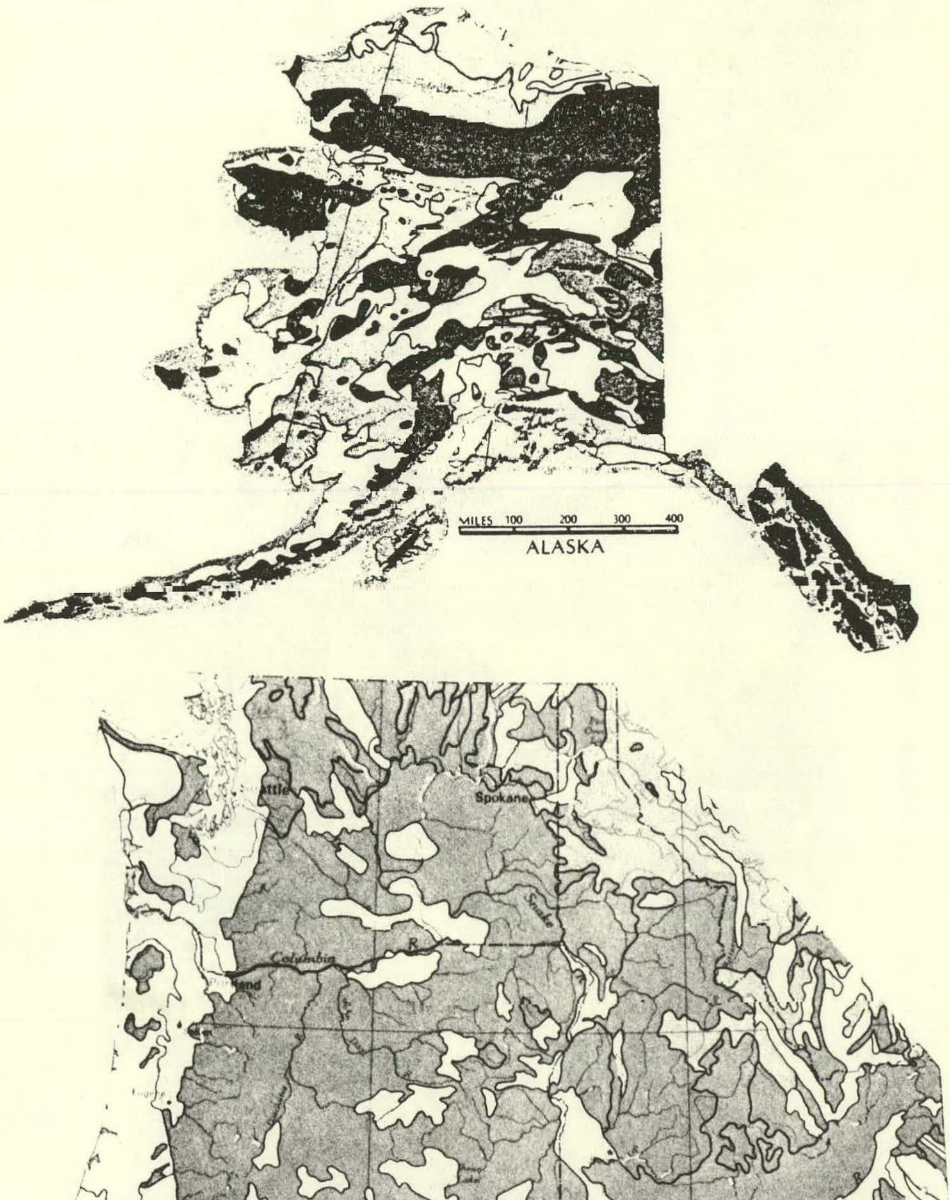
Figure 4.11

Geology: Great Lakes Region

Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.12

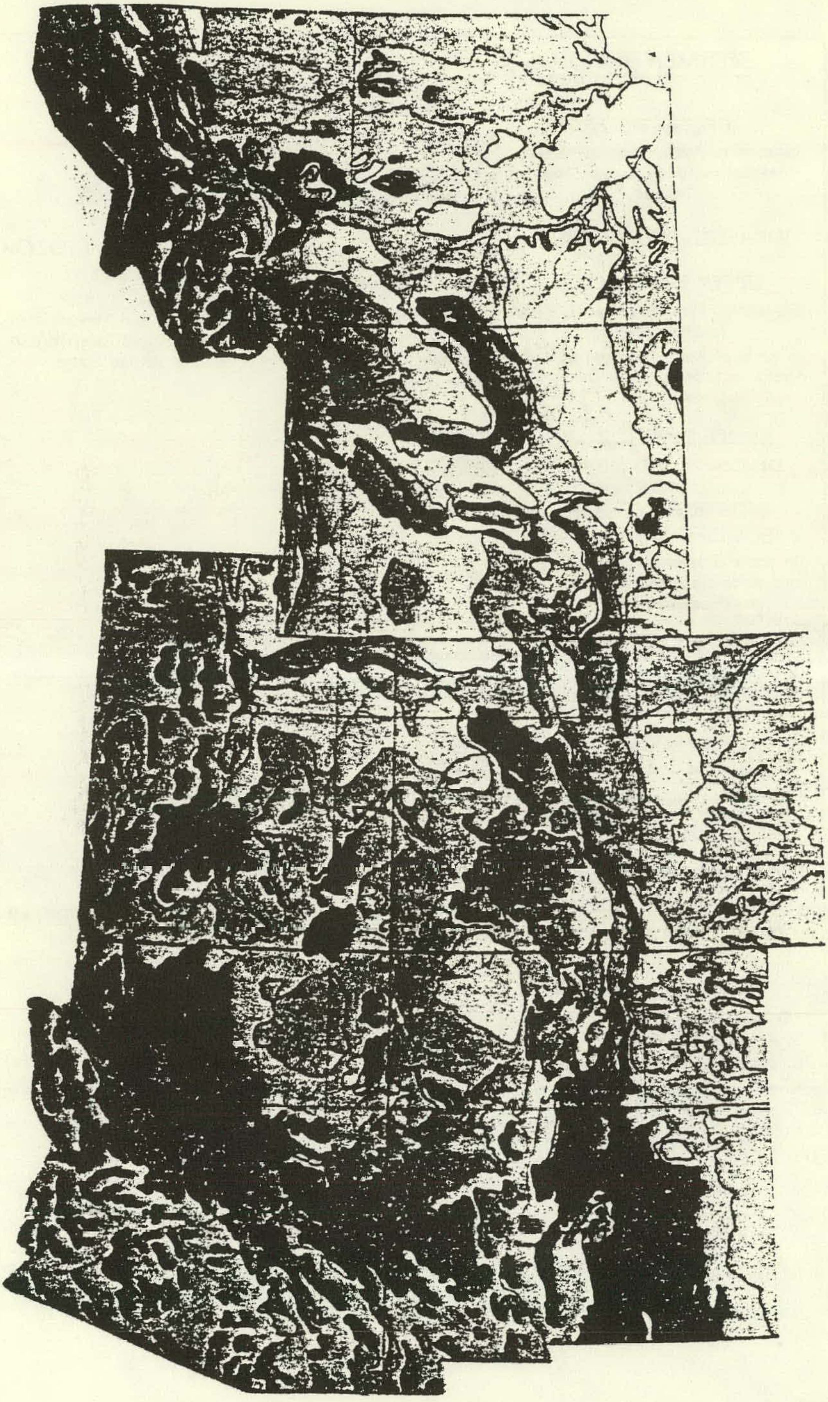
Geology: Alaska and Northwest Region



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.13

Geology: Rocky Mountain Region



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.14

Key for Northwest and Rocky Mountain Regions

SEDIMENTARY ROCKS

CRETACEOUS
In parts of Rocky Mountains and Alaska includes Jurassic and Triassic

JURASSIC AND TRIASSIC

UPPER PALEOZOIC
PERMIAN, PENNSYLVANIAN, AND MISSISSIPPIAN
In parts of Rocky Mountains and Alaska includes middle and lower Paleozoic

MIDDLE PALEOZOIC
DEVONIAN AND SILURIAN

LOWER PALEOZOIC
ORDOVICIAN AND CAMBRIAN
In parts of Missouri, Oklahoma, and Arkansas includes Devonian and Silurian

YOUNGER PRECAMBRIAN
In southeastern United States and Alaska includes metamorphosed Paleozoic

OLDER PRECAMBRIAN
Metamorphic and igneous rocks

QUATERNARY
RECENT AND PLEISTOCENE

UPPER TERTIARY
PLIOCENE AND MIOCENE
In Western States includes Recent and Pleistocene

LOWER TERTIARY
OLIGOCENE, EOCENE, AND PALEOCENE
In Alaska includes some Miocene

INTRUSIVE ROCKS

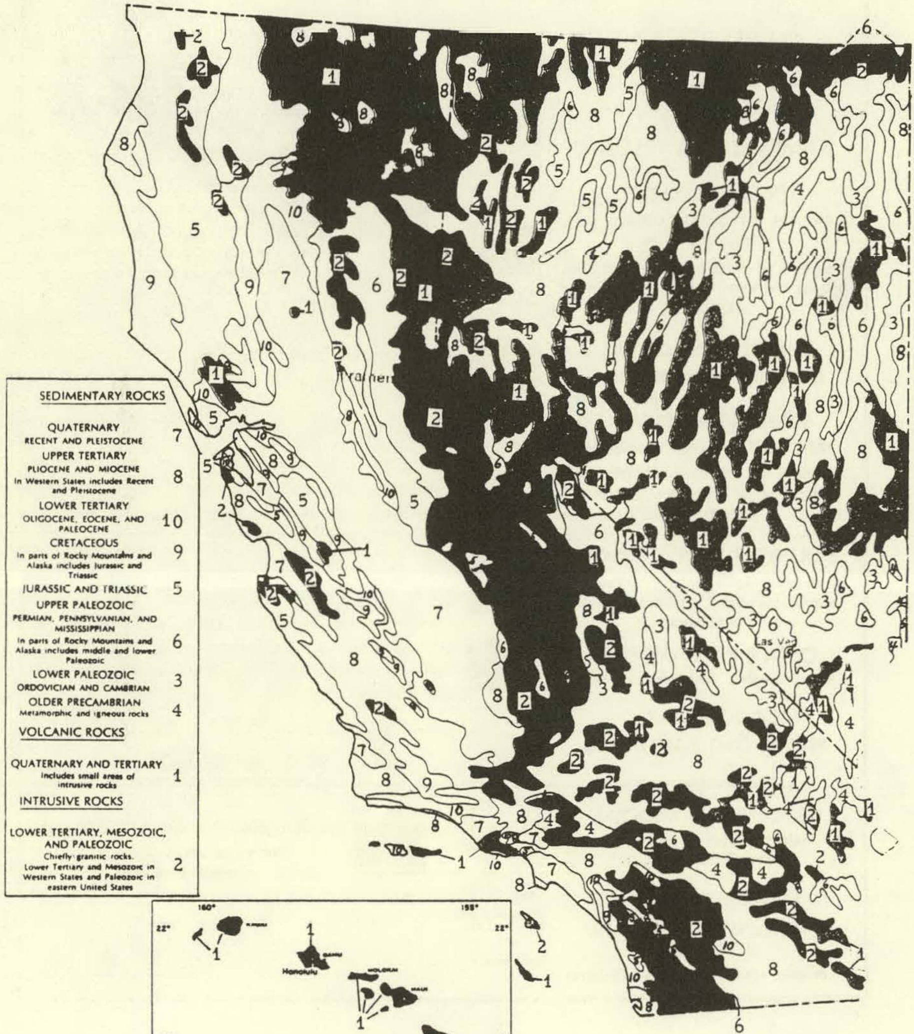
LOWER TERTIARY, MESOZOIC, AND PALEOZOIC
Chiefly granitic rocks.
Lower Tertiary and Mesozoic in Western States and Paleozoic in eastern United States

VOLCANIC ROCKS

QUATERNARY AND TERTIARY
Includes small areas of intrusive rocks

Figure 4.15

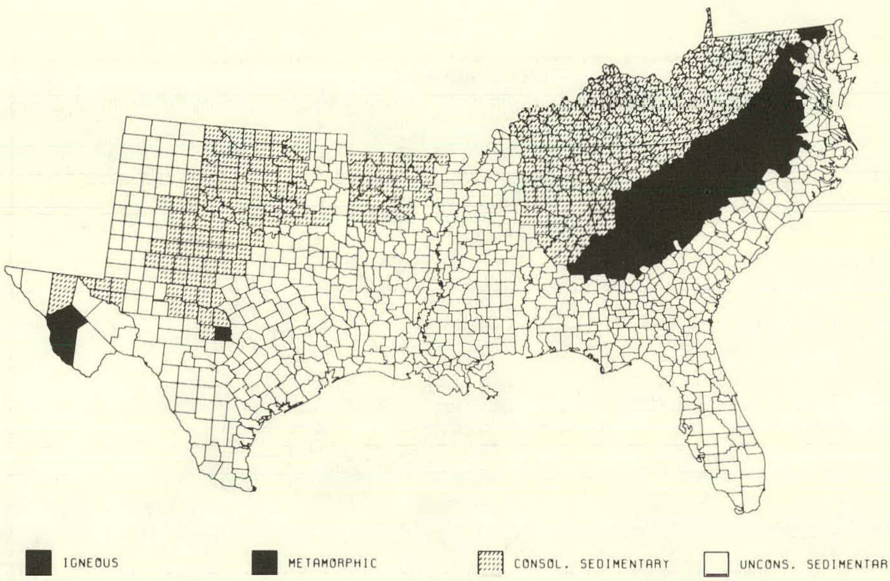
Geology: California, Nevada and Hawaii



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.16

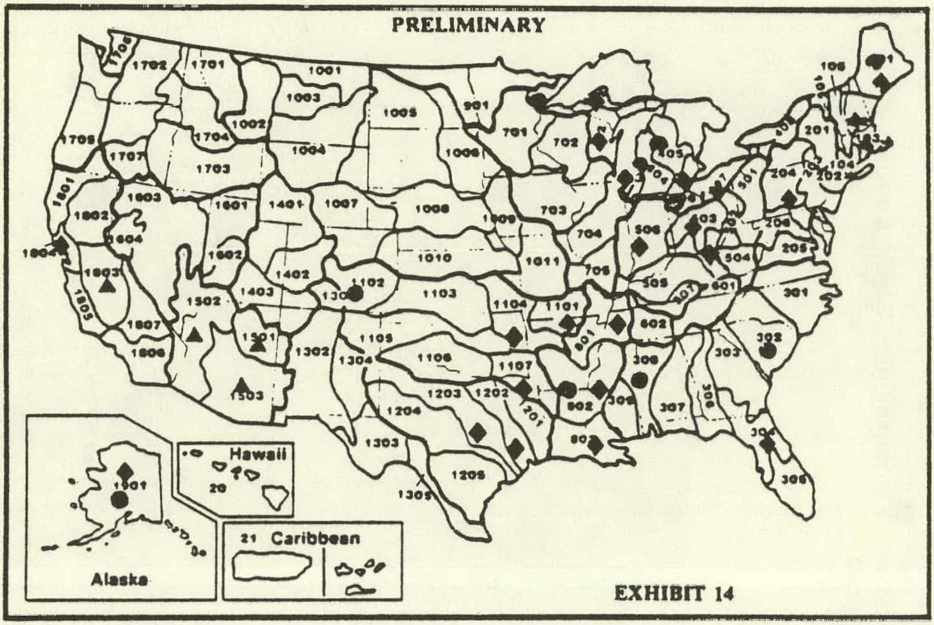
Geology: Southeast and South Central Regions



Source: U.S. Geological Survey, *The National Atlas of the United States of America,* Washington, D.C., 1970.

Figure 4.17

Restricted Land Use From Wet Soils



LEGEND

Areas with Greatest Total Impact

Areas with 50,000 acres or more of potentially productive cropland with a soil wetness problem that may be drained.

Location of Specific Impacts[1]

● Areas with expected increases in cropland to meet production needs.

◆ Urban and residential areas with unresolved drainage problems.

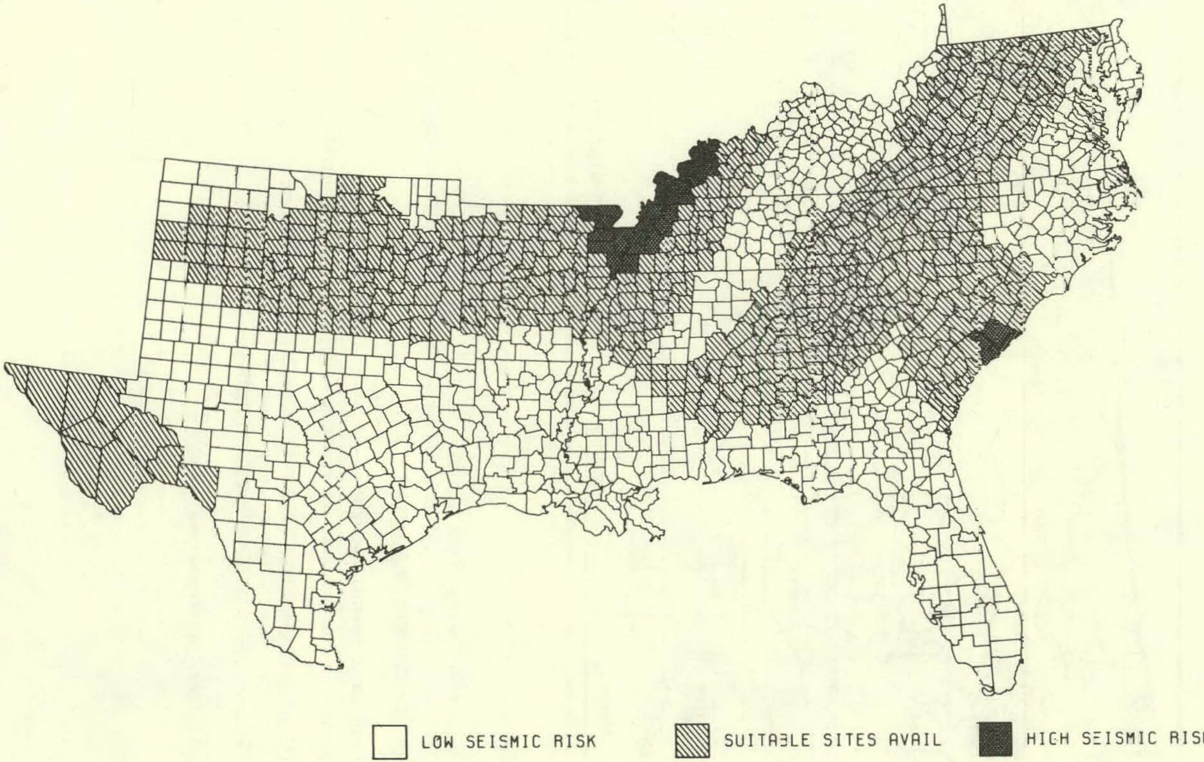
▲ Irrigated areas with major drainage problems.

[1]*Identified by State/Regional study teams.*

Source: "Preliminary Water Resources Problem Statements," 1971 National Conference on Water, St. Louis, Mo, U.S. Water Resources Council, Washington, D.C., 1977.

Figure 4.18

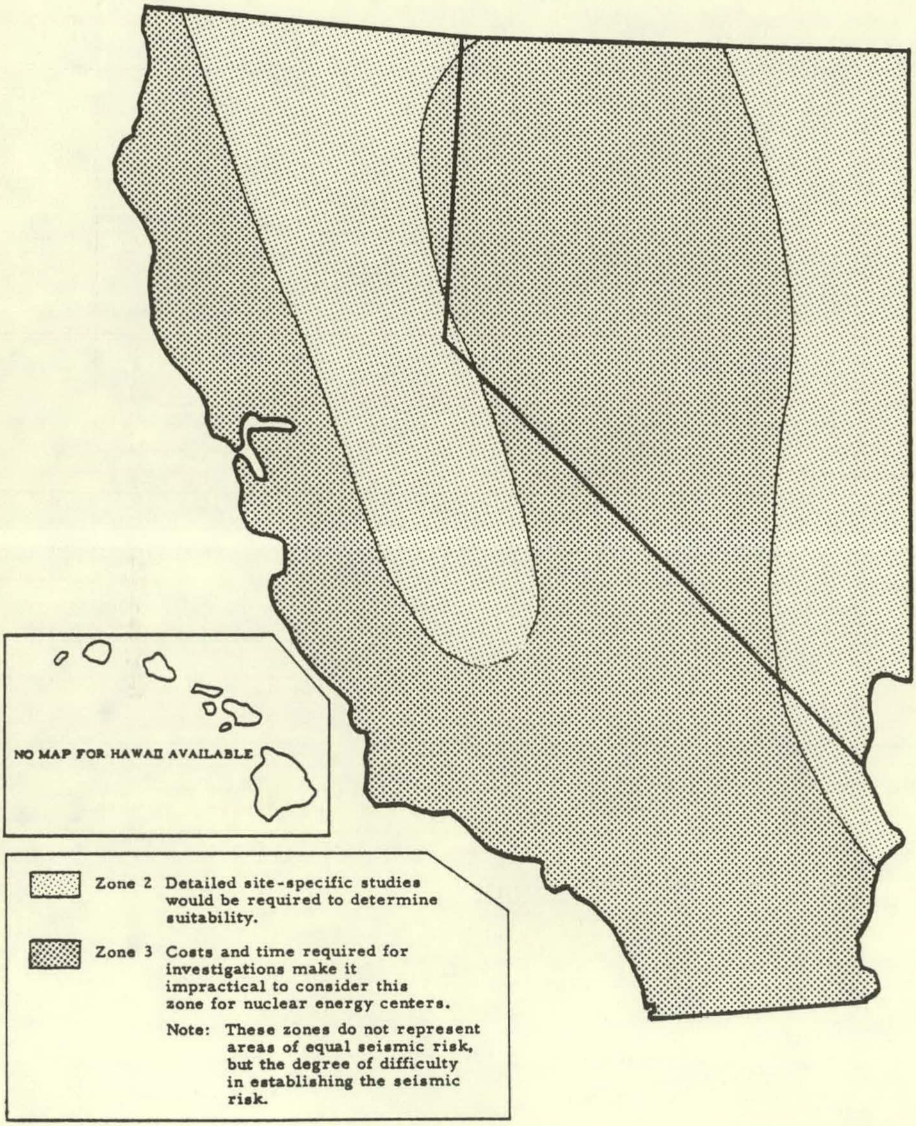
County Seismic Suitability Classification: Southeast and South Central Regions



Source: U.S. Nuclear Regulatory Commission, *Nuclear Energy Center Site Survey - 1975,* Vol. 5, NUREG 0001, Washington, D.C., Jan., 1976.

Figure 4.19

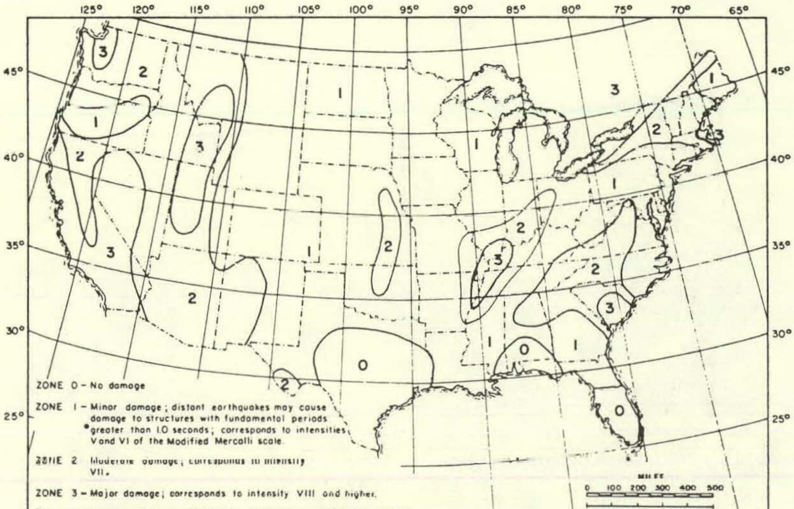
Areas of Relative Seismic Suitability: California and Nevada



Source: U.S. Nuclear Regulatory Commission, *Nuclear Energy Center Site Survey - 1975,* Vol. 5, NUREG 0001, Washington, D.C., Jan., 1976.

Figure 4.20

Seismic Zoning Map, Mercalli Intensity Scale



I. Not felt except by a very few under specially favorable circumstances.

II. Felt only by a few persons at rest, expecially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, expecially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors distributed; walls made crackling sound. Sensation like heavy truck striking building; standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structure. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.

IX. Damage consierable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

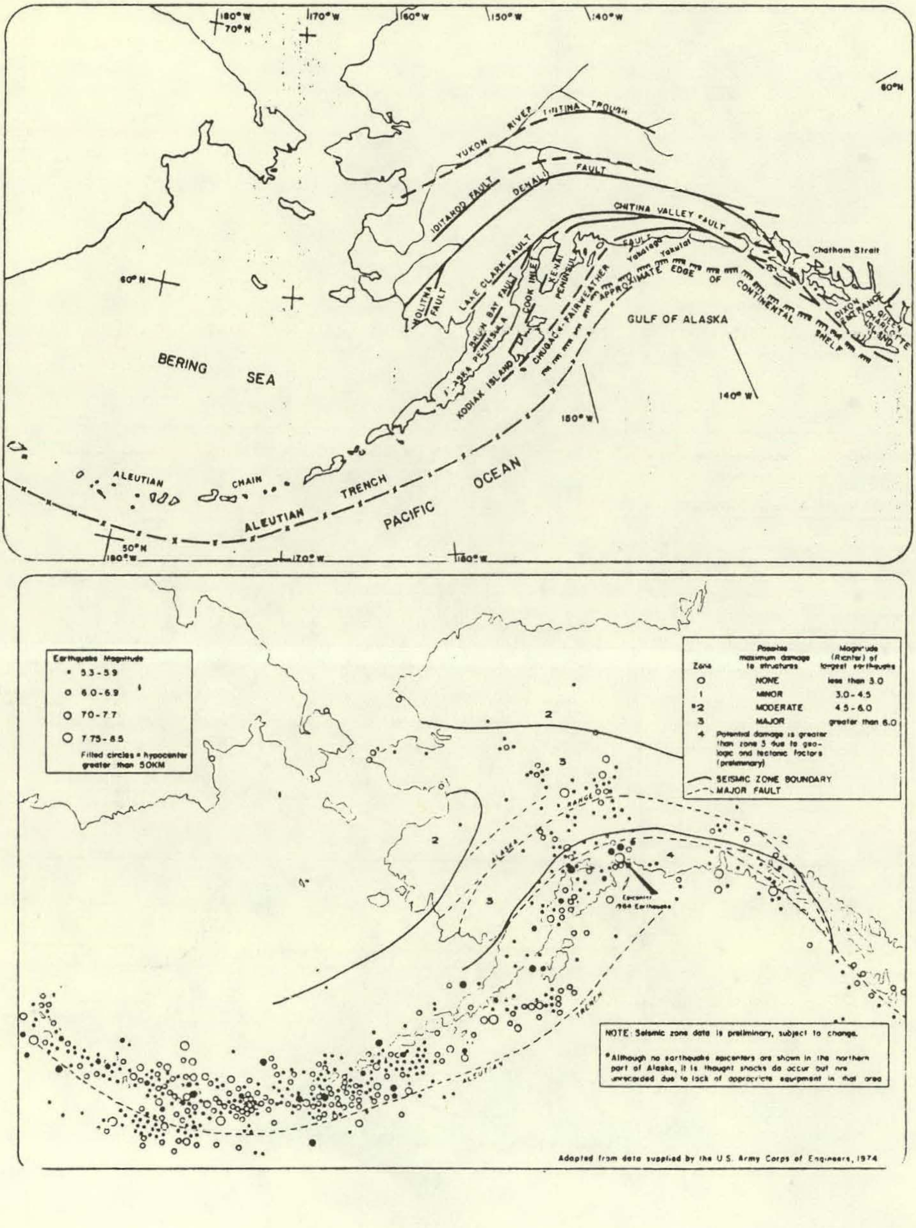
XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Source: Bonneville Power Administration, *The Role of the BPA in the Pacific Northwest Power Supply System,* U.S. Department of the Interior, Washington, D.C., 1977.

Figure 4.21

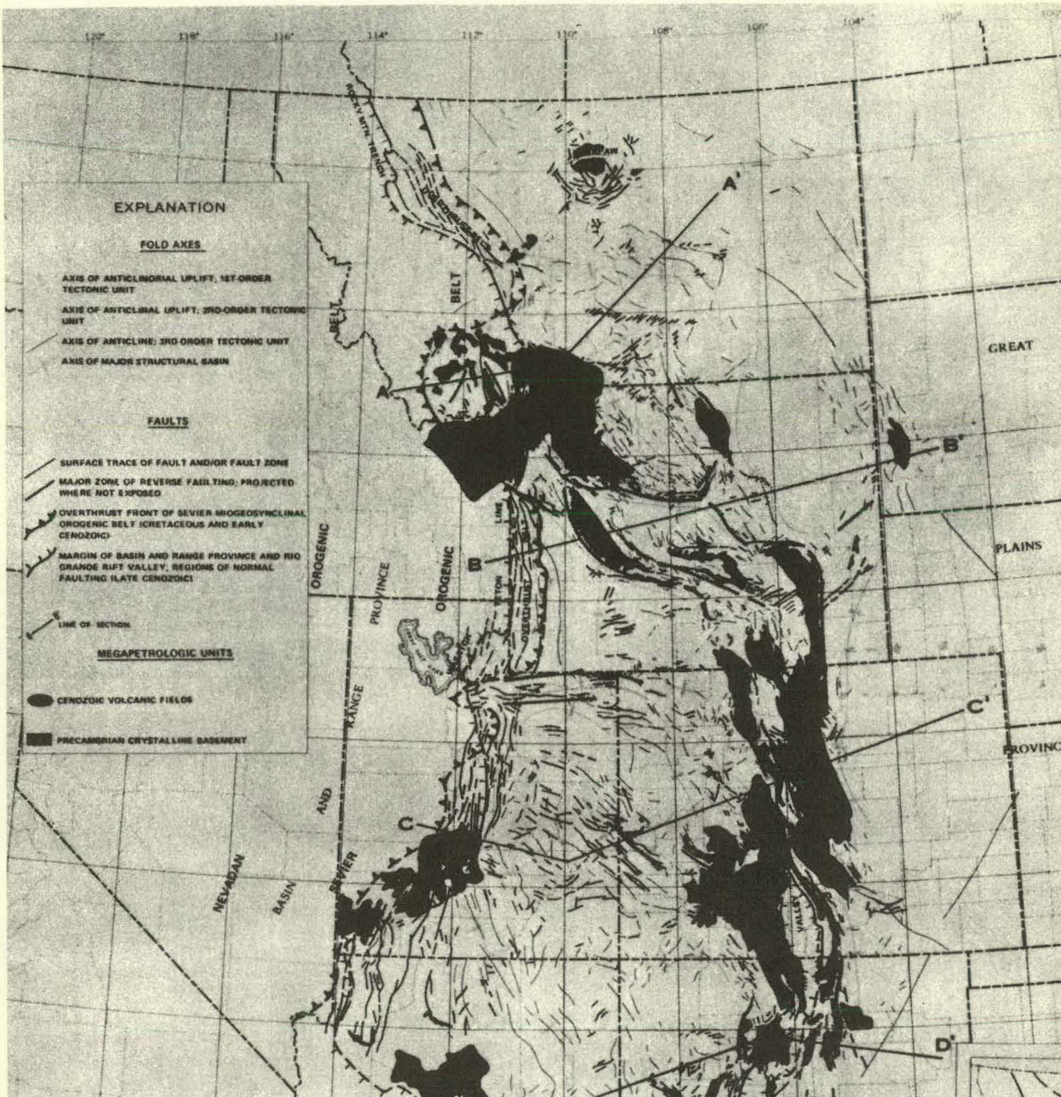
Principal Faults and Seismic Zones of Alaska



Source: Office of the Governor, *Alaska Regional Profiles,* State of Alaska, Arctic Environmental and Information Data Center, Six volumes, 1974.

Figure 4.22

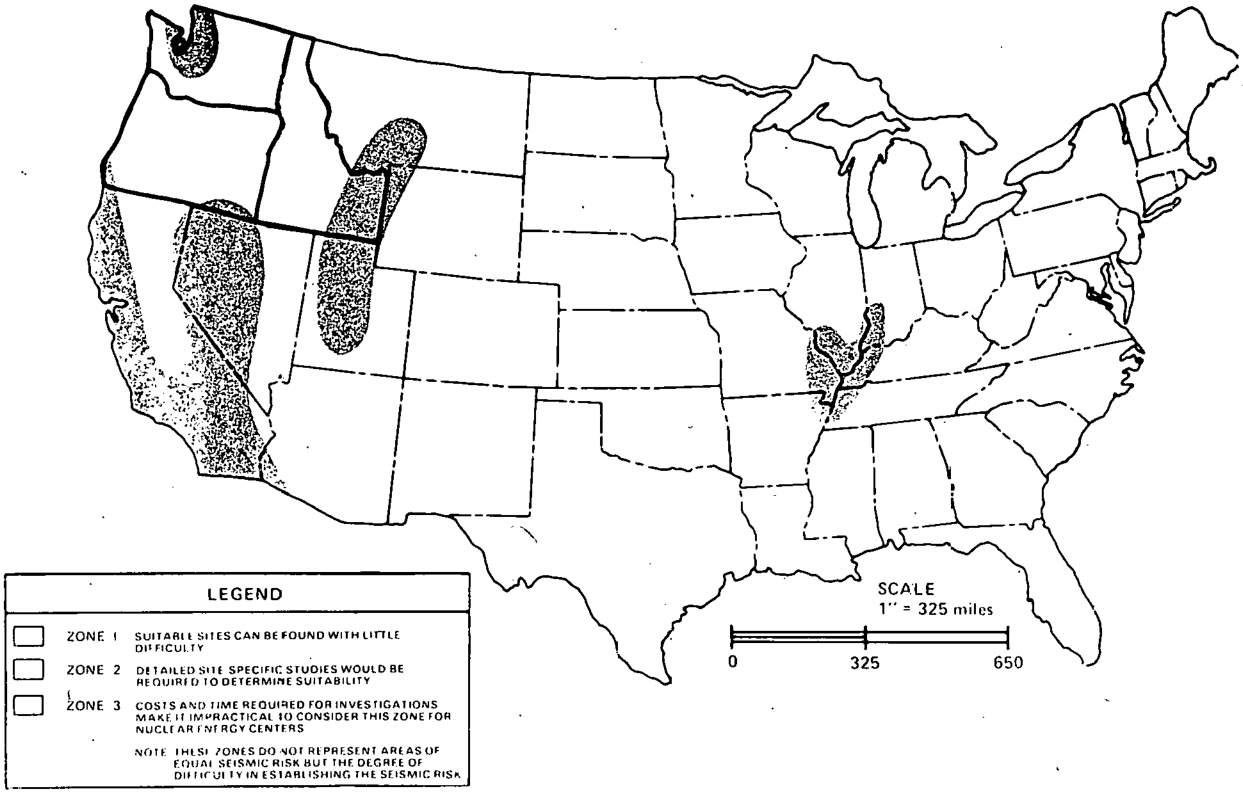
Anticlines and Faults: Rocky Mountain Region



Source: U.S. Geological Survey, *Geologic Atlas of the Rocky Mountain Region,* U.S. GPO, Washington, D.C., 1972

Figure 4.23

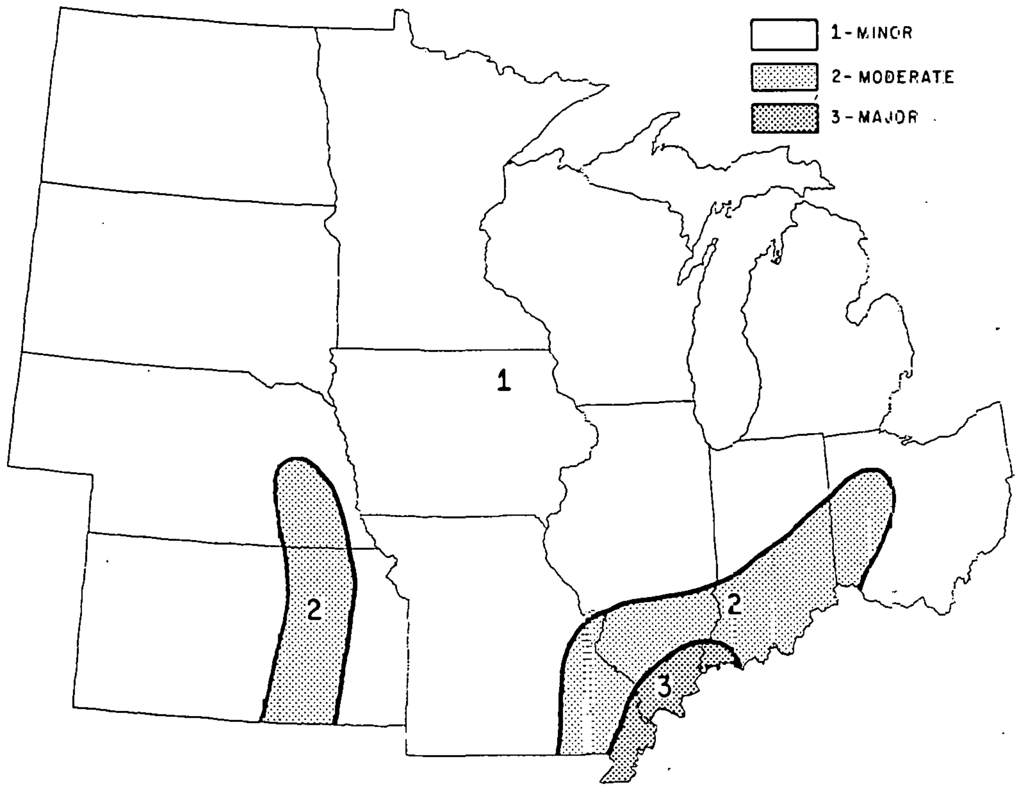
Areas of Relative Seismic Suitability for Nuclear Energy Centers



Source: U.S. Nuclear Regulatory Commission, "Resource Availbility and Site Screening," *Nuclear Energy Center Site Survey,* Vol. 5, NUREG 0001, Jan., 1976.

Figure 4.24

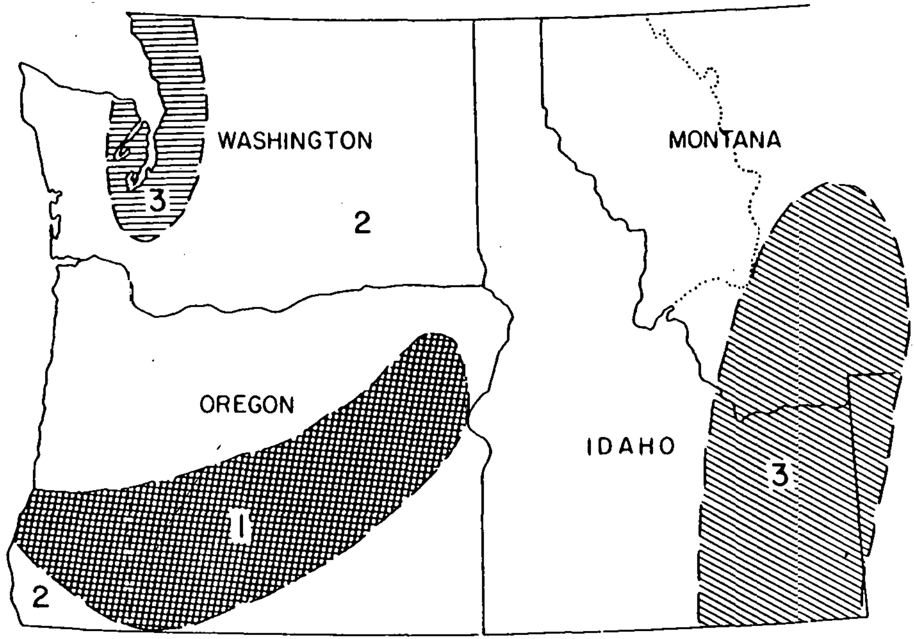
Probability of Earthquake Damage: Great Lakes Region



Source: Aplin, C.L. and G.O. Argall, Jr., *Tailing Disposal Today,* Proceedings of First International Tailing Symposium, San Francisco, CA, Miller Freemen Publications, Inc., 1973.

Figure 4.25

Seismic Risk: Washington, Oregon, and Idaho



ZONE 1 - Minor damage, distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the M.M.* Scale.
ZONE 2 Moderate damage; corresponds to intensity VII of the M.M.* Scale.
ZONE 3 Major damage; corresponds to intensity VIII and higher of the M.M.* Scale.
*M.M Modified Mercalli Intensity Scale; see table III- 1.

Source: Bonneville Power Administration, *The Role of BPA in the Pacific Northwest Power Supply,* U.S. Department of Interior, Washington, D.C., 1977.

Table 4.2

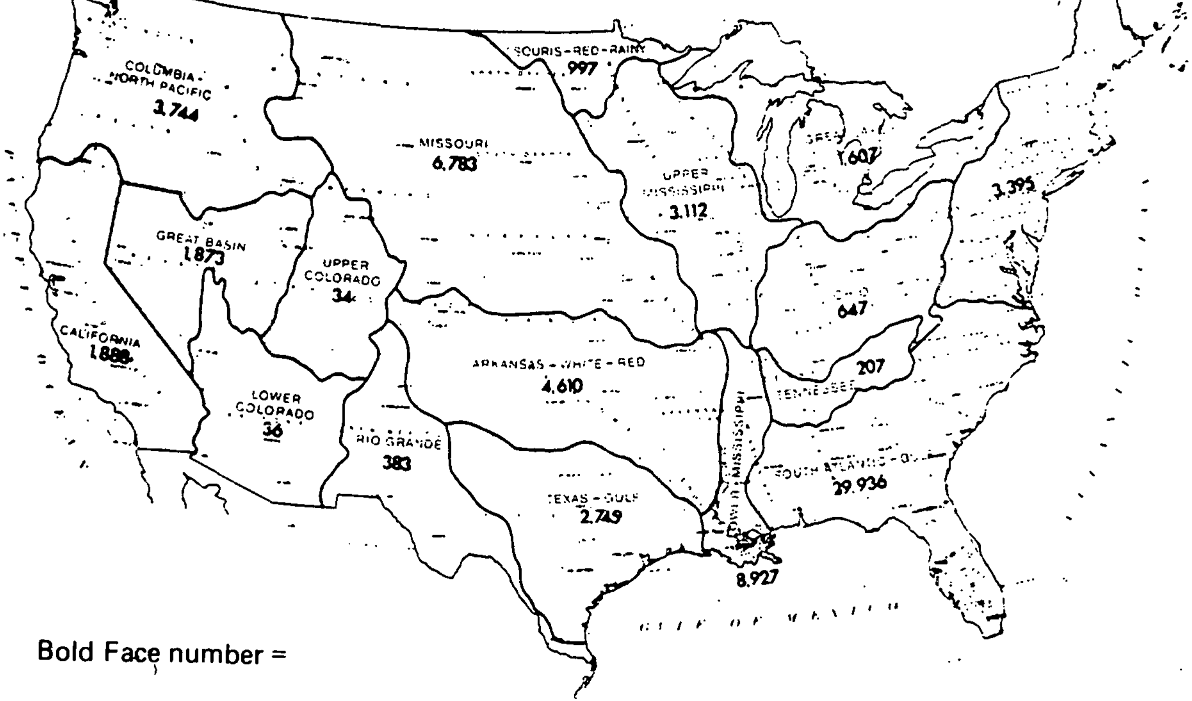
Areas of Relative Seismic Suitability By State

State	Seismic Zone (% of area)			Total	State	Seismic Zone (% of area)			Total
	I	II	III	(mi²)		I	II	III	(mi²)
Alabama	43	57	0	51,609	Nebraska	83	17	0	77,227
Arizona	0	97	3	113,909	Nevada	0	41	59	110.540
Arkansas	19	70	11	53,104	New Hampshire	0	100	0	9,304
California	0	41	59	158,693	New Jersey	62	38	0	7,836
Colorado	19	81	0	104,247	New Mexico	17	83	0	121,666
Connecticut	0	100	0	5,009	New York	18	82	0	49,576
Delaware	97	3	0	2,057	North Carolina	62	38	0	52,586
Florida	100	0	0	58,560	North Dakota	100	0	0	70,665
Georgia	44	56	0	58,876	Ohio	83	17	0	41,222
Idaho	0	77	23	83,557	Oklahoma	30	70	0	69,919
Illinois	54	23	23	56,400	Oregon	0	98	2	96,981
Indiana	42	50	8	36,291	Pennsylvania	27	73	0	45,333
Iowa	100	0	0	56,290	Rhode Island	0	100	0	1,214
Kansas	84	16	0	82,264	South Carolina	0	87	13	31,055
Kentucky	55	32	13	40,395	South Dakota	87	13	0	77,047
Louisiana	100	0	0	48,523	Tennessee	33	41	26	42,244
Maine	0	100	0	33,215	Texas	90	10	0	42,244
Maryland	15	85	0	10,577	Utah	0	53	47	84,916
Massachusetts	0	100	0	8,257	Vermont	0	100	0	9,609
Michigan	100	0	0	58,216	Virginia	24	76	0	40,817
Minnesota	100	0	0	84,068	Washington	0	72	28	68,192
Mississippi	54	46	0	47,716	West Virginia	17	183	0	24,181
Missouri	30	43	27	69,686	Wisconsin	100	0	0	56,154
Montana	16	74	10	147,138	United States	44	47	9	

Source: Nuclear Regulatory Commission, *Nuclear Energy Site Survey-1975: Resource Availability and Site Screening,* NUREG 0001, Vol. 5, Table 4.3, January, 1976.

Figure 4.26

Natural Wetlands



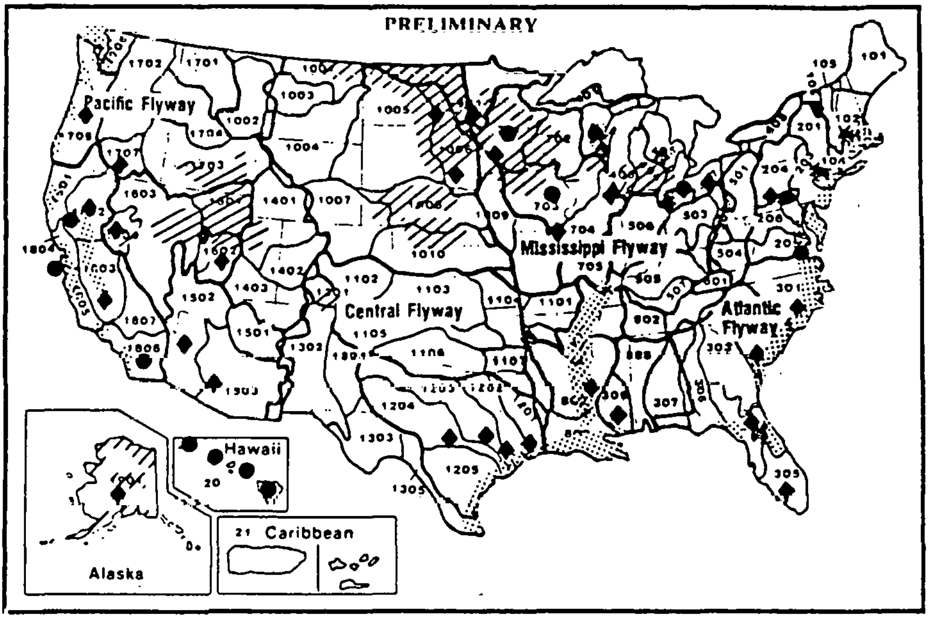
Bold Face number =

Area of natural wetlands of significant value to fish and wildlife in thousands of acres.

Source: Geraghty, van der Luden, Miller, and Troise, *Water Atlas of the United States*, Water Information Center, Inc., Huntington, New York.

Figure 4.27

Wetland Wildlife Habitat Loss



LEGEND

Areas with Greatest Total Impact

Areas with potential drainage of 100,000 acres or more of wet soils, including wetlands.

Location of Specific Impacts'

Wetland waterfowl breeding habitat needing protection.

Wetland waterfowl wintering habitat needing protection.

Urban or industrial encroachment on wetlands.

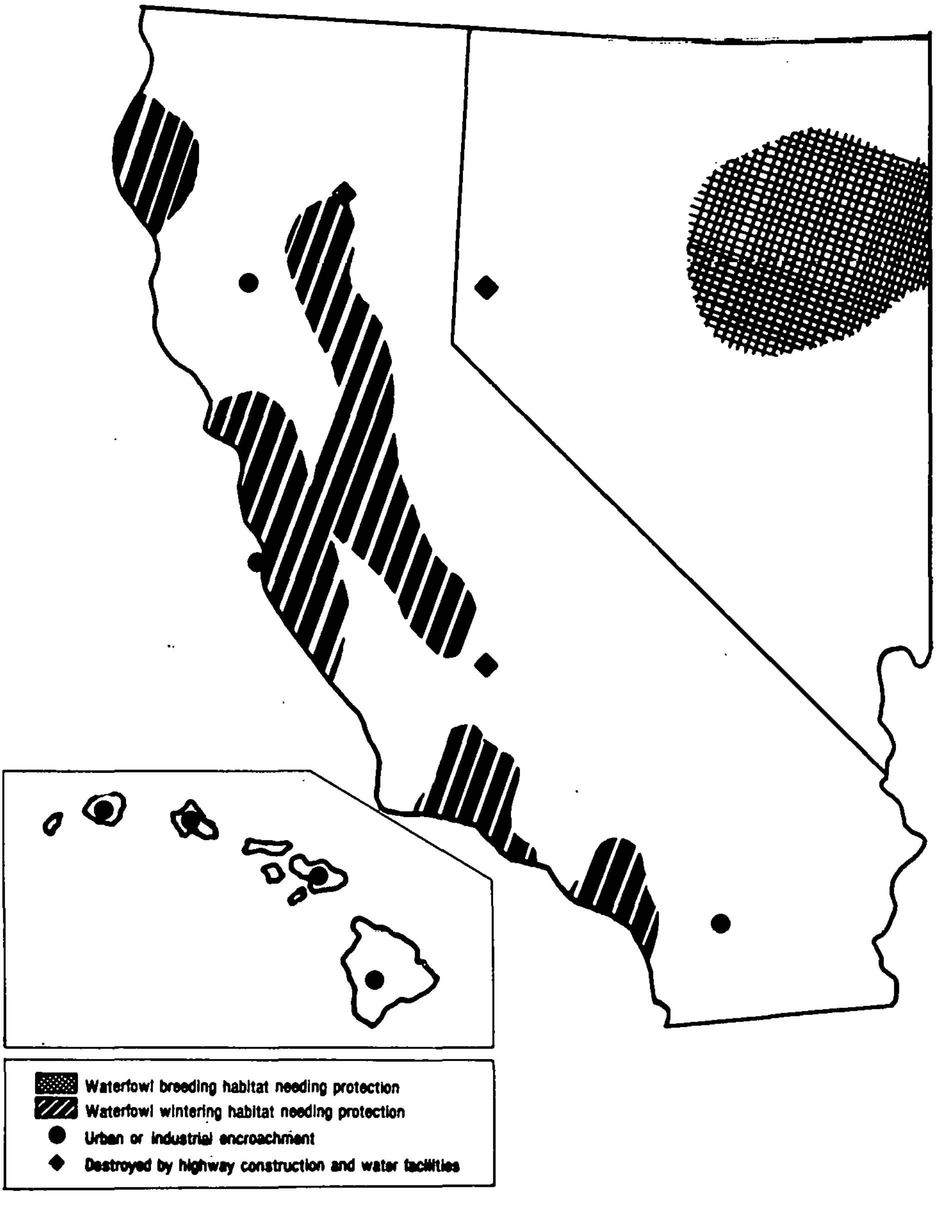
Wetlands destroyed by construction of highways and water facilities.

Identified by State/Regional study teams.

Source: "Preliminary Water Resources Problem Statements," 1977 National Conference on Water, St. Louis, Mo, U.S. Water Resources Council, Washington, D.C.

Figure 4.28

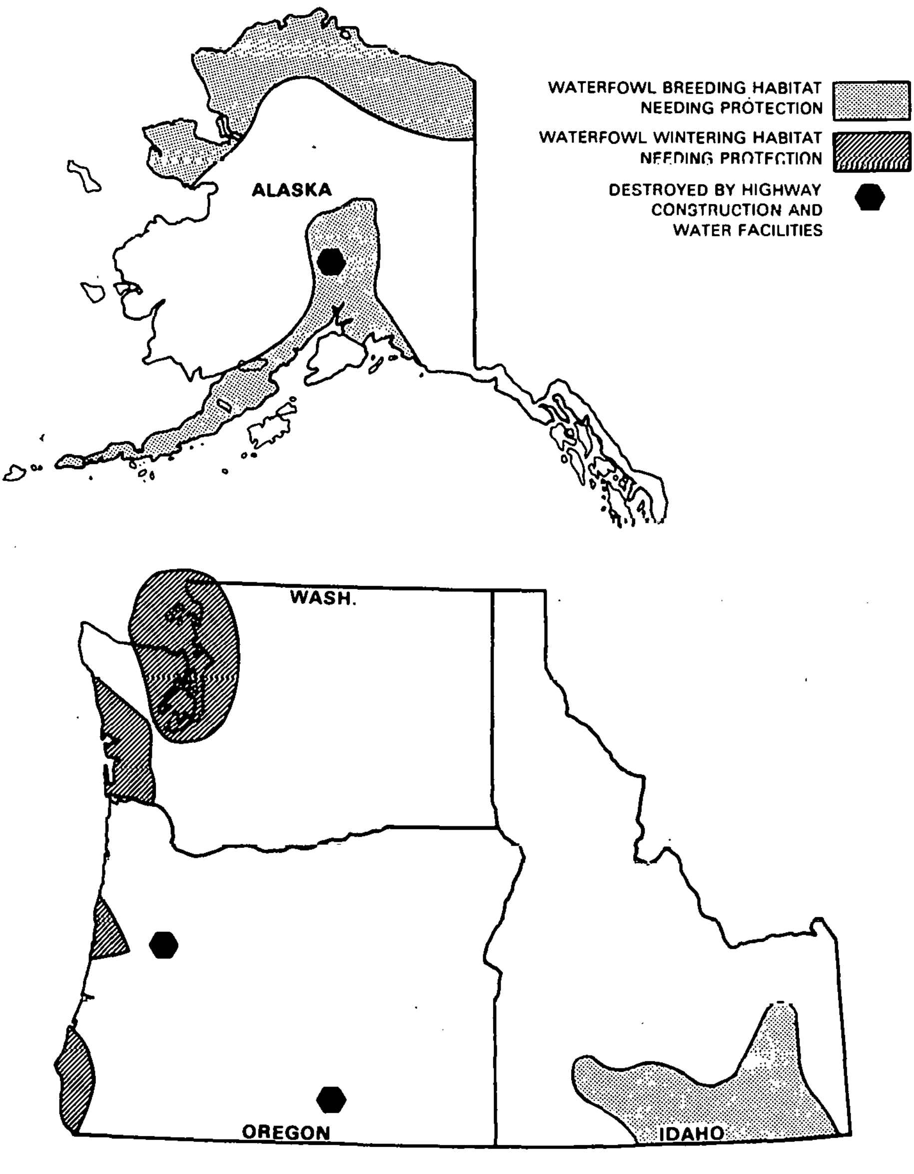
Wetland Wildlife Habitat Loss, California, Nevada, & Hawaii 1955-1975



Source: Council on Environmental Quality, *Environmental Quality Annual Report - 1977,* U.S. GPO, Washington, D.C. 1977

Figure 4.29

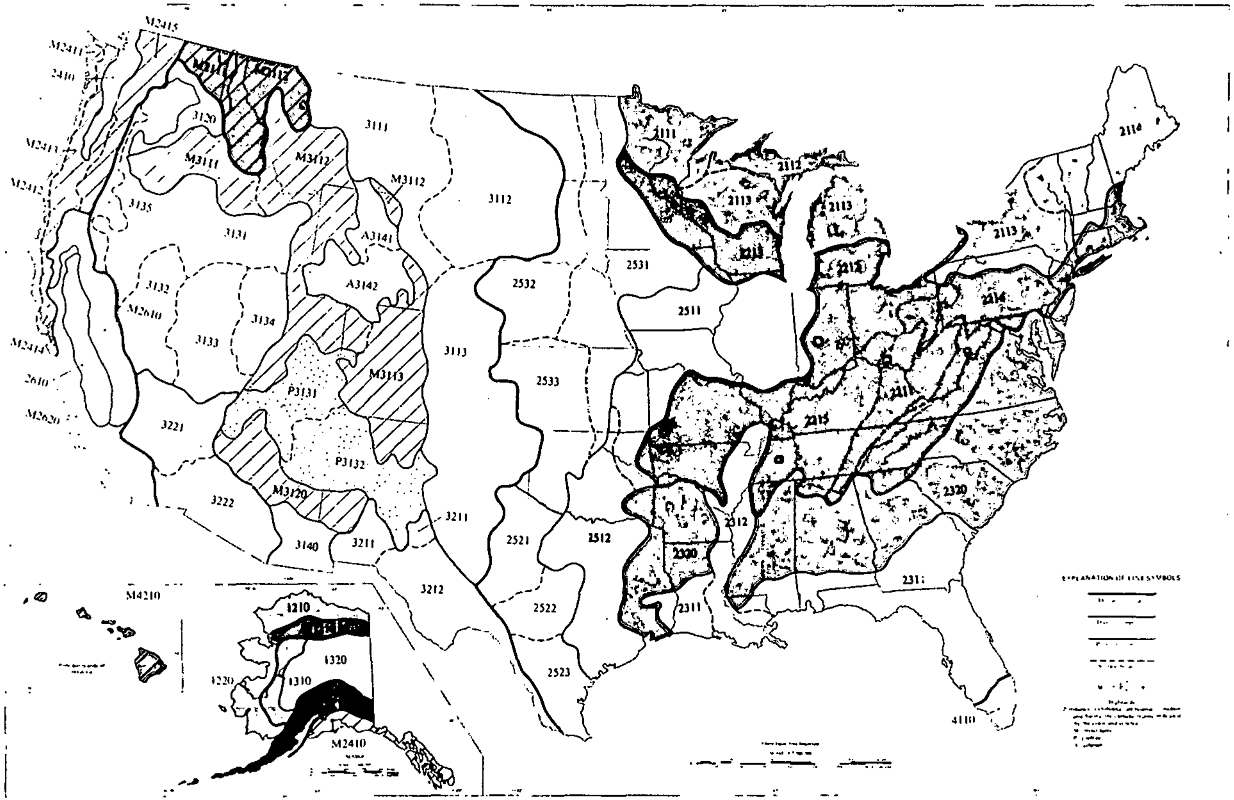
Wetland Wildlife Habitat Loss: Northwest Region - 1955-75



Source: U.S. Council on Environmental Quality, *Environmental Quality Annual Report - 1977,* U.S. GPO, Washington, D.C. 1977

Figure 4.30

Bailey's Ecoregions



Source: Bailey, R.C., *Ecoregions in the United States,* U.S. DA Forest Service, Washington, D.C., 1976.

Figure 4.30 (cont.)

Key for Bailey's Ecoregions

DOMAIN	DIVISION	LOWLAND ECOREGIONS		HIGHLAND ECOREGIONS*	
		PROVINCE	SECTION	PROVINCE	SECTION
1000 POLAR	1200 TUNDRA	1210 ARCTIC TUNDRA 1220 BERING TUNDRA		M1210 BROOKS RANGE	
	1300 SUBARCTIC	1310 YUKON PARKLAND 1320 YUKON FOREST		M1310 ALASKA RANGE	
2000 HUMID TEMPERATE	2100 CONTINENTAL COOL - SUMMER	2110 LAURENTIAN MIXED FOREST	2111 SPRUCE-FIR FOREST 2112 NORTHERN HARDWOODS FIR FOREST 2113 NORTHERN HARDWOODS FOREST 2114 NORTHERN HARDWOODS SPRUCE FOREST	M2110 COLUMBIA FOREST (DRY SUMMER)	M2111 DOUGLAS FIR FOREST M2112 CEDAR-HEMLOCK-DOUGLAS FIR FOREST
	2200 CONTINENTAL WARM - SUMMER	2210 EASTERN DECIDUOUS FOREST	2211 MIXED MESOPHYTIC 2212 BEECH-MAPLE FOREST 2213 MAPLE-BASSWOOD FOREST + OAK SAVANNA 2214 APPALACHIAN OAK FOREST 2215 OAK-HICKORY FOREST		
	2300 HOT - SUMMER	2310 OUTER COASTAL PLAIN FOREST 2320 SOUTHEASTERN MIXED FOREST	2311 BEECH-SWEETGUM-MAGNOLIA-PINE OAK FOREST 2312 SOUTHERN FLOOD-PLAIN FOREST		
	2400 MARITIME	2410 WILLAMETTE-PUGET FOREST		M2410 PACIFIC FOREST	M2411 SITKA SPRUCE-CEDAR-HEMLOCK FOREST M2412 REDWOOD FOREST M2413 CEDAR-HEMLOCK DOUGLAS FIR FOREST M2414 CALIFORNIA MIXED EVERGREEN FOREST M2415 SILVER FIR-DOUGLAS FIR FOREST
	2500 PRAIRIE	2510 PRAIRIE PARKLAND	2511 OAK-HICKORY-BLUESTEM PARKLAND 2512 OAK + BLUESTEM PARKLAND		
		2520 PRAIRIE BRUSHLAND	2521 MESQUITE-BUFFALO GRASS 2522 JUNIPER - OAK - MESQUITE 2523 MESQUITE - ACACIA		
		2530 TALL GRASS PRAIRIE	2531 BLUESTEM PRAIRIE 2532 WHEATGRASS - BLUESTEM NEEDLEGRASS 2533 BLUESTEM - GRAMA PRAIRIE		
	2600 MEDITERRANEAN (DRY - SUMMER SUBTROPICAL)	2610 CALIFORNIA GRASSLAND		M2610 SIERRAN FOREST M2620 CALIFORNIA CHAPARRAL	
3000 DRY	3100 STEPPE	3110 GREAT PLAINS SHORT-GRASS PRAIRIE	3111 GRAMA - NEEDLEGRASS-WHEATGRASS 3112 WHEATGRASS - NEEDLEGRASS 3113 GRAMA - BUFFALO GRASS	M3110 ROCKY MOUNTAIN FOREST	M3111 GRAND FIR DOUGLAS-FIR FOREST M3112 DOUGLAS-FIR FOREST M3113 PONDEROSA PINE - DOUGLAS-FIR FOREST
		3120 PALOUSE GRASSLAND		M3120 UPPER GILA MOUNTAINS FOREST	
		3130 INTERMOUNTAIN SAGE-BRUSH	3131 SAGEBRUSH - WHEATGRASS 3132 LAHONTAN SALTBUSH-GREASEWOOD 3133 GREAT BASIN SAGEBRUSH 3134 BONNEVILLE SALTBUSH - GREASEWOOD 3135 PONDEROSA SHRUB FOREST	P3130 COLORADO PLATEAU	P3131 JUNIPER PINYON WOODLAND + SAGEBRUSH SALTBRUSH MOSAIC P3132 GRAMA-GALLETA STEPPE + JUNIPER - PINYON WOODLAND MOSAIC
		3140 MEXICAN HIGHLANDS SHRUB STEPPE		A3140 WYOMING BASIN	A3141 WHEATGRASS - NEEDLEGRASS-SAGEBRUSH A3142 SAGEBRUSH - WHEATGRASS
	3200 DESERT	3210 CHIHUAHUAN DESERT	3211 GRAMA - TOBOSA 3212 TARBUSH - CREOSOTE BUSH		
		3220 AMERICAN DESERT (MOJAVE-COLORADO-SONORAN)	3221 CREOSOTE BUSH 3222 CREOSOTE BUSH - BUR SAGE		
4000 HUMID TROPICAL	4100 SAVANNA	4110 EVERGLADES			
	4200 RAINFOREST			M4210 HAWAIIAN ISLANDS	

*Key to letter symbols: M - mountains, P - plateau, A - altiplano

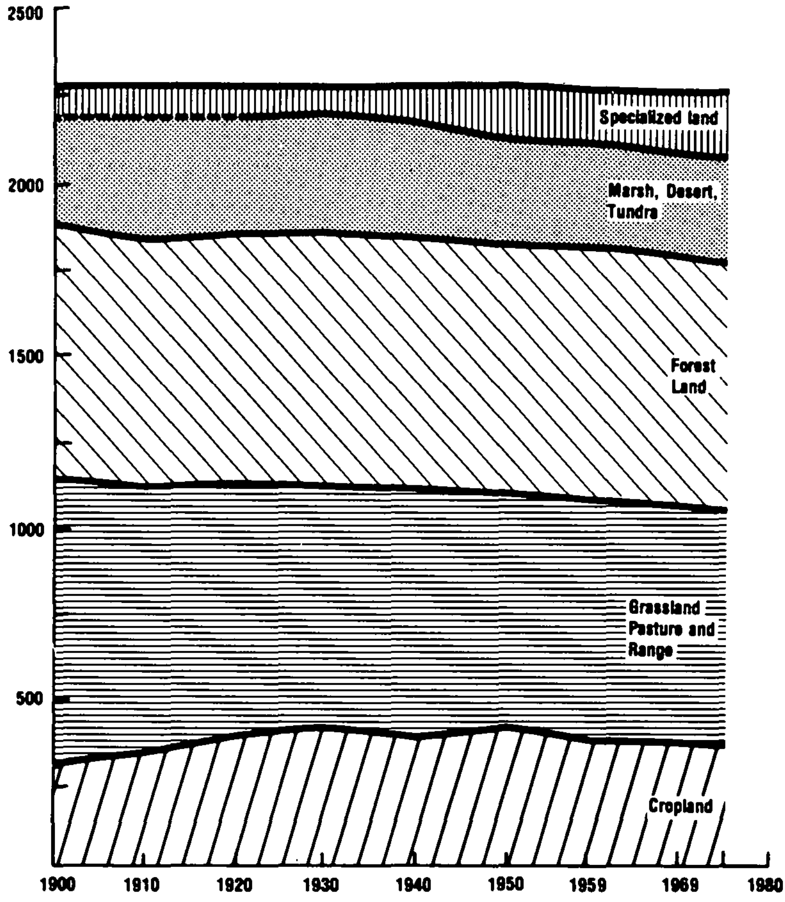
LAND USAGE

List of Tables

List of Figures

Figure 4.31

Major Uses of Land in the United States, 1900—74 (millions of acres)



Note: Forest Land excludes reserved forest land in parks, wildlife refuges, and other special-use areas. Specialized Land is urban and built-up areas (including cities and towns, rural highway and road rights-of-way, railroads, airports, and public institutions in rural areas) and nonurban special-use areas (including Federal and State parks and other rural parks, recreational areas, Federal and State wildlife refuges, national defense sites, flood-control areas, Federal industrial areas, farmsteads, and farm roads).

Source: U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service, *Major Uses of Land in the United States Summary for 1974,* draft, June, 1978, Table 3, p 3a; U.S. Department of Agriculture, Economic Research Service, *Major Uses of Land and Water in the United States, Summary for 1959,* Agricultural Economic Report No. 13, pp. 10, 11; U.S. Department of Agruculture, Economics, Statistics, and Cooperative Service, unpublished data.

Table 4.3

Major Uses of Land, By State and Region, 1974
(1,000 acres)

State and Region	Cropland[1]	Grassland, Pasture and Range[2]	Forest Land[3]	Special Use[4]	Other Land[5]	Approximate Land Area[6]
Federal Region 1	2,214	557	32,024	3,528	1,366	40,239
Connecticut	240	47	1,846	673	306	3,112
Maine	666	156	17,505	787	675	19,739
Massacusetts	263	45	2,848	1,289	564	5,009
New Hampshire	174	56	5,046	311	190	5,777
Vermont	841	248	4,384	169	189	5,931
Rhode Island	30	5	395	199	42	671
Federal Region 2	6,653	1,278	16,753	7,214	3,527	34,925
New Jersey	678	49	1,856	1,628	607	4,313
New York	5,975	1,229	14,897	5,586	2,925	30,612
Federal Region 3	15,139	4,185	49,154	7,609	1,192	77,279
Delaware	547	24	390	196	111	1,268
District of Columbia	0	0	0	39	0	39
Maryland	1,908	207	2,925	1,044	246	6,330
Pennsylvania	5,996	809	17,638	3,777	563	18,778
Virginia	4,925	2,282	16,075	1,961	216	25,459
West Virginia	1,763	863	12,126	597	56	15,405
Federal Region 4	53,760	18,644	13,884	18,807	6,812	236,907
Alabama	5,885	2,410	21,748	1,909	500	32,452
Florida	3,773	5,834	17,753	4,794	2,464	34,618
Georgia	7,103	1,275	25,157	2,747	885	37,167
Kentucky	9,810	1,871	11,887	1,524	284	25,376
Mississippi	8,394	2,864	16,892	1,290	829	30,269
North Carolina	6,480	1,216	20,224	2,693	618	31,231
South Carolina	3,663	979	12,403	1,614	685	19,344
Tennessee	8,652	2,195	12,820	2,236	547	26,450
Federal Region 5	96,288	12,058	66,343	18,912	13,369	206,470
Illinois	25,089	2,429	3,745	3,240	1,176	35,679
Indiana	14,143	1,656	3,870	2,051	1,382	23,102
Michigan	8,445	1,264	19,000	3,909	3,745	36,363
Minnesota	23,759	2,579	18,415	4,016	1,976	50,745
Ohio	12,800	1,829	6,422	3,014	2,159	26,224

Table 4.3 (cont.)

Major Uses of Land, By State and Region, 1974
(1,000 acres)

State and Region	Cropland[1]	Grassland, Pasture and Range[2]	Forest Land[3]	Special Use[4]	Other Land[5]	Approximate Land Area[6]
Federal Region 6	74,466	167,484	83,825	17,830	7,884	351,489
Arkansas	10,202	2,895	18,237	1,501	410	33,245
Louisiana	5,962	2,674	15,342	1,803	2,974	28,755
New Mexico	2,259	50,566	17,256	5,358	2,264	77,703
Oklahoma	16,036	16,599	8,926	2,142	317	44,020
Texas	40,007	94,750	24,064	7,026	1,919	167,766
Federal Region 7	104,184	46,663	17,486	8,307	4,612	181,252
Iowa	28,040	2,218	2,430	2,060	1,054	35,802
Kansas	31,826	16,016	1,363	2,245	894	52,344
Missouri	20,796	6,404	12,661	2,353	1,943	44,157
Nebraska	23,522	22,025	1,032	1,649	721	48,949
Federal Region 8	80,863	184,137	62,010	22,018	18,259	367,287
Colorado	10,473	29,571	19,387	3,272	3,707	66,410
Montana	16,035	49,741	19,899	4,673	2,828	93,176
North Dakota	29,695	11,233	419	1,854	1,138	44,339
South Dakota	20,007	24,622	1,700	1,636	646	48,611
Utah	1,932	22,945	14,720	5,200	7,744	52,541
Wyoming	2,721	46,025	5,885	5,383	2,196	62,210
Federal Region 9	13,828	112,773	66,127	32,414	21,956	247,098
Arizona	1,794	40,292	17,420	8,720	4,361	72,587
California	10,879	22,856	39,826	15,834	10,676	100,071
Hawaii	372	987	1,626	617	510	4,112
Nevada	783	48,638	7,255	7,243	6,409	70,328

Table 4.3 (cont.)

Major Uses of Land, By State and Region, 1974 (1,000 acres)

State and Region	Cropland[1]	Grassland, Pasture and Range[2]	Forest Land[3]	Special Use[4]	Other Land[5]	Approximate Land Area[6]
Federal Region 10	19,607	53,435	186,432	42,598	217,519	519,591
Alaska	18	1,624	118,276	30,529	212,069	362,516
Idaho	6,166	22,073	18,030	4,051	2,593	52,913
Oregon	5,145	22,756	29,387	2,520	1,749	61,557
Washington	8,278	6,982	20,739	5,498	1,108	42,605
U.S.	467,002	601,214	719,038	179,237	297,096	2,262,587

[1]Total acreage in the crop rotation.
[2]Grassland and other nonforested pasture in farms excluding cropland used only for pasture, plus estimates of open or nonforested grazing land not in farms.
[3]Forest land, excluding reserved forest land and some unreserved areas duplicated in parks and other special uses of land.
[4]Urban, transportation, recreational, and other special uses of land.
[5]Miscellaneous areas with low agricultural use value, such as marshes, open swamps, bare rock areas, deserts and tundra.
[6]Approximate land area as developed by the Bureau of the Census in conjunction with the 1970 Census of Population (1972). Includes all dryland and land temporarily or partially covered with water, such as marshland, swamps, and river flood plains; streams, sloughs, estuaries, and canals less than one-eighth mile wide; and lakes, reservoirs, and ponds less than 40 acres in area.

Source: Department of Energy, Assistant Secretary for Environment, *Regional Energy Data Books* (Six Regional Volumes), DOE/TIC-10114/1-6, October 1978.

Table 4.4

Agricultural Land Data Sheet

FARM PRODUCTION REGIONS & STATES	USE STATUS OF NONFEDERAL LAND AVAILABLE FOR AGRICULTURE											
	Cropland		Pastureland		Rangeland		Forest Land		Other Land in Farms		Farmsteads	Total
	Nonirrigated	Irrigated	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential		
Northeast												
Connecticut	193	8	112	30	0	0	1,410	55	50	15	16	1,795
Delaware	505	37	23	19	0	0	360	93	4	2	13	942
Maine	885	22	249	83	0	0	16,520	101	39	10	45	17,770
Maryland	1,638	39	486	187	0	0	2,148	325	74	6	91	4,476
Massachusetts	264	18	91	38	0	0	2,756	104	38	6	24	3,191
New Hampshire	273	0	95	53	0	0	3,976	160	7	4	12	4,363
New Jersey	622	155	144	81	0	0	1,905	230	81	52	52	3,019
New York	5,894	75	2,286	726	0	0	15,445	444	609	240	215	24,524
Pennsylvania	5,651	10	1,797	599	0	0	14,349	540	531	160	257	22,595
Rhode Island	30	0	18	4	0	0	301	12	3	0	3	355
Vermont	590	7	534	119	0	0	3,928	73	22	6	16	5,097
Total Northeast	**16,545**	**371**	**5,835**	**1,939**	**0**	**0**	**63,164**	**2,197**	**1,458**	**501**	**744**	**88,127**
Appalachian												
Kentucky	5,419	9	5,735	2,424	0	0	10,048	644	130	28	282	22,223
North Carolina	5,926	271	2,030	978	0	0	16,813	3,893	114	92	328	25,482
Tennessee	4,902	26	5,474	2,303	0	0	11,038	1,319	64	60	287	22,391
Virginia	3,127	82	3,274	823	0	0	13,233	1,262	83	32	208	20,007
West Virginia	981	10	2,037	299	0	0	9,805	113	25	19	76	12,934
Total Appalachian	**20,355**	**398**	**18,550**	**6,887**	**0**	**0**	**62,137**	**7,231**	**416**	**231**	**1,181**	**103,037**

Table 4.4 (cont.)

Agricultural Land Data Sheet

FARM PRODUCTION REGIONS & STATES	NONFEDERAL LAND UNAVAILABLE FOR AGRICULTURE: Urban & Built-Up	Rural Transportation	Other Nonfarm	Water	Total	AGRICULTURAL LAND CONVERTED TO URBAN & BUILT-UP, TRANSPORTATION & WATER 1967-1977	PRIME FARMLAND: Total	In Cropland Use	LAND AREA: Total	Federally Owned	Nonfederal
Northeast											
Connecticut	971	56	244	39	1,310	360	394	133	3,113	8	3,105
Delaware	151	20	95	14	280	60	350	276	1,260	38	1,222
Maine	433	224	1,173	109	1,939	<1	853	324	19,843	134	19,709
Maryland	1,196	139	310	50	1,695	780	1,262	814	6,323	152	6,171
Massachusetts	1,243	106	385	51	1,785	300	448	169	5,051	75	4,976
New Hampshire	337	89	230	50	706	190	144	86	5,778	709	5,069
New Jersey	1,176	67	367	37	1,647	140	1,249	502	4,809	143	4,666
New York	2,994	603	1,982	257	5,836	810	4,000	2,286	30,589	229	30,360
Pennsylvania	3,370	609	1,360	169	5,508	1,280	4,448	2,351	28,746	643	28,103
Rhode Island	248	12	46	9	315	150	84	23	677	7	670
Vermont	316	100	114	28	558	220	374	128	5,931	276	5,655
Total Northeast	**12,435**	**2,025**	**6,306**	**813**	**21,579**	**4,290**	**13,606**	**7,092**	**112,120**	**2,414**	**109,706**
Appalachian											
Kentucky	1,222	450	255	154	2,081	760	5,994	3,334	25,399	1,095	24,304
North Carolina	2,151	651	709	291	3,802	1,280	5,006	2,729	31,208	1,924	29,284
Tennessee	1,698	583	370	151	2,802	770	6,447	3,078	26,403	1,210	25,193
Virginia	2,074	321	574	195	3,164	1,400	4,324	1,508	25,477	2,306	23,171
West Virginia	798	211	304	77	1,390	480	502	285	15,404	1,080	14,324
Total Appalachian	**7,943**	**2,216**	**2,212**	**868**	**13,239**	**4,690**	**22,873**	**10,934**	**123,891**	**7,615**	**116,276**

Table 4.4 (cont.)

Agricultural Land Data Sheet

FARM PRODUCTION REGIONS & STATES	USE STATUS OF NONFEDERAL LAND AVAILABLE FOR AGRICULTURE											
	Cropland		Pastureland		Rangeland		Forest Land		Other Land in Farms		Farmsteads	Total
	Nonirrigated	Irrigated	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential		
Southeast												
Alabama	4,402	37	4,122	2,300	0	0	19,792	1,763	96	24	231	28,740
Florida	1,469	1,720	5,483	2,121	3,017	640	12,140	814	238	38	117	24,184
Georgia	5,851	636	3,234	1,888	0	0	21,560	3,861	41	29	242	31,570
South Carolina	3,287	44	1,242	700	0	0	10,770	1,515	33	29	121	15,497
Total Southeast	**15,069**	**2,437**	**14,081**	**7,069**	**3,017**	**640**	**64,268**	**7,953**	**408**	**120**	**711**	**99,991**
Lake States												
Michigan	9,256	228	1,230	642	0	0	15,323	894	962	278	315	27,314
Minnesota	22,518	398	2,889	1,403	110	15	13,806	1,919	1,080	314	698	41,499
Wisconsin	11,401	340	2,738	1,116	4	0	13,259	1,353	1,275	127	350	29,367
Total Lake States	**43,175**	**966**	**6,857**	**3,221**	**114**	**15**	**42,388**	**4,166**	**3,317**	**719**	**1,363**	**98,180**
Corn Belt												
Illinois	23,770	66	3,070	1,220	0	0	3,028	497	527	212	501	30,962
Indiana	13,180	140	2,147	1,001	0	0	3,534	596	418	197	384	19,803
Iowa	26,356	75	4,530	1,803	0	0	1,487	183	215	179	708	33,371
Missouri	13,797	776	12,823	5,764	35	23	10,832	727	216	86	422	38,901
Ohio	11,719	43	2,615	1,077	0	0	5,865	629	384	162	366	20,992
Total Corn Belt	**88,822**	**1,100**	**25,185**	**10,871**	**35**	**23**	**24,746**	**2,632**	**1,760**	**836**	**2,381**	**144,029**
Delta States												
Arkansas	5,547	2,443	5,628	1,966	248	47	14,072	1,194	99	74	197	28,234
Louisiana	4,738	1,161	2,945	1,344	326	0	12,595	1,550	58	26	162	21,985
Mississippi	6,948	354	4,041	1,806	30	0	14,412	1,916	92	44	246	26,123
Total Delta States	**17,233**	**3,958**	**12,614**	**5,116**	**604**	**47**	**41,079**	**4,660**	**249**	**144**	**605**	**76,342**

Table 4.4 (cont.)

Agricultural Land Data Sheet

FARM PRODUCTION REGIONS & STATES	NONFEDERAL LAND UNAVAILABLE FOR AGRICULTURE					AGRICULTURAL LAND CONVERTED TO URBAN & BUILT-UP, TRANSPORTATION & WATER 1967-1977	PRIME FARMLAND		LAND AREA		
	Urban & Built-Up	Rural Transportation	Other Nonfarm	Water	Total		Total	In Cropland Use	Total	Federally Owned	Nonfederal
Southeast											
Alabama	1,728	605	257	228	2,818	890	7,856	2,913	32,434	876	31,558
Florida	4,273	600	2,432	496	7,801	3,470	1,417	404	34,473	2,488	31,985
Georgia	2,026	439	693	396	3,554	1,400	7,767	3,655	37,160	2,036	35,124
South Carolina	1,543	439	533	178	2,693	920	3,484	1,543	19,301	1,111	18,190
Total Southeast	**9,570**	**2,083**	**3,915**	**1,298**	**16,866**	**6,680**	**20,524**	**8,515**	**123,368**	**6,511**	**116,857**
Lake States											
Michigan	3,287	798	1,680	211	5,976	1,220	8,382	5,695	36,364	3,074	33,290
Minnesota	1,397	1,072	3,105	406	5,980	490	19,513	15,302	50,698	3,219	47,479
Wisconsin	1,602	724	1,198	246	3,770	190	10,319	6,475	34,844	1,707	33,137
Total Lake States	**6,286**	**2,594**	**5,983**	**863**	**15,726**	**1,900**	**38,214**	**27,472**	**121,906**	**8,000**	**113,906**
Corn Belt											
Illinois	2,662	830	483	264	4,239	1,060	21,400	19,100	35,661	460	35,201
Indiana	1,834	518	306	161	2,819	740	14,162	11,515	23,087	465	22,622
Iowa	857	1,062	163	222	2,304	440	19,127	16,875	35,828	153	35,675
Missouri	1,375	1,056	328	372	3,131	480	15,067	9,544	44,126	2,094	42,032
Ohio	3,532	626	542	202	4,902	1,310	11,280	9,216	26,195	301	25,894
Total Corn Belt	**10,260**	**4,092**	**1,822**	**1,221**	**17,395**	**4,030**	**81,036**	**66,250**	**164,897**	**3,473**	**161,424**
Delta States											
Arkansas	1,049	516	148	257	1,970	370	13,250	6,633	33,291	3,087	30,204
Louisiana	999	434	3,862	358	5,653	250	9,353	5,267	28,746	1,108	27,638
Mississippi	1,389	521	229	412	2,551	720	10,227	5,200	30,225	1,551	28,674
Total Delta States	**3,437**	**1,471**	**4,239**	**1,027**	**10,174**	**1,340**	**32,830**	**17,100**	**92,262**	**5,746**	**86,516**

Table 4.4 (cont.)

Agricultural Land Data Sheet

FARM PRODUCTION REGIONS & STATES	USE STATUS OF NONFEDERAL LAND AVAILABLE FOR AGRICULTURE											
	Cropland		Pastureland		Rangeland		Forest Land		Other Land in Farms		Farmsteads	Total
	Nonirrigated	Irrigated	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential		
Northern Plains												
Kansas	25,631	3,175	2,701	1,356	16,276	3,992	788	115	328	95	378	49,277
Nebraska	13,794	6,905	2,899	1,253	22,001	2,499	444	36	253	157	478	46,774
North Dakota	26,835	78	1,544	816	10,564	1,913	366	62	1,010	91	397	40,794
South Dakota	17,684	472	2,413	1,289	22,198	4,101	330	20	531	83	477	44,105
Total Northern Plains	**83,944**	**10,630**	**9,557**	**4,714**	**71,039**	**12,505**	**1,928**	**233**	**2,122**	**426**	**1,730**	**180,950**
Southern Plains												
Oklahoma	11,073	710	8,713	2,785	14,560	2,709	4,931	253	82	47	274	40,349
Texas	22,510	7,929	18,768	4,781	95,401	8,781	9,240	524	874	140	619	155,341
Total Southern Plains	**33,583**	**8,639**	**27,481**	**7,566**	**109,967**	**11,490**	**14,171**	**777**	**956**	**187**	**893**	**195,690**
Mountain												
Arizona	145	1,167	11	9	35,091	313	1,803	1	17	14	17	38,251
Colorado	7,699	3,394	1,598	254	23,801	2,408	3,343	30	225	42	183	40,243
Idaho	2,743	3,547	1,109	500	6,589	793	4,230	144	51	4	126	18,395
Montana	13,294	2,061	2,647	1,136	38,834	4,476	6,341	55	194	32	162	63,533
Nevada	4	1,103	298	24	7,351	231	230	0	19	7	17	9,022
New Mexico	1,203	1,079	382	33	42,096	1,249	3,426	1	191	4	76	48,453
Utah	655	1,160	626	145	9,385	363	1,071	0	23	10	33	12,953
Wyoming	1,320	1,650	736	254	26,109	1,000	1,164	4	9	7	52	31,100
Total Mountain	**27,063**	**15,161**	**7,407**	**2,355**	**189,316**	**11,433**	**21,608**	**235**	**729**	**120**	**666**	**261,950**

Table 4.4 (cont.)

Agricultural Land Data Sheet

FARM PRODUCTION REGIONS & STATES	NONFEDERAL LAND UNAVAILABLE FOR AGRICULTURE					AGRICULTURAL LAND CONVERTED TO URBAN & BUILT-UP, TRANSPORTATION & WATER 1967 1977	PRIME FARMLAND		LAND AREA		
	Urban & Built-Up	Rural Transportation	Other Nonfarm	Water	Total		Total	In Cropland Use	Total	Federally Owned	Nonfederal
Northern Plains											
Kansas	747	1,089	310	293	2,439	<1	27,318	19,520	52,354	638	51,716
Nebraska	509	814	55	172	1,550	250	14,203	11,899	48,972	648	48,324
North Dakota	269	986	150	381	1,786	320	13,915	12,701	44,303	1,723	42,580
South Dakota	256	733	474	216	1,079	530	5,071	4,312	48,568	2,784	45,784
Total Northern Plains	**1,781**	**3,622**	**989**	**1,062**	**7,454**	**1,100**	**60,507**	**48,432**	**194,197**	**5,793**	**188,404**
Southern Plains											
Oklahoma	1,132	745	283	312	2,472	250	15,622	8,390	43,920	1,099	42,821
Texas	5,171	2,088	1,599	685	9,543	2,260	37,498	17,631	167,782	2,898	164,884
Total Southern Plains	**6,303**	**2,833**	**1,882**	**997**	**12,015**	**2,510**	**53,120**	**26,021**	**211,702**	**3,997**	**207,705**
Mountain											
Arizona	900	153	1,384	11	2,448	320	1,161	1,086	72,587	31,888	40,699
Colorado	827	584	1,010	136	2,557	400	1,760	1,613	66,407	23,607	42,800
Idaho	377	232	381	67	1,057	190	3,512	2,998	52,739	33,287	19,452
Montana	438	705	1,091	249	2,483	350	1,240	889	93,131	27,115	66,016
Nevada	235	106	1,254	19	1,614	<1	303	243	70,318	59,682	10,636
New Mexico	717	334	1,748	52	2,851	290	524	504	77,720	26,416	51,304
Utah	564	157	2,895	35	3,651	290	650	641	52,537	35,933	16,604
Wyoming	222	320	913	97	1,552	<1	259	224	62,140	29,488	32,652
Total Mountain	**4,280**	**2,591**	**10,676**	**666**	**18,213**	**1,840**	**9,409**	**8,198**	**547,579**	**267,416**	**280,163**

Table 4.4 (cont.)

Agricultural Land Data Sheet

USE STATUS OF NONFEDERAL LAND AVAILABLE FOR AGRICULTURE

FARM PRODUCTION REGIONS & STATES	Cropland		Pastureland		Rangeland		Forest Land		Other Land in Farms		Farmsteads	Total
	Nonirrigated	Irrigated	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential	Total	With Cropland Conversion Potential		
Pacific												
Alaska[1]	46	0	1	0	6,270	0	6,900	124	0	0	1	13,224
California	1,920	8,153	1,127	613	17,554	1,789	9,855	63	281	112	257	39,147
Hawaii[1]	139	154	992	74	0	0	1,443	11	90	3	3	2,821
Oregon	3,139	2,009	1,767	512	10,110	390	10,066	219	127	12	151	27,369
Washington	6,179	1,772	1,252	480	6,041	605	12,382	430	173	33	234	28,033
Total Pacific	**11,423**	**12,088**	**5,139**	**1,679**	**39,981**	**2,784**	**40,646**	**847**	**671**	**160**	**646**	**110,594**
Total All Regions	**357,212**	**55,758**	**132,706**	**51,417**	**414,073**	**38,937**	**376,135**	**30,931**	**12,086**	**3,444**	**10,920**	**1,358,890**

EXPLANATION OF TABLE COLUMN HEADINGS AND ELEMENTS

FARM PRODUCTION REGIONS

Grouping of states used by USDA agencies to present natural and related resource data.

LAND AREA

Based on Bureau of the Census data and adjusted for (1) new water bodies greater than 40 acres in size (2) changes in Federal ownership.

USE STATUS OF NONFEDERAL LAND AVAILABLE FOR AGRICULTURE

The definitions of the land use and cover categories are those of the USDA Soil Conservation Service's 1977 National Resource Inventories. Definitions of rangeland and forest land are used by both the USDA Forest Service and the Soil Conservation Service.

Cropland

Land used to produce adapted crops for harvest, either alone or in rotation with grasses and legumes. Cropland production includes row crops, close grown field crops, hay crops, rotation hay and pasture, nursery crops, orchard crops, and other similar specialty crops, summer fallow, and other cropland not harvested or pastured.

Pastureland

Lands producing forage plants, principally introduced species for animal consumption. In addition to regulating the intensity of grazing management practices typically include such cultural treatments as reseeding, renovation reestablishment, mowing, weed or brush control, liming or fertilization. Pastureland may be on drained or irrigated lands. Also included in pastureland, regardless of treatment, is land being managed to establish or maintain stands of grasses such as bluegrass, bromegrass, or bermuda grass, either alone or in mixtures with clover or other legumes.

Rangeland

Land on which the potential or natural vegetation climax species are predominantly grasses, grass-like plants, forbs, or shrubs. Included are lands revegetated either naturally or artificially and managed to duplicate native vegetation. Rangelands include natural grasslands, savannahs, shrublands, most deserts, tundra, alpine communities, coastal marshes, and wet meadows. They include land with less than 10 percent stocking with forest trees of any size.

Rangelands in Alaska are dominantly tundra and alpine communities. There is some use of the rangeland by caribou and also some limited reindeer herding.

Forest Land (Woodland)

Land with at least a 25-percent tree canopy cover or land at least 10-percent stocked by forest trees of any size, including land formerly having such tree cover and suitable for natural or artificial reforestation.

Table 4.4 (cont.)

Agricultural Land Data Sheet

FARM PRODUCTION REGIONS & STATES	NONFEDERAL LAND UNAVAILABLE FOR AGRICULTURE					AGRICULTURAL LAND CONVERTED TO URBAN & BUILT-UP, TRANSPORTATION & WATER 1967-1977	PRIME FARMLAND		LAND AREA		
	Urban & Built-Up	Rural Transportation	Other Nonfarm	Water	Total		Total	In Cropland Use	Total	Federally Owned	Nonfederal
Pacific											
Alaska[1]	83	257	405	31	770	<1	0	0	362,515	348,5[illegible]	14,000
California	4,110	850	9,355	239	14,500	1,500	7,805	6,545	100,076	46,369	53,707
Hawaii[1]	139	18[illegible]	79[illegible]	7	954	60	227	184	4,112	337	3,775
Oregon	788	325	557	110	1,780	270	2,373	1,823	61,462	32,[illegible]3	29,149
Washington	1,368	431	389	154	2,342	630	2,016	1,453	42,595	12,220	30,375
Total Pacific	**6,494**	**[illegible],881**	**11,496**	**541**	**20,412**	**2,460**	**12,421**	**10,005**	**570,761**	**439,755**	**131,006**
Total All Regions	**68,789**	**25,408**	**49,520**	**9,356**	**153,073**	**30,840**	**344,540**	**230,011**	**2,261,683**	**750,720**	**1,511,963**

Other Land in Farms
Land reserved for wildlife and windbreaks, not directly associated with farmsteads. Includes commercial feedlots, greenhouses, and nurseries.

Farmsteads
Land for dwellings, buildings, barns, pens, corrals, farmstead windbreaks, family gardens, and other uses connected with operating farms and ranches.

Potential For Cropland of 1977 Pastureland, Rangeland, Forest Land, And Other Land In Farms
Determinations of cropland potential for each data point were made by a group representing a variety of USDA agencies. They were made on the basis of 1976 commodity prices, as well as development and production costs. A "high potential" rating required favorable physical characteristics and also evidence of similar land being converted to cropland during the last three years. A "medium potential" rating required favorable physical characteristics, but generally conversion costs were expected to be higher than those for soils with a high potential rating.

Potential ratings for Alaska were made by the State USDA Land Use Committee. They represent conversions to cropland anticipated by 1985.

Areas with cropland potential include acreages rated as having "high" or "medium" potential. They represent a portion of the pastureland, rangeland, forest land and other land in farm acreages, and thus are not a component of the "totals" of nonfederal land available for agriculture.

NONFEDERAL LAND UNAVAILABLE FOR AGRICULTURE
The definition of land use and cover categories are those used by the Soil Conservation Service in its *1977 National Resources Inventories*.

Urban & Built Up
Land used for residences, industrial sites, commercial sites, construction sites, railroad yards, small parks of less than 10 acres within urban and built-up areas, cemeteries, airports, golf courses, sanitary land fills, sewage treatment plants, water control structures and spillways, shooting ranges and so forth. The rights-of-way of highways, railroads and other transportation facilities are included if they are within urban and built-up areas. In 197?, this category included four million acres of "small" built-up areas of from ¼ to 10 acres in size.

Rural Transportation
Land used for roads and railroads in rural areas. Generally, this includes the entire right-of-way.

Table 4.4 (cont.)

Agricultural Land Data Sheet

Other Nonfarm

Land used for greenbelts, large unwooded parks and other nonfarm uses not elsewhere defined. This category also includes land in strip mines, quarries, gravel pits, and borrow pits that have not been reclaimed for other uses. Between 2 and 3 million acres have cropland conversion potential.

Water

Water bodies less than 40 acres in size and streams less than ⅛ mile wide.

PRIME FARMLAND

Prime farmland is the best land for farming. Prime acres are flat or gently rolling and susceptible to little or no soil erosion. They are our most energy-efficient acres, producing the most food, feed, fiber, forage and oilseed crops with the least amount of fuel, fertilizer and labor.

Their soil quality, growing season and moisture supply assure continuous, high productivity without degrading the environment.

Prime farmland includes cropland, pastureland, range and forest lands. It does not include land converted to urban, industrial, transportation or water.

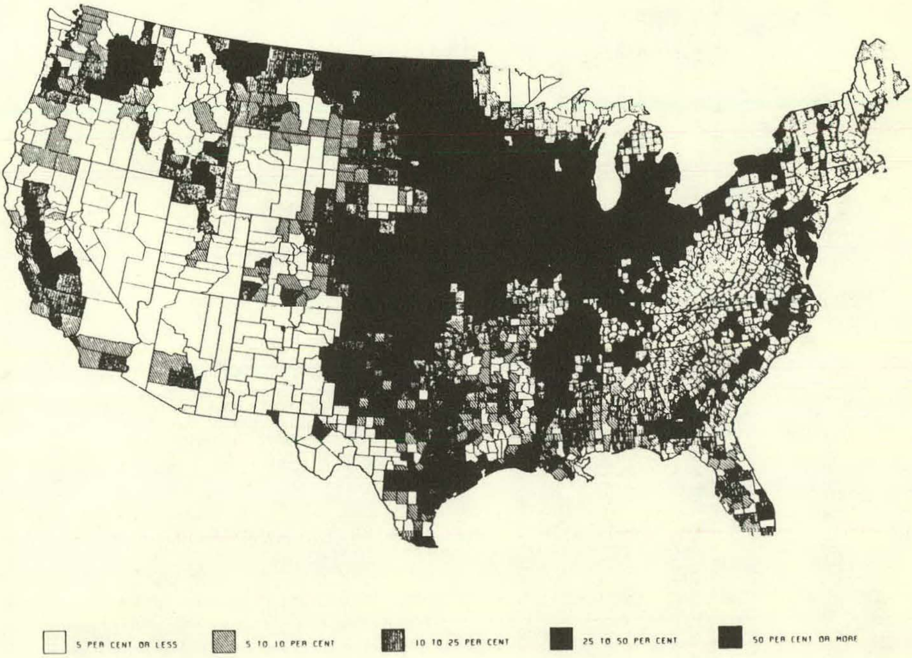
AGRICULTURAL LAND CONVERTED TO URBAN, BUILT-UP, RURAL TRANSPORTATION & WATER 1967-1977

Data sources and definitions are those of the USDA 1967 *Conservation Needs Inventory* and the USDA SCS 1977 *National Resources Inventories*. There are some differences in the inventory procedures used to determine the extent of urban, built-up, rural transportation and water in these two inventories. Therefore, the "converted" acreages should be interpreted as estimates rather than precise measures of land use change over the period.

Source: National Agricultural Lands Study, "Interim Report No. 2," Washington, D.C., June, 1980.

Figure 4.32

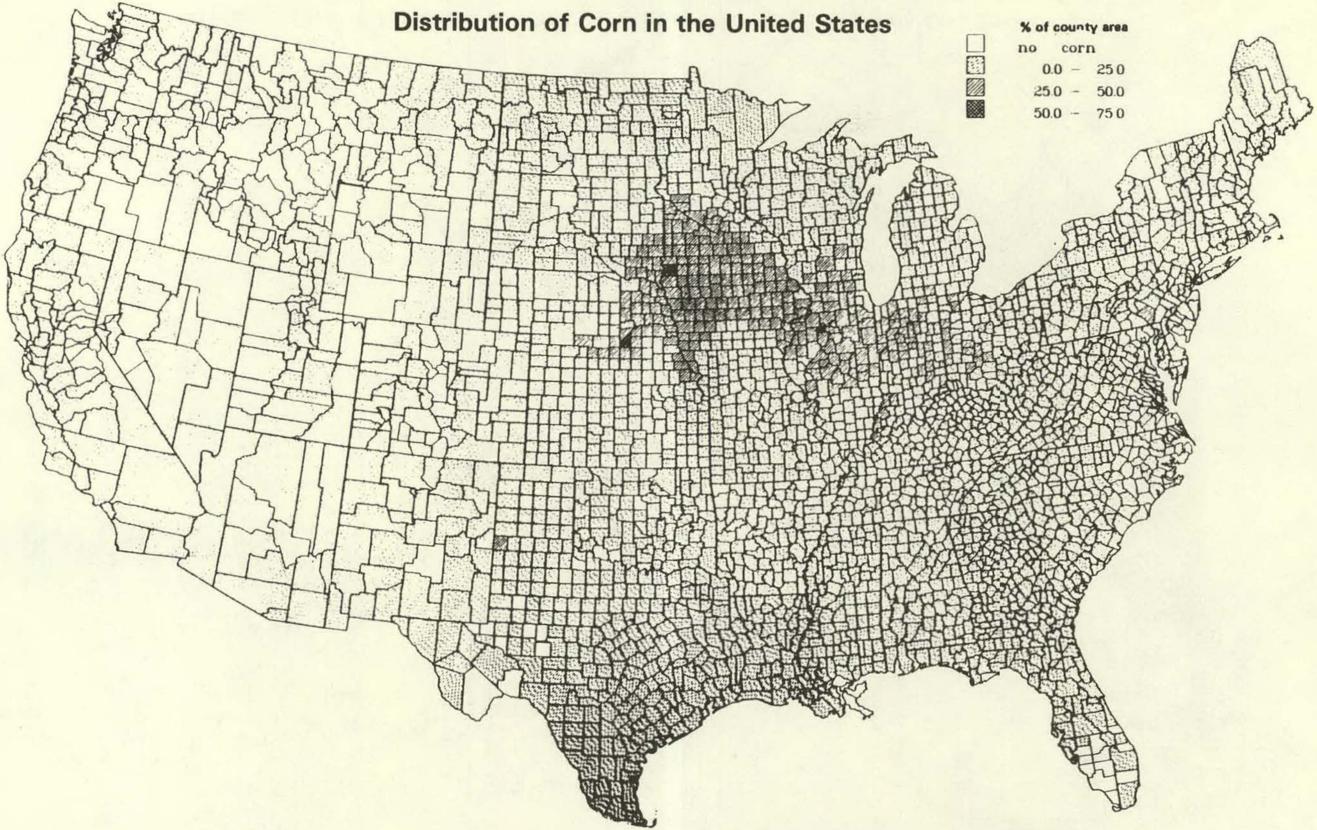
Cropland



Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 4.33

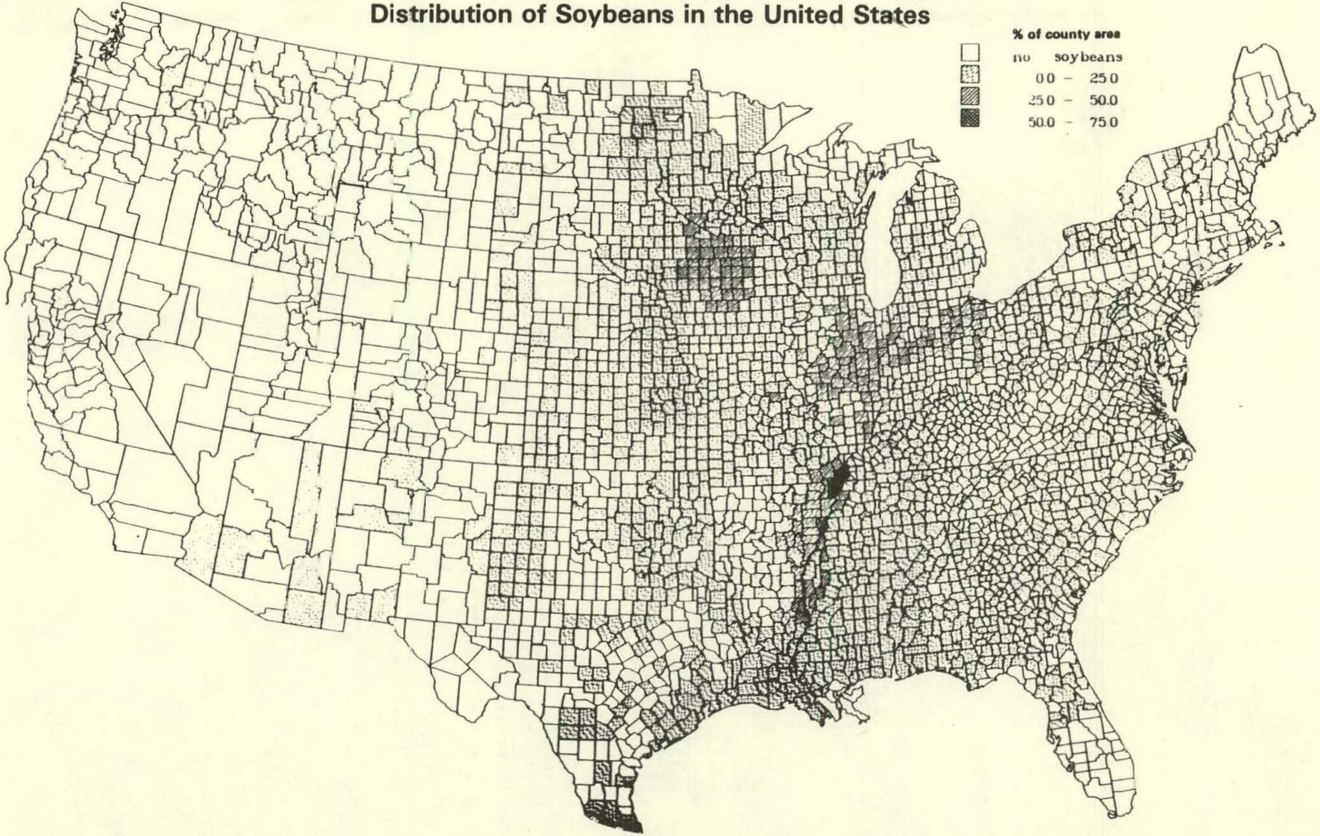
Distribution of Corn in the United States



Source: Olson, R.J., C.J. Emerson, M.K. Nungensser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 4.34

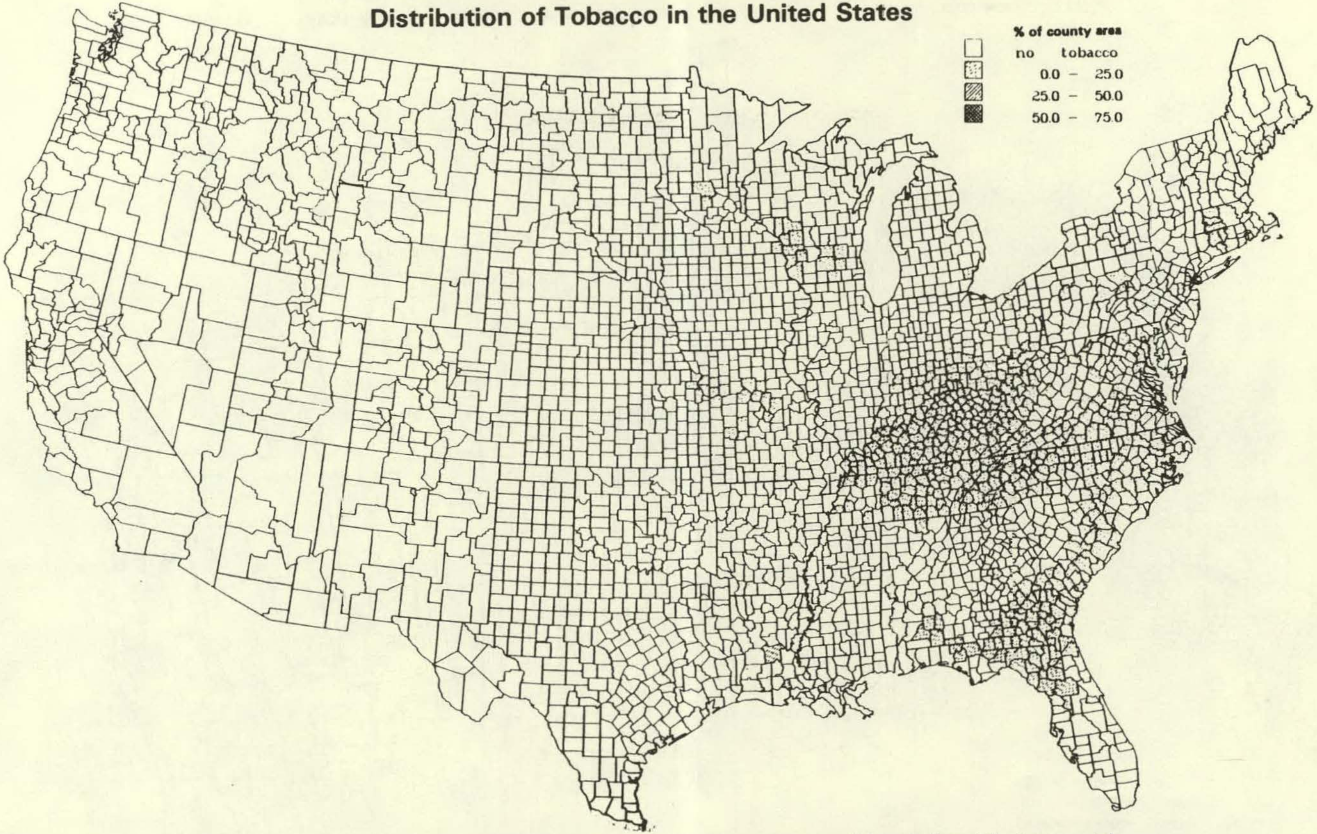
Distribution of Soybeans in the United States



Source: Olson, R.J , C.J. Emerson, M.K. Nungensser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 4.35

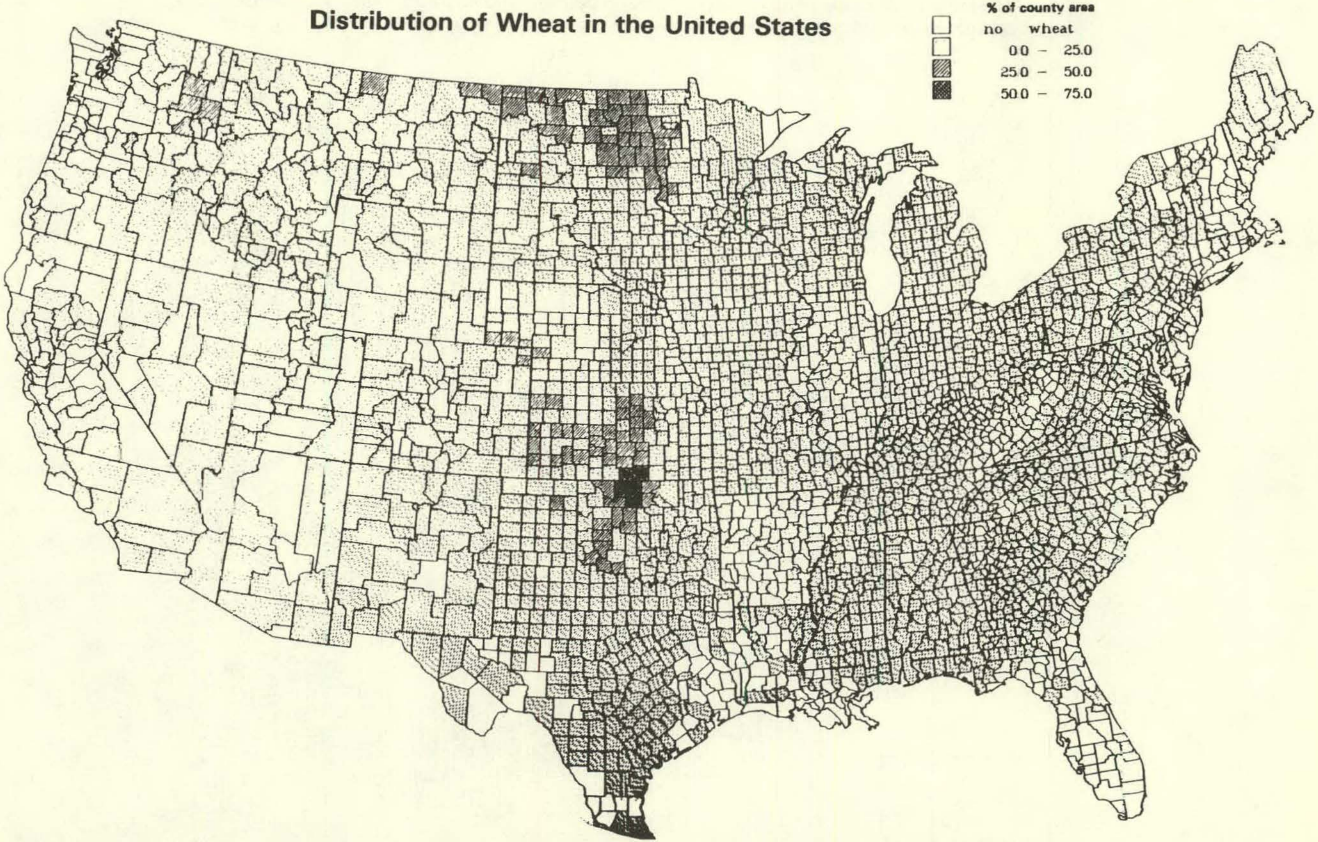
Distribution of Tobacco in the United States



Source: Olson, R.J., C.J. Emerson, M.K. Nungensser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 4.36

Distribution of Wheat in the United States



Source: Olson, R.J , C.J. Emerson, M.K. Nungensser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Table 4.5

Land Use for Harvested Corn, 1975 (hectares)

State	Harvested Area	State Area	Percent
Alabama	609810	32596892	1.87
Alaska	N/A	N/A	N/A
Arizona	21177	72680320	0.03
Arkansas	29183	33468152	0.09
California	353678	99584966	0.36
Colorado	1524844	65887360	2.31
Connecticut	50762	3127056	1.62
Delaware	158655	1265883	12.53
Washington, D.C.	N/A	N/A	N/A
Florida	322854	33730240	0.96
Georgia	1756008	37121953	4.73
Hawaii	N/A	N/A	N/A
Idaho	114416	52933030	0.22
Illinois	9950090	35765625	27.82
Indiana	5311243	23131769	22.96
Iowa	12706571	35838903	35.45
Kansas	1975682	52425277	3.77
Kentucky	1130086	25510880	4.43
Louisiana	54468	28468908	0.19
Maine	42451	19847680	0.21
Maryland	618882	6318969	9.79
Massachusetts	37409	4968725	0.75
Michigan	2378270	35806107	6.64
Minnesota	6050574	50303095	12.03
Mississippi	178163	30250140	0.59
Missouri	2817492	44235332	6.37
Montana	87670	91402923	0.10
Nebraska	6436708	49020574	13.13
Nevada	2788	70096640	0.00
New Hampshire	21469	5768578	0.37
New Jersey	111037	4810475	2.31
New Mexico	66962	77757010	0.09
New York	1063841	29423020	3.62
North Carolina	1455255	31083026	4.68
North Dakota	495926	44442126	1.12
Ohio	3421942	26205601	13.06
Oklahoma	128562	43819111	0.29
Oregon	38758	61587460	0.06
Pennsylvania	1386632	28804480	4.81
Rhode Island	3312	676419	0.49
South Carolina	494094	19338269	2.55
South Dakota	3634336	48611904	7.48
Tennessee	559408	26443526	2.12
Texas	873413	170923080	0.52
Utah	73332	52721550	0.14
Vermont	94412	5936820	1.59
Virginia	750147	25358421	2.96
Washington	71533	42615550	0.17
West Virginia	91561	15060660	0.61
Wisconsin	3451032	34779460	9.92
Wyoming	85303	62308985	0.14

Note: N/A = not available.

Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Table 4.6

Land Use for Harvested Soybeans, 1975
(hectares)

State	Harvested Area	State Area	Percent
Alabama	809461	32596892	2.48
Alaska	N/A	N/A	N/A
Arizona	726	72680320	0.00
Arkansas	3805841	33468152	11.36
California	333	99584966	0.00
Colorado	648	05087300	0.00
Connecticut	77	3127056	0.00
Delaware	209977	1265883	16.59
Washington, D.C.	N/A	N/A	N/A
Florida	217439	33736240	0.04
Georgia	785367	37121953	2.12
Hawaii	N/A	N/A	N/A
Idaho	N/A	N/A	N/A
Illinois	8317180	35765625	23.25
Indiana	3734160	23131759	16.14
Iowa	6905647	35838003	19.27
Kansas	931135	52425277	1.78
Kentucky	874551	25510880	3.43
Louisiana	1607010	28468908	5.64
Maine	N/A	N/A	N/A
Maryland	334389	6310909	5.30
Massachusetts	N/A	N/A	N/A
Michigan	570683	35806107	1.59
Minnesota	3323124	50303095	6.61
Mississippi	2075772	30250140	6.86
Missouri	4065228	44235332	9.19
Montana	N/A	N/A	N/A
Nebraska	1048372	49020574	2.14
Nevada	N/A	N/A	N/A
New Hampshire	27	5768578	0.00
New Jersey	96774	4810475	2.01
New Mexico	1103	77757010	0.00
New York	12385	29423020	0.04
North Carolina	1208909	31083026	3.89
North Dakota	151911	44442128	0.34
Ohio	3095563	26205601	11.81
Oklahoma	215276	43819111	0.49
Oregon	31	61587460	0.00
Pennsylvania	52677	28804480	0.18
Rhode Island	N/A	N/A	N/A
South Carolina	1081703	19338269	5.59
South Dakota	339969	48611904	0.70
Tennessee	1401705	26443526	5.30
Texas	222214	170923080	0.13
Utah	22	52721550	0.00
Vermont	107	5936820	0.00
Virginia	421462	25358421	1.66
Washington	499	42615550	0.00
West Virginia	2309	15060660	0.02
Wisconsin	194962	34779460	0.56
Wyoming	N/A	N/A	N/A

Note: N/A = not available.

Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Table 4.7

Land Use for Harvested Tobacco, 1975
(hectares)

State	Harvested Area	State Area	Percent
Alabama	533	32596892	0.00
Arkansas	2	33468152	0.00
Connecticut	4956	3127056	0.16
Florida	11219	33736240	0.03
Georgia	65051	37121953	0.18
Indiana	6100	23131759	0.03
Kansas	15	52425277	0.00
Kentucky	179078	25510880	0.70
Louisiana	201	28468908	0.00
Maryland	20459	6318969	0.32
Massachusetts	1568	4968725	0.03
Michigan	1	35806107	0.00
Minnesota	33	50303095	0.00
Missouri	2072	44235332	0.00
New Jersey	12	4810475	0.00
North Carolina	366842	31083026	1.18
Ohio	10279	26205601	0.04
Pennsylvania	10393	28804480	0.04
South Carolina	71102	19338269	0.37
Tennessee	49491	26443526	0.19
Virginia	67312	25358421	0.27
West Virginia	1228	15060660	0.01
Wisconsin	9196	34779460	0.03

Source: Argonne National Laboratory, Land Use Data Base, compiled under contract to the Office of Environmental Assessments, U.S. Department of Energy, 1980.

Table 4.8

Land Use for Harvested Wheat, 1975
(hectares)

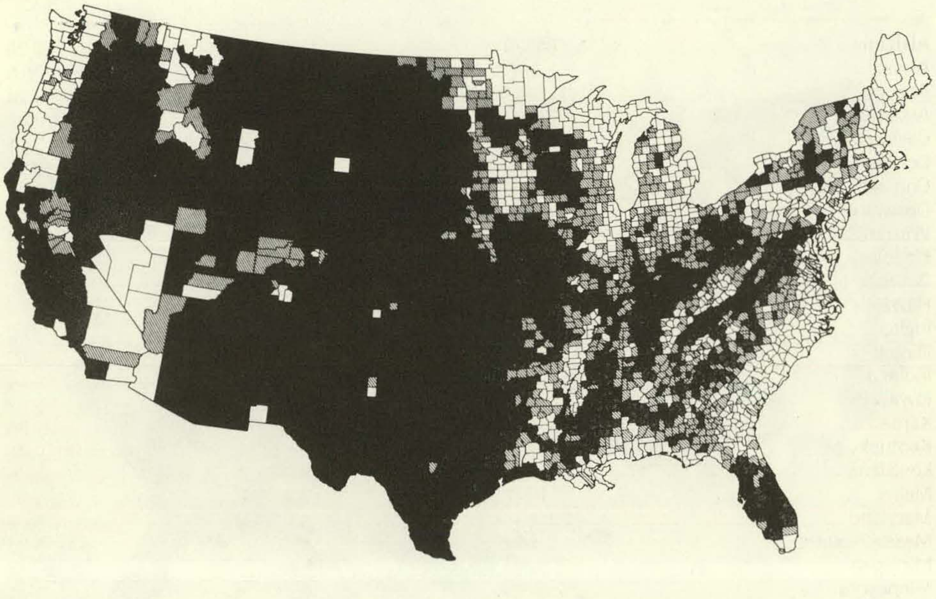
State	Harvested Area	State Area	Percent
Alabama	84270	32506802	0.26
Alaska	N/A	N/A	N/A
Arizona	175737	72680320	0.24
Arkansas	294665	33468152	0.88
California	702932	99584966	0.71
Colorado	5673106	65887360	8.61
Connecticut	62	3127056	0.00
Delaware	41216	1265883	3.26
Washington, D.C.	N/A	N/A	N/A
Florida	12058	33736240	0.04
Georgia	117268	37121953	0.32
Hawaii	N/A	N/A	N/A
Idaho	1413811	52933030	2.67
Illinois	1678393	35765625	4.69
Indiana	1178919	23131759	5.10
Iowa	59874	35838903	0.17
Kansas	11040335	52425277	21.06
Kentucky	331421	25510880	1.30
Louisiana	15092	28468908	0.05
Maine	1921	19847680	0.01
Maryland	131951	6318969	2.09
Massachusetts	41	4968725	0.00
Michigan	810197	35806107	2.26
Minnesota	2586938	50303095	5.14
Mississippi	103618	30250140	0.34
Missouri	1237112	44235332	2.80
Montana	4729604	91402923	5.17
Nebraska	2823818	49020574	5.76
Nevada	28169	70096640	0.04
New Hampshire	8	5768578	0.00
New Jersey	48521	4810475	1.01
New Mexico	205119	77757010	0.26
New York	205634	29423020	0.70
North Carolina	248308	31083026	0.80
North Dakota	10189207	44442126	22.93
Ohio	1384591	26205601	5.28
Oklahoma	5934410	43819111	13.54
Oregon	1249448	61587460	2.03
Pennsylvania	267810	28804480	0.93
Rhode Island	95	676419	0.01
South Carolina	101057	19330209	0.52
South Dakota	3018578	48611904	6.21
Tennessee	241891	26443526	0.91
Texas	3488327	170923080	2.08
Utah	264168	52721550	0.50
Vermont	252	5936820	0.00
Virginia	258366	25358421	1.02
Washington	3022861	42615550	7.09
West Virginia	9779	16060660	0.06
Wisconsin	77463	34779460	0.22
Wyoming	302986	62308985	0.49

Note: N/A = not available.

Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351; ESD Pub. No. 1537, September, 1980.

Figure 4.37

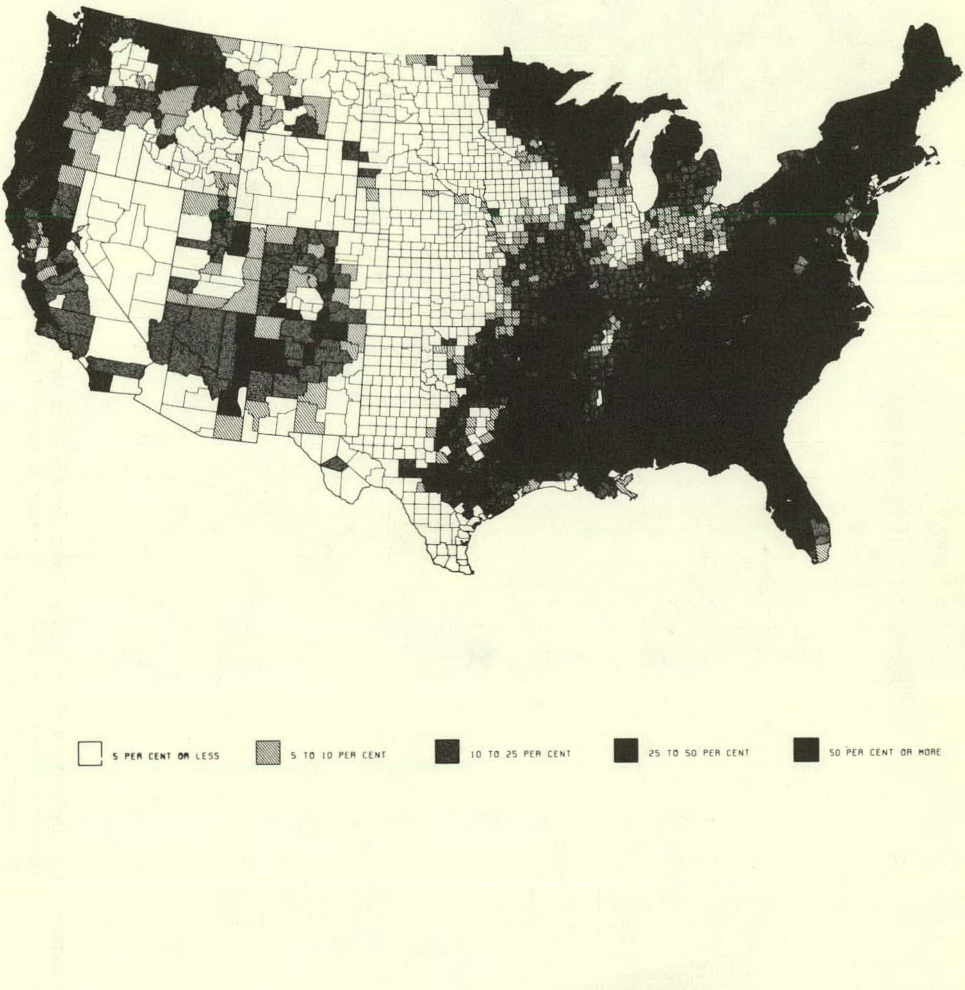
Pasture and Rangeland



Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 4.38

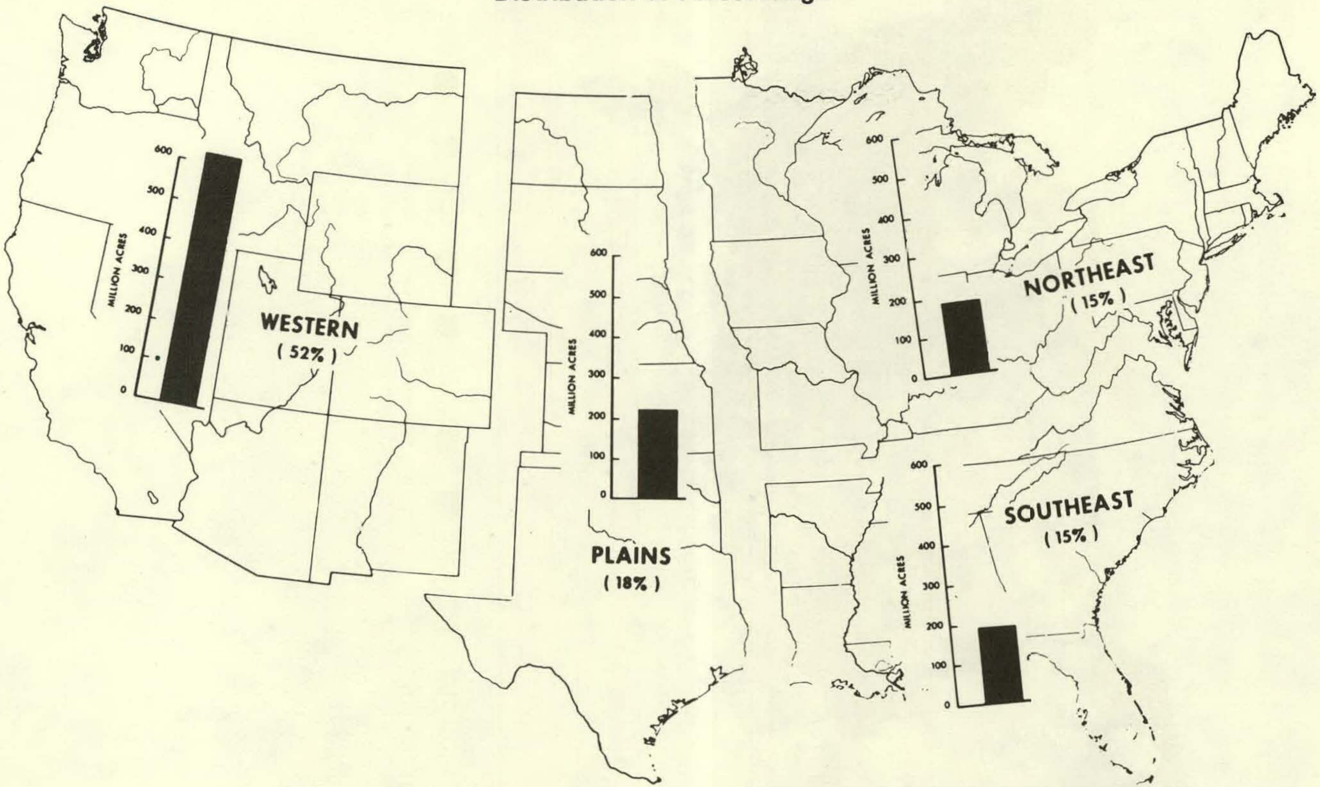
Non-federal Forest Land



Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 4.39

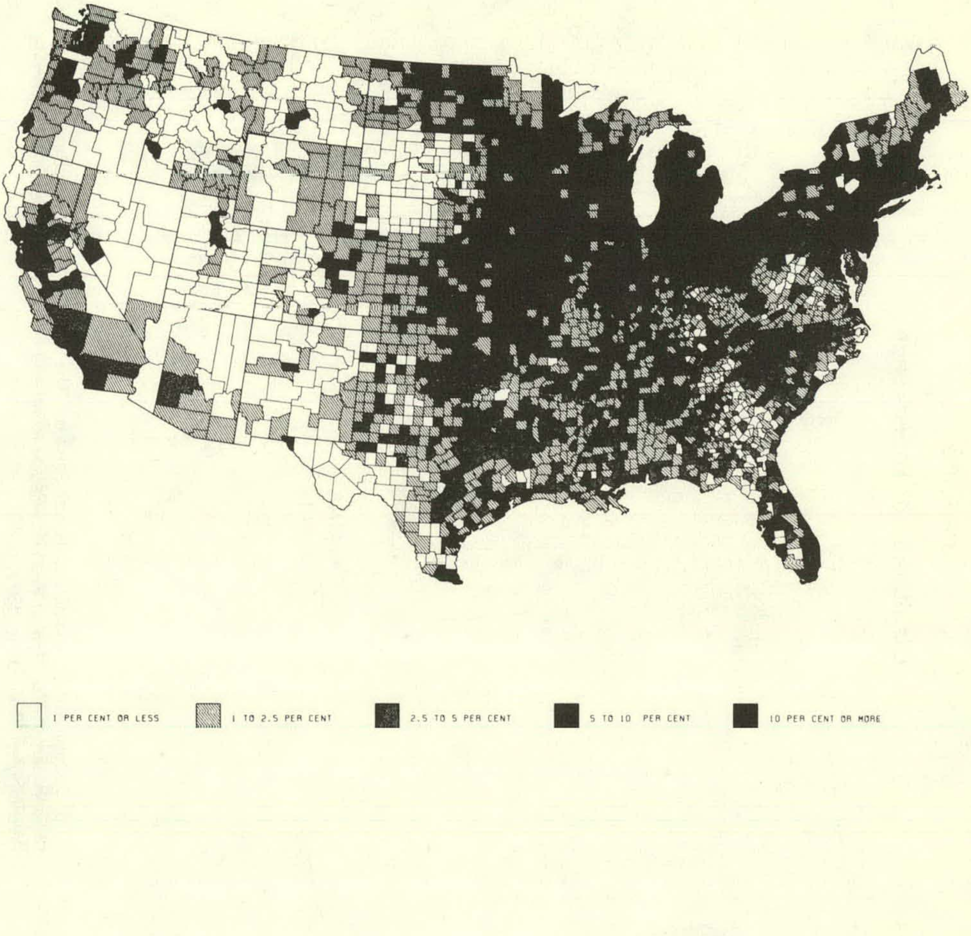
Distribution of Forest-range



Source: U.S. Department of Agriculture, Forest Service, "The Nation's Renewable Resources - An Assessment, 1975," Forest Resource Report Number 21, U.S. Government Printing Office, Washington, D.C., June, 1977, p. 121.

Figure 4.40

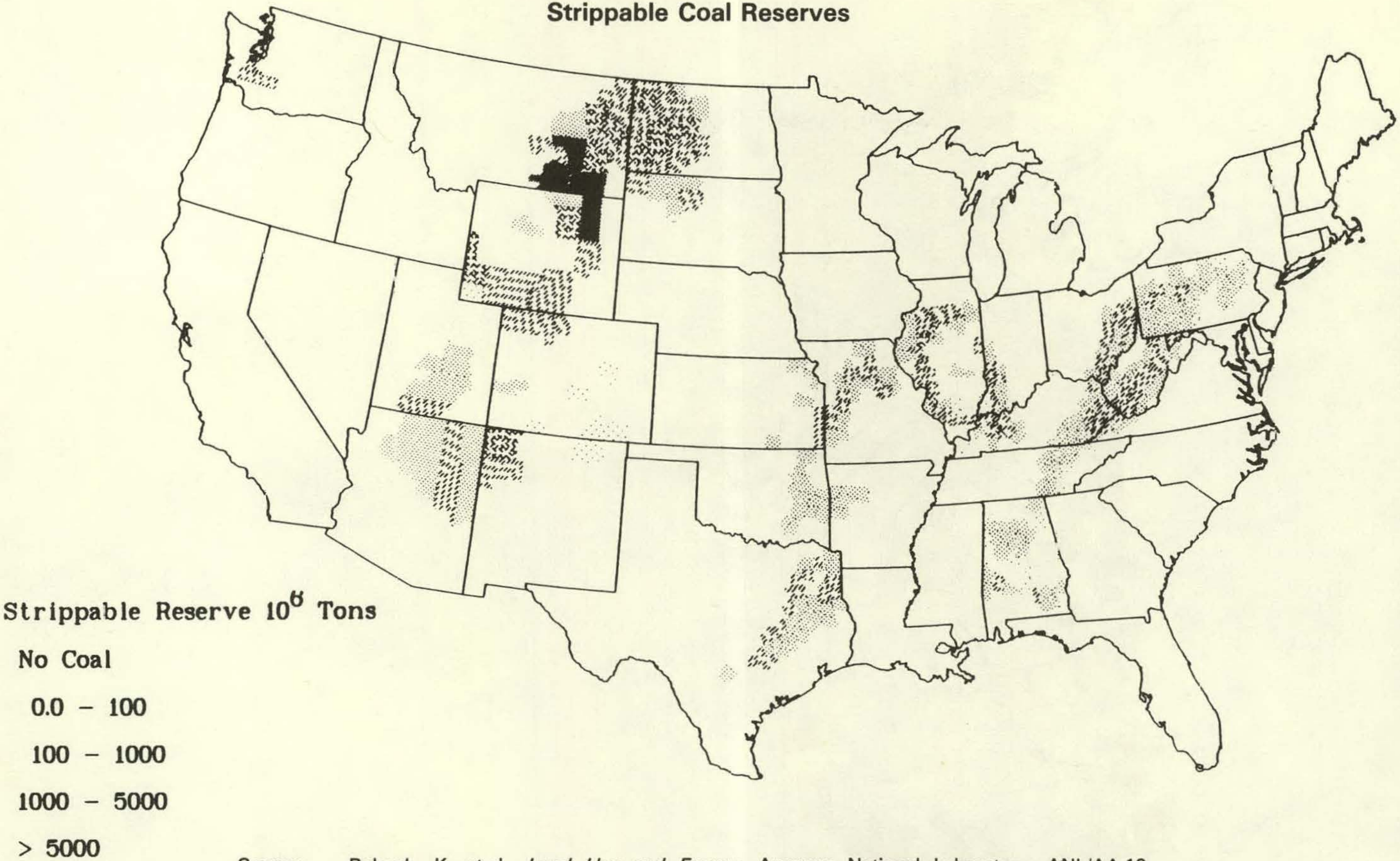
Urban Land Use



Source: Olson, R.J., C.J. Emerson, M.K. Nungesser, *Geoecology: A County Level Environmental Database for the Coterminous United States,* Oak Ridge National Laboratory, ORNL/TM-7351, ESD Pub. No. 1537, September, 1980.

Figure 4.41

Strippable Coal Reserves



Source: Robeck, K. et.al., *Land Use and Energy*, Argonne National Laboratory, ANL/AA-19, September 1980.

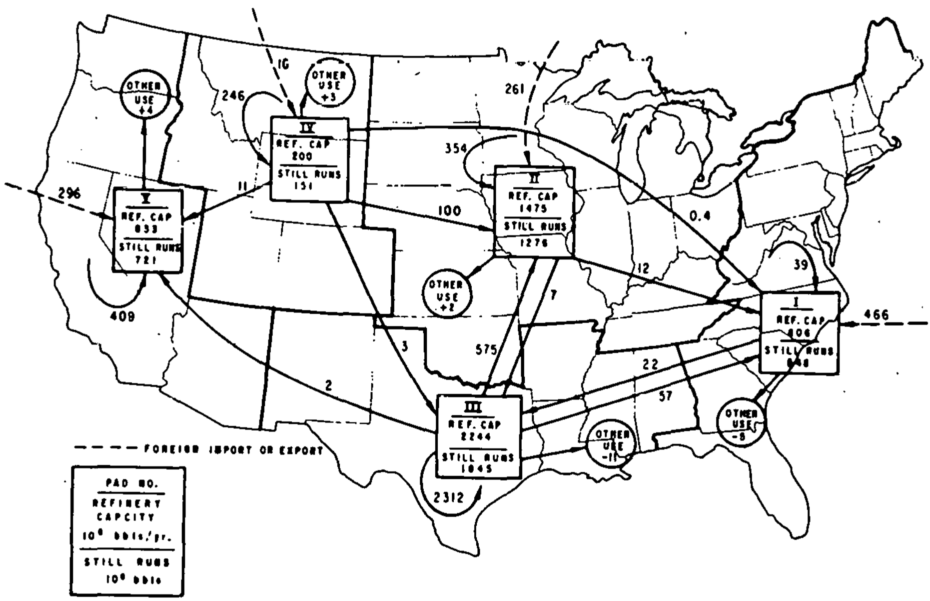
Figure 4.42

Oil Fields in the United States

Source: Cerillo, T.D., et.al., *An Evaluation of Regional Trends in Power Plant Siting and Energy Transport,* Argonne National Laboratory ANL/AA-9, July, 1977.

Figure 4.43

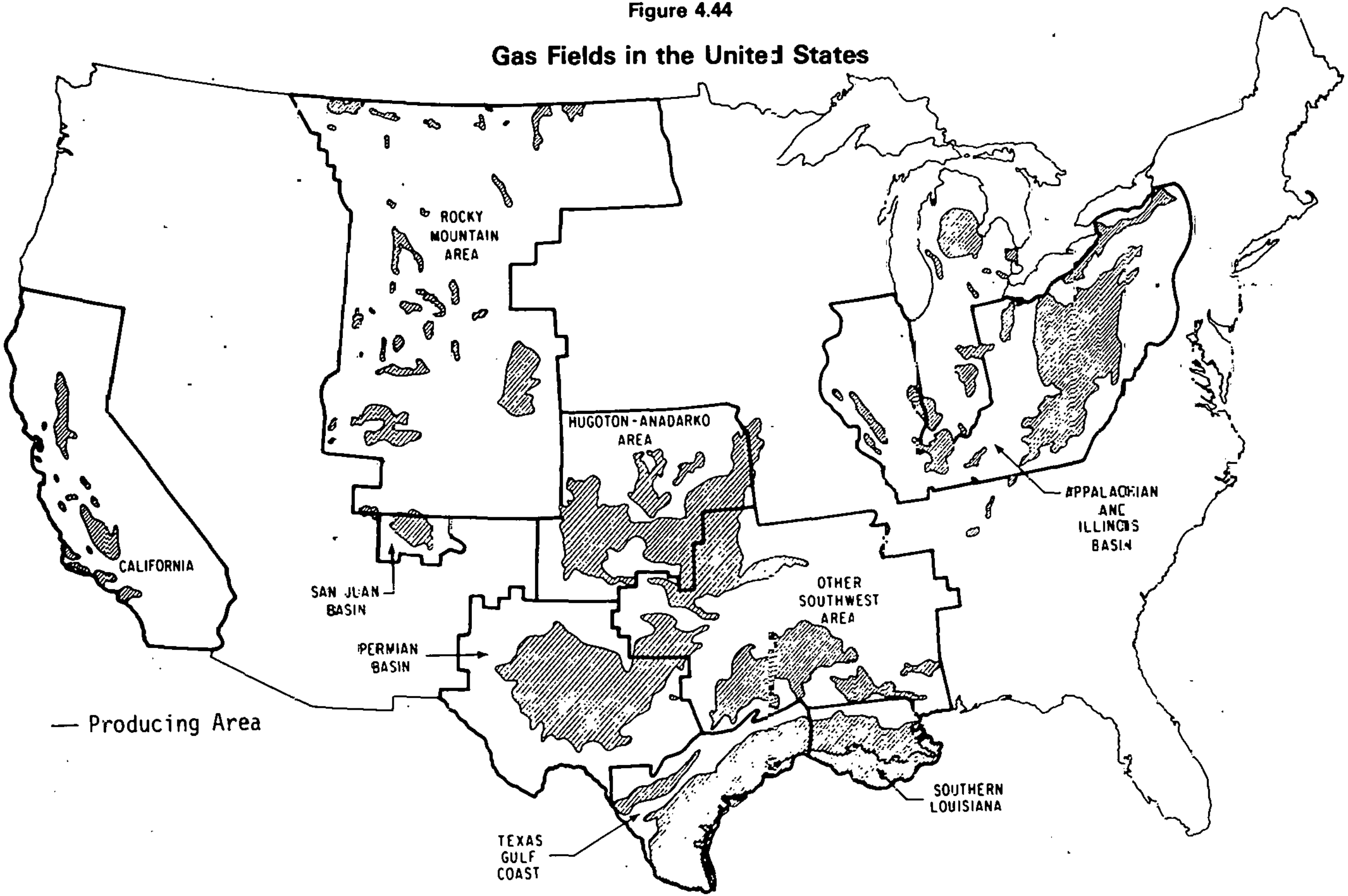
Movement of Crude Oil



Source: Cerillo, T.D., et.al., *An Evaluation of Regional Trends in Power Plant Siting and Energy Transport,* Argonne National Laboratory ANL/AA-9, July, 1977.

Figure 4.44

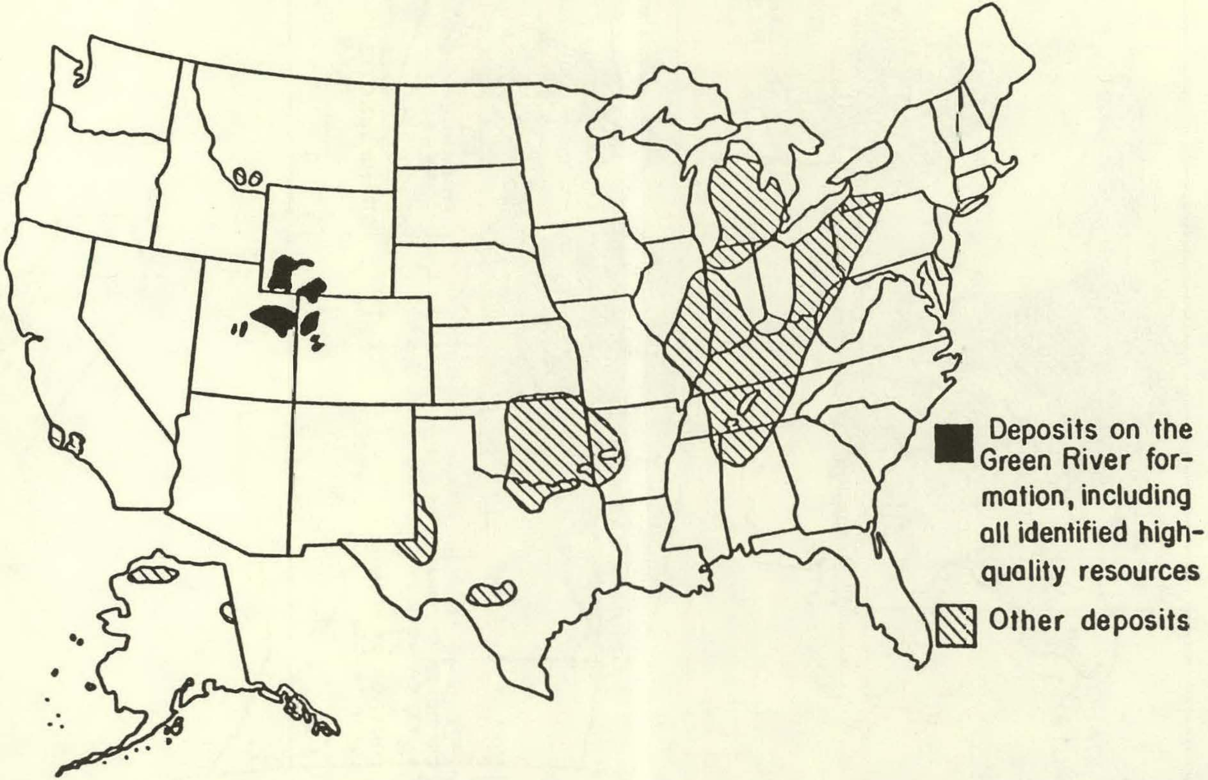
Gas Fields in the United States



Source: Cerillo, T.D., et.al., *An Evaluation of Regional Trends in Power Plant Siting and Energy Transport,* Argonne National Laboratory ANL/AA-9, July, 1977.

Figure 4.45

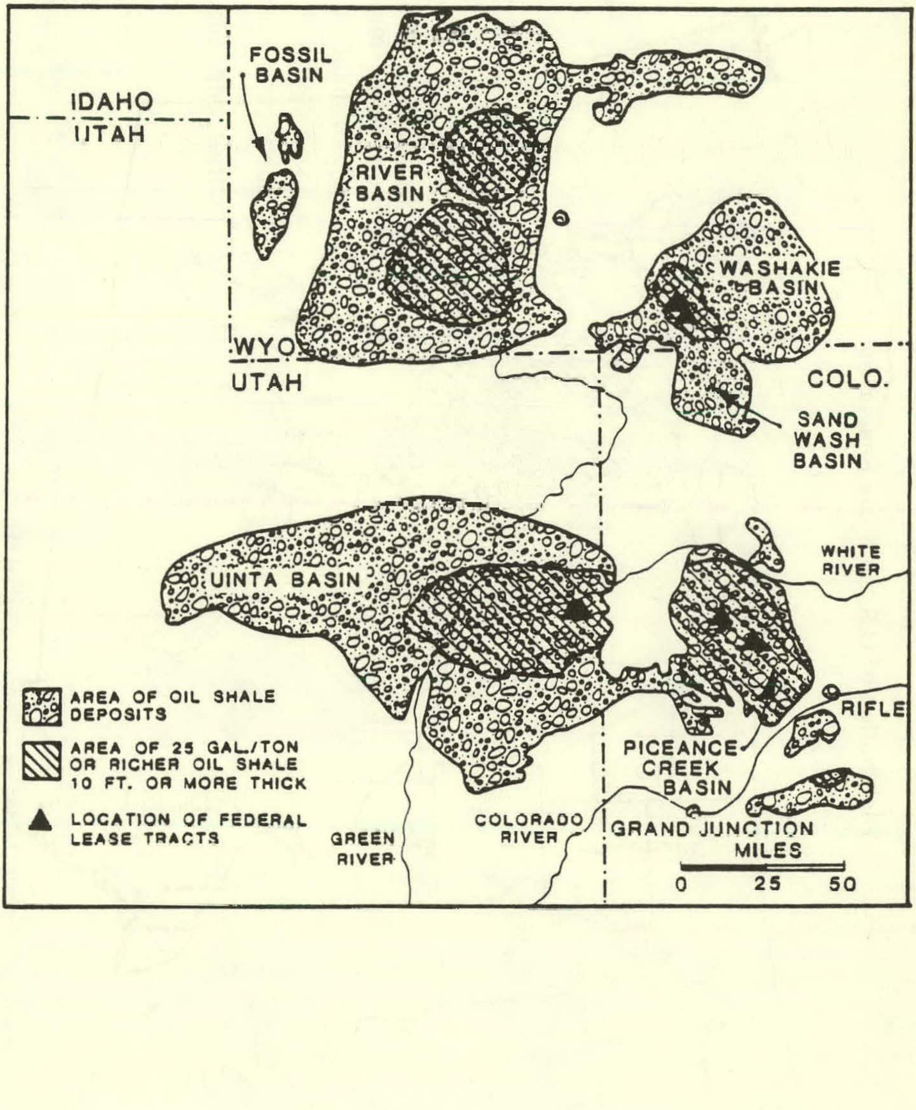
Distribution of U.S. Oil Shale Resources



Source: Duncan, D.C., and V.E. Swanson, *Organic Rich Shale of the United States and World Land Areas,* U.S. Geological Survey Circular 523, U.S. GPO, Washington, D.C., 1965.

Figure 4.46

Oil Shale Areas in Colorado, Utah, and Wyoming



Source: U.S. Department of the Interior, *Final Environmental Statement for the Prototype Oil Shale Leasing Program,* 6 vols., U.S. GPO, Washington, D.C. 1973.

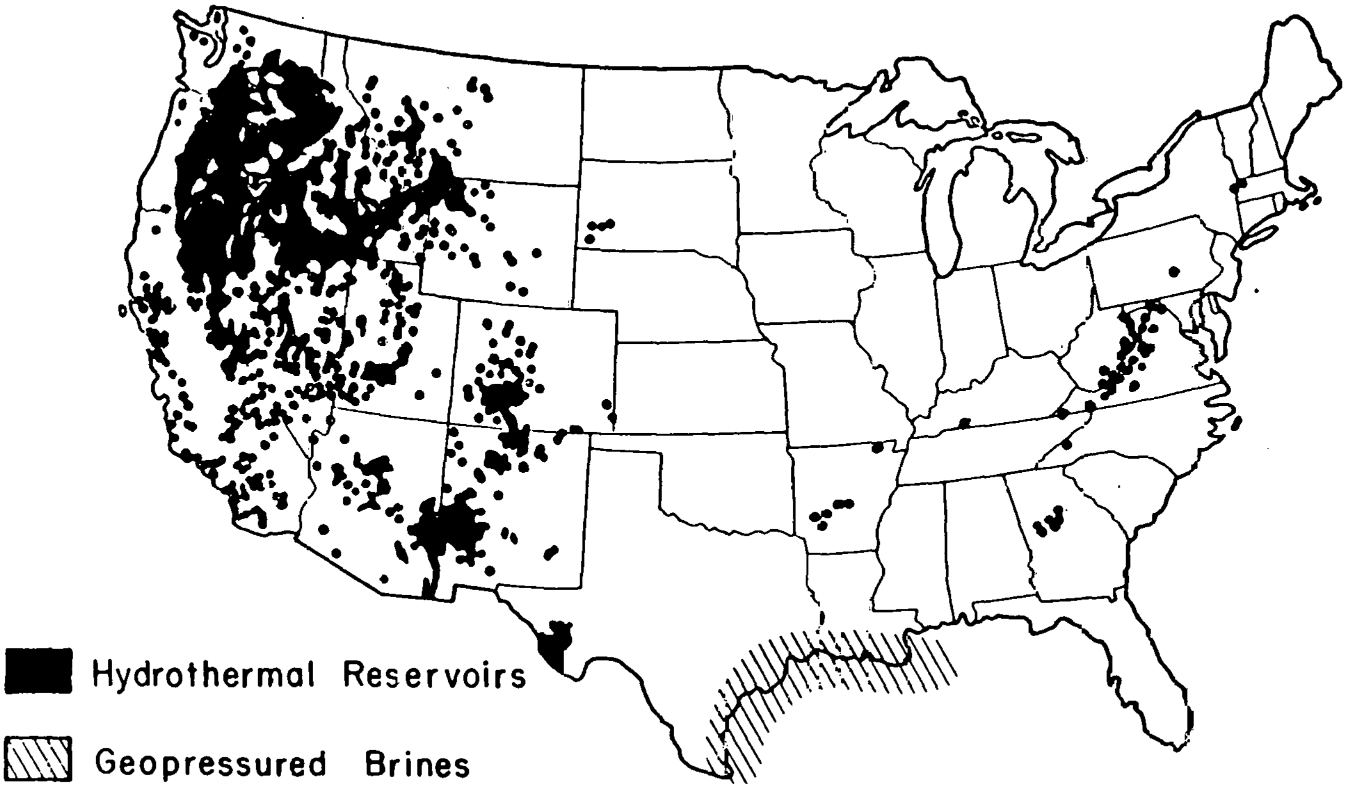
Figure 4.47

Uranium Deposits in the Western United States

Source: Nuclear Assurance Corporation, *U.S. Uranium Economics and Technology,* Atlanta, Georgia, Nuclear Assurance Corp., NAC-1, p. VI-6

Figure 4.48

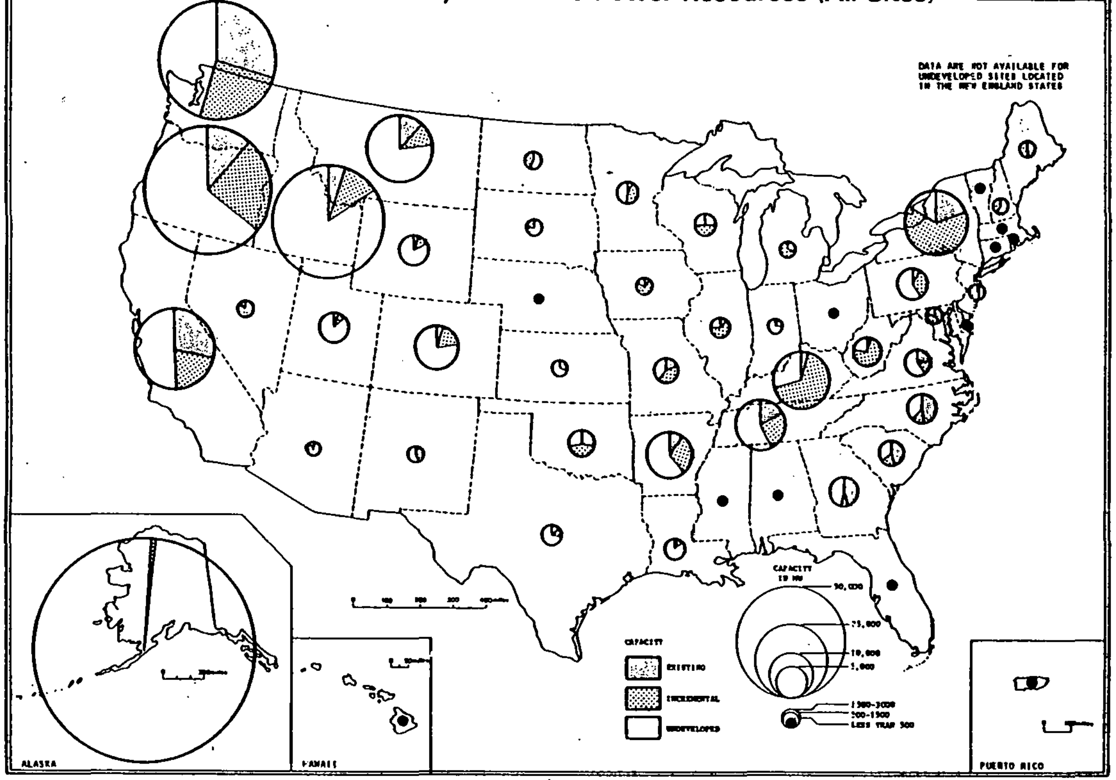
Distribution of U.S. Geothermal Resources



Source: U.S. Department of the Interior, *Final Environmental Statement for the Prototype Oil Shale Leasing Program*, 4 Vols., U.S. GPO, Washington, D.C. 1973.

Figure 4.49

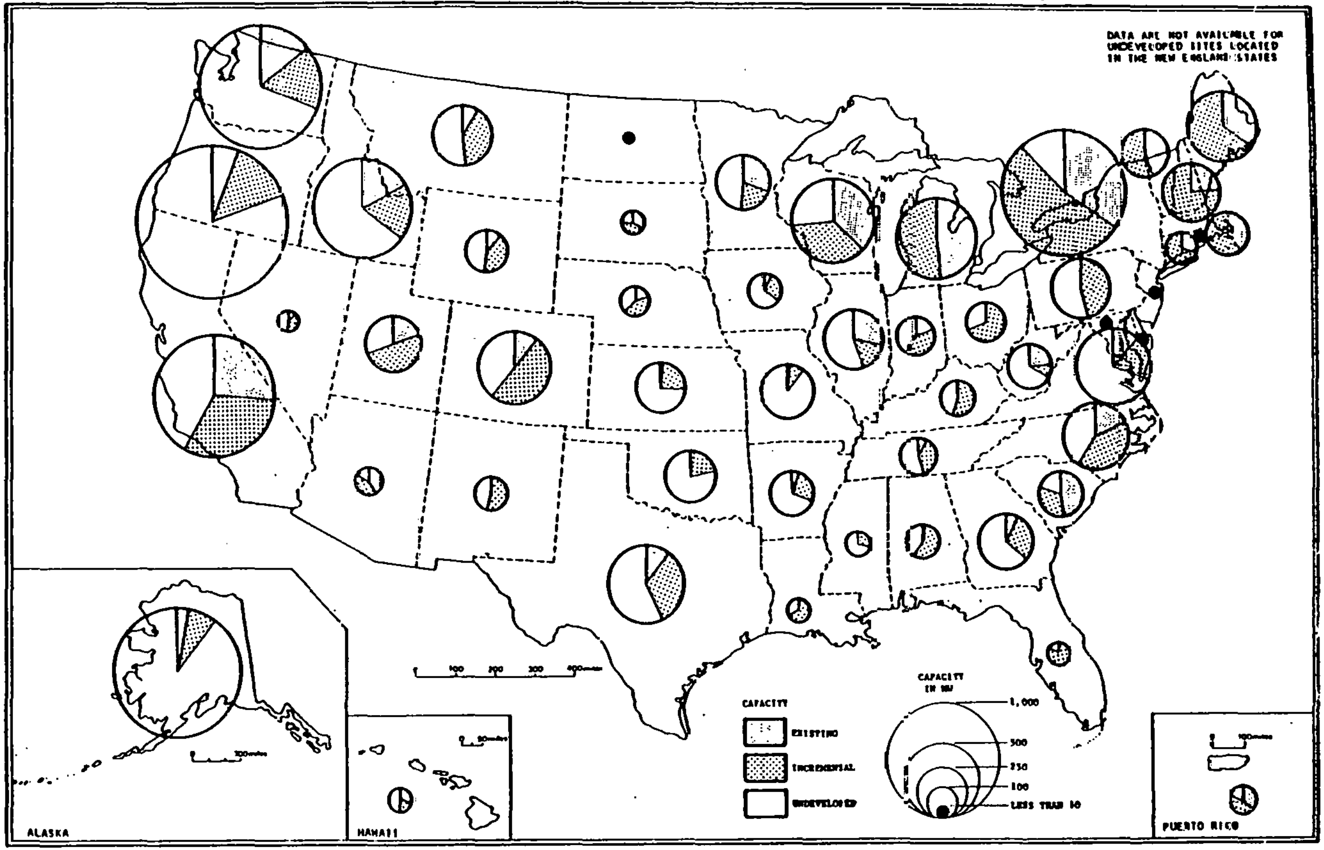
National Hydroelectric Power Resources (All Sites)



Source: U.S. Corps of Engineers, *National Hydroelectric Power Resources Study, Preliminary Inventory of Hydropower Resources, 1979.*

Figure 4.50

National Hydroelectric Power Resources (Small-Scale Sites)



Source: U.S. Corps of Engineers, *National Hydroelectric Power Resources Study, Preliminary Inventory of Hydropower Resources*, 1979.

Table 4.9

Acres of Land Utilized for Mining Selected Commodities in Leading Mining States, 1930-71

State	All Commodities (except coal)	Copper	Iron	Phosphate	Clay	Uranium	Sand and Gravel	Stone
California	226,970		2,720		10,400	5	81,000	31,300
Minnesota	136,000		80,300		560		28,400	3,880
Pennsylvania	134,000		770		11,700		16,500	6,260
Arizona	101,780	84,000	5		620		10,800	2,140
Michigan	98,940	4,800	4,470		6,700		40,500	33,200
New York	96,300		1,830		4,670		30,600	28,300
Florida	88,800			47,900	1,710		5,970	22,100
Ohio	85,000				17,300		31,300	35,500
Texas	77,230	5	1,010		11,600	240	27,400	28,800
Utah	63,480	38,900	3,310	1,530	840	20	8,990	2,560
Illinois	63,000				7,880		31,700	21,900
Tennessee	49,900	940	30	16,200	4,420		6,420	19,100
Wisconsin	49,900		1,740		440		29,900	14,000
Iowa	46,700				3,390		14,000	25,200
Idaho	41,290	30	5	8,220	120	5	7,350	2,070
Nevada	41,100	12,800	540		30	10	5,830	1,360
Colorado	40,170	30	50		1,590	330	14,700	5,630
New Mexico	39,540	13,000	30		230	6,670	6,950	1,690
Montana	35,980	10,900	10	2,660	300	5	12,300	3,310
Georgia	34,260		370		13,700		2,580	15,000
Washington	34,530	110	5		890	350	20,500	10,400
Alabama	30,200		7,540		6,390		5,280	10,700
Wyoming	18,200		1,430	650	3,900	4,300	5,640	1,850

Source: Bureau of Mines Information Circular 8642 (1974), *Land Utilization and Reclamation in the Mining Industry*, 1930-71, Table 9, p.20.

Table 4.10

Land Disturbed by Surface and Open-Pit Mining, 1930-71

Mineral	Acres Disturbed
Coal	1,500,000
Sand and Gravel	660,000
Stone	516,00
Miscellaneous Commodities	480,000
Clays	167,000
Copper	166,000
Iron Ore	108,000
Phosphate Rock	77,300
Uranium	12,800

Source: U.S. Department of the Interior, U.S. Bureau of Mines, *Land Utilization and Reclamation in the Mining Industry, 1930-71,* U.S. GPO, Washington, D.C., 1974.

Table 4.11

Land Area Occupied by Refinery Complexes Within Federal Regions

Region	Number of Plants	Crude Capacity b/sd	Refinery Occupied Land Area (acres)
1	1	13,000	228
2	8	878,978	15,382
3	17	1,105,494	19,346
4	22	863,079	15,104
5	34	2,949,464	51,616
6	111	8,337,448	145,905
7	13	603,291	10,558
8	32	668,952	11,707
9	43	2,629,362	46,014
10	14	659,460	11,541

Source: Great Lakes Basin Commission, *Energy Facility Siting in the Great Lakes Coastal Zone: Analysis and Policy Options, for the Office of Coastal Zone Management,* NOAA, DOC, January, 1977.

Table 4.12

Land Area Allocation for Existing Refinery Complexes, January, 1980

State	Number of Plants	Crude Capacity (b/sd*)	Average Crude Capacity (b/sd*)	Refinery Occupied Land Area (acres)
Alabama	6	144,700	24,117	2,432
Alaska	4	120,410	30,103	2,107
Arizona	1	6,315	6,315	111
Arkansas	4	67,150	16,788	1,175
California	41	2,618,547	63,867	47,000
Colorado	3	59,500	19,833	1,041
Delaware	1	150,000	150,000	2,625
Florida	1	14,000	14,000	245
Georgia	2	24,000	12,000	420
Hawaii	2	119,894	59,946	2,098
Illinois	11	1,274,156	115,832	22,297
Indiana	6	641,787	80,223	11,231
Kansas	11	486,131	44,194	8,507
Kentucky	4	252,500	63,125	4,419
Louisiana	30	2,429,510	80,984	42,516
Maryland	2	29,999	15,000	525
Michigan	6	143,816	23,969	2,417
Minnesota	3	224,905	74,968	3,936
Mississippi	7	371,564	53,081	6,502
Missouri	1	111,000	111,000	1,943
Montana	6	162,000	27,000	2,835
Nebraska	1	6,160	6,160	108
Nevada	1	4,500	4,500	79
New Hampshire	1	13,000	13,000	228
New Jersey	5	732,578	146,516	12,820
New Mexico	9	133,139	14,793	2,330
New York	3	146,400	48,800	2,462
North Carolina	1	12,495	12,495	219
North Dakota	3	68,200	22,733	1,194
Ohio	7	618,000	88,286	10,815
Oklahoma	12	577,145	48,095	10,100
Oregon	1	15,789	15,789	276
Pennsylvania	10	849,395	84,940	14,864
Tennessee	1	43,820	43,820	767
Texas	56	5,130,504	91,616	89,784
Utah	8	172,668	21,584	3,022
Virginia	1	55,000	55,000	963
Washington	7	403,367	57,624	7,059
West Virginia	3	21,100	7,033	369
Wisconsin	1	46,800	46,800	819
Wyoming	12	206,584	17,215	3,615
	295	18,708,528	62,992	327,399

*Barrels/Stream Day

Source: Great Lakes Basin Commission, *Energy Facility Siting in the Great Lakes Coastal Zone: Analysis and Policy Options, for the Office of Coastal Zone Management,* NOAA, DOC, January, 1977.

Table 4.13

Acreage for Uranium Mills by State and Type, 1979

	Production		
	Tons Ore/Day	Tons Ore/Year	Acreage
Conventional Mills			
Wyoming	13,200		6,800
Utah	2,150		1,200
Texas	3,200		1,900
Colorado	1,750		1,200
New Mexico	21,000		8,250
Washington	2,450		1,200
	43,750	16,000 - 18,000	20,500
Solution, Phosphoric Acid Byproduct, and Heap Leaching Mining			
Wyoming			9
Utah			19
Texas			82
Colorado			38
Louisiana			5
Florida			10
		1,200 – 2,000[a]	163

[a]Capacity distributed equally to calculate acreage, assume 300 operation days/year

Source: Office of Technology Impacts, DOE/EV-0061/2, January, 1980

Table 4.14

Fuel Fabrication Plants Site Size and Demography

Plant Location	Site Size, Acres	Population Density People/sq. mi. (1972)	City	Population of nearby Cities (1972)	Distance (Miles)
Babcock & Wilcox Lynchburg, Va.	506	40	Lunchburg	54,000	4
Combustion Eng. Windsor, Conn.	532	620	East Granby	3,500	3
			Windsor	22,500	5
General Electric Wilmington, N.C.	1650	50	Castle Hayne	700	2
			Wilmington	46,000	8
Gulf United Nuclear Hematite, Mo.	150	300	Hematite	<2,500	3/4
			St. Louis	622,000	33
Gulf United Nuclear New Haven, Conn.	76*	620	Hartford	158,000	9
			New Haven	138,000	0
Jersey Nuclear Richland, Wash.	160	20	Richland	26,000	3
Keer-McGee Crescent, Okla.	1000	110	Crescent	1,600	5
			Oklahoma City	363,000	30
Nuclear Fuel Services Erwin, Tenn.	58	110	Erwin	4,700	1-1/2
			Johnson City	33,800	13
NUMEC Appollo, Pa	5	420	Apollo	< 2,500	0
			Pittsburgh	520,000	25
Westinghouse Columbia, S.C.	1140	140	Columbia	113,500	8

*Shared by manufacturing and reseach divisions of Olin Corportation and naval reactor fuel operations of United Nuclear Corp.

Source: Atomic Energy Commission, *Environmental Survey of the Uranium Fuel Cycle,* WASH-1248, April, 1974.

Table 4.15

Estimated Direct Land Use by Existing Fossil Fuel Power Plants, 1975

Regions	Coal MW	Coal Acres	Oil MW	Oil Acres
1	2224	1130	11004	890
2	4630	2310	5995	400
3	32968	16480	11556	930
4	56464	28220	13400	1075
5	66219	33360	7647	620
6	4945	2470	2663	215
7	14304	7160	484	45
8	8195	4110	330	60
9	3414	1710	24434	1955
10	1335	670	126	20
National	194698	97620	77639	6290

Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Table 4.16

Land Area Occupied By Nuclear Reactor Facilities, 1975[a]

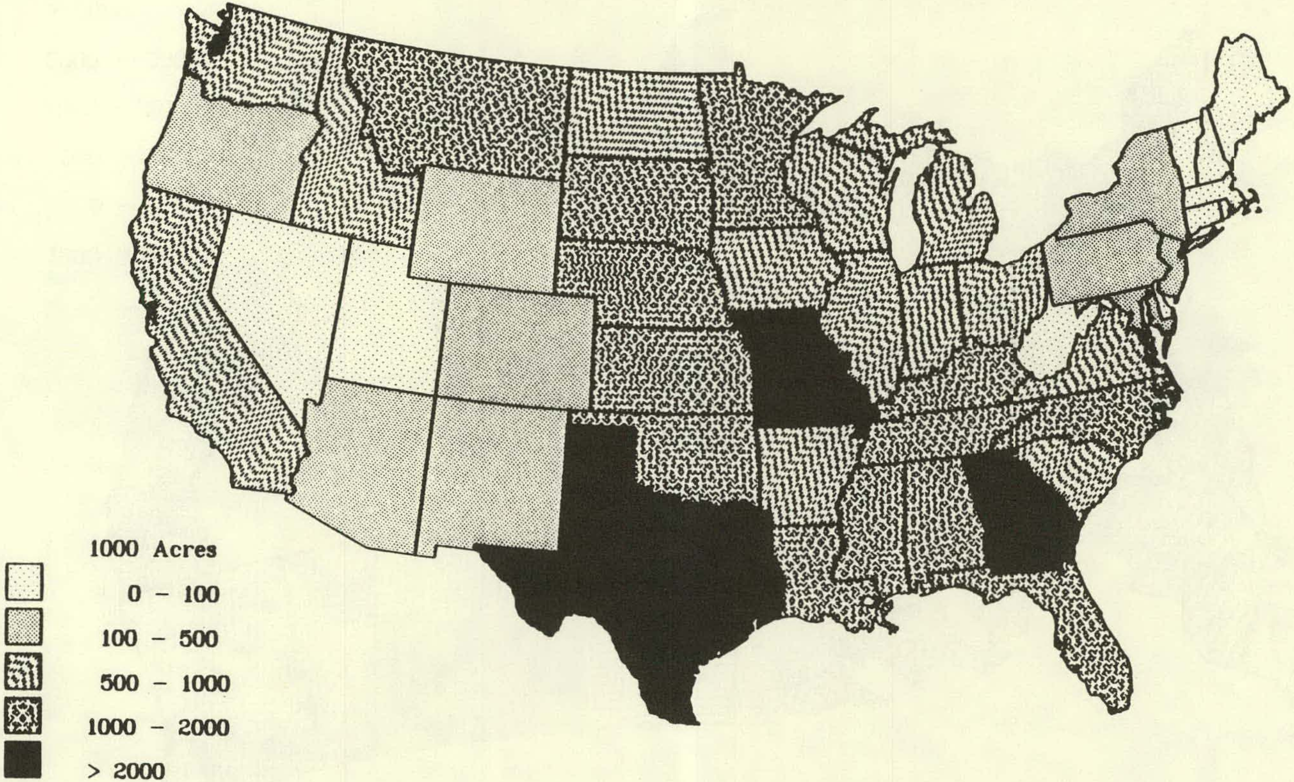
Region	Megawatt Capacity	Number of Reactor Sites	Site Area (acres)	Total Area (acres)[b]	Number of Sites Within SMSA
1	5753	6	4307	12322	1
2	3642	4	1987	6801	3
3	5463	5	3863	13253	3
4	5400	4	32470	44794	2
5	10081	10	9931	26201	2
8	836	1	1164	4880	0
7	1733	3	1972	7217	1
9	2506	4	3341	6581	2
10	862	1	1089	1569	0
TOTAL	36,276	38	60,124	123,618	14

[a]Using the RIIA-High scenario megawatt capacities and siting locations.
[b]Includes site area, transmission line corridors and substations, railroad spurs, and water supply facilities.

Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.51

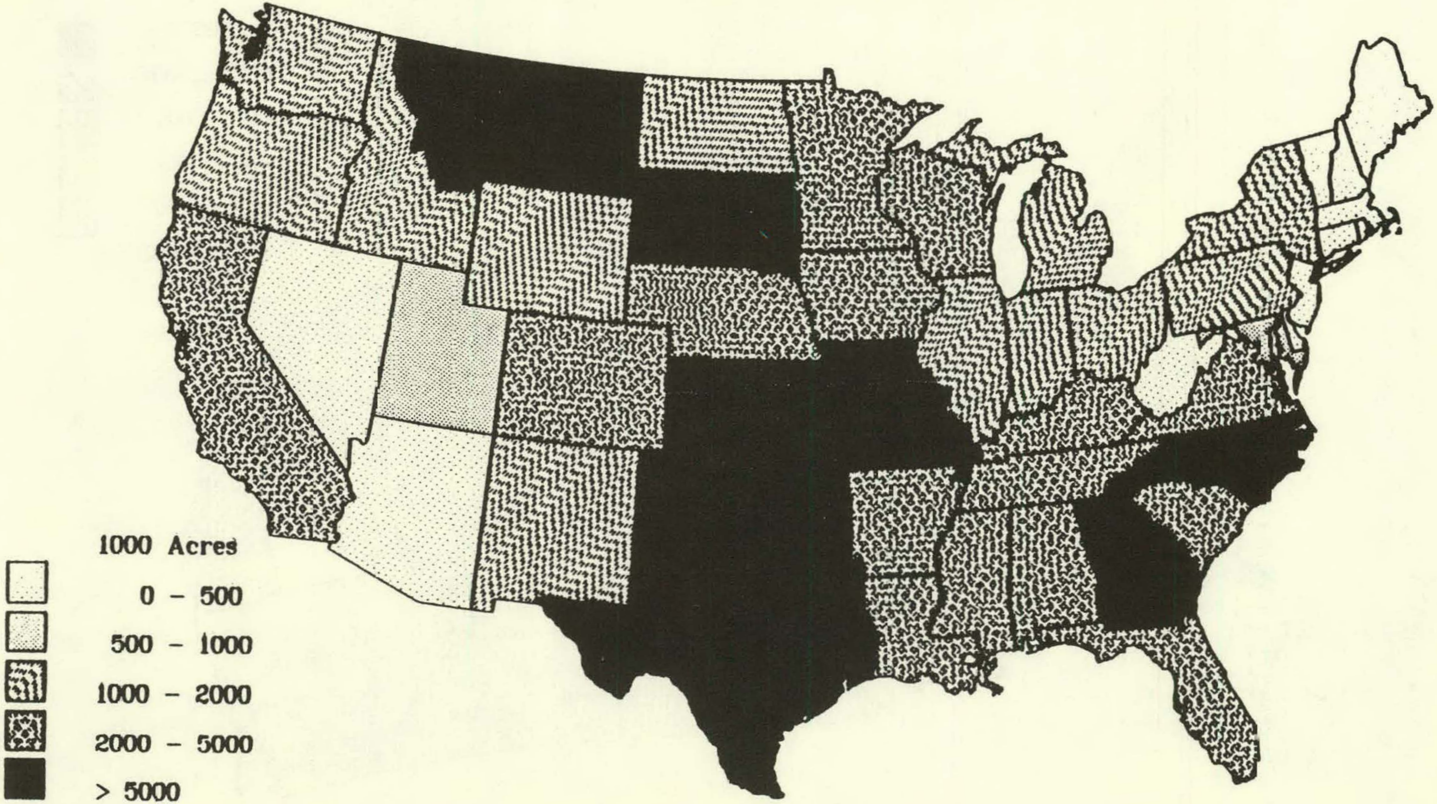
Land with High Potential for Conversion to Cropland, 1977



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.52

Land with High to Medium Potential for Conversion to Cropland, 1977



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Table 4.17

Potential for Cropland of 1977 Pasture, Range, Forest, and Other Land, by State (1000 acres)

State	High Potential	Medium Potential	Conversion Unlikely	Zero Potential	Total
Alabama	1,084	3,083	7,428	12,923	24,498
Arizona	155	216	3,625	34,327	38,323
Arkansas	657	2,634	9,243	7,868	20,402
California	800	2,009	5,029	30,591	38,429
Colorado	365	2,369	7,570	19,856	30,160
Connecticut	23	69	306	1,420	1,836
Delaware	28	87	186	194	495
Florida	1,117	2,534	11,022	8,754	23,427
Georgia	2,120	3,670	8,484	11,502	25,776
Hawaii	39	62	543	2,674	3,318
Idaho	525	916	1,727	9,318	12,486
Illinois	582	1,385	2,414	3,228	7,609
Indiana	804	1,008	2,068	2,909	6,789
Iowa	700	1,488	2,144	2,771	7,103
Kansas	1,893	3,673	5,593	9,622	20,781
Kentucky	1,302	1,801	2,936	11,011	17,050
Louisiana	1,129	1,864	6,272	10,663	19,948
Maine	29	286	9,093	8,621	18,029
Maryland	145	382	1,116	1,466	3,109
Massachusetts	33	144	764	2,353	3,294
Michigan	561	1,409	5,750	11,790	19,510
Minnesota	1,108	2,845	8,516	9,219	21,658
Mississippi	1,306	2,491	4,934	10,319	19,050
Missouri	2,226	4,395	7,154	10,881	24,656
Montana	1,339	4,360	11,264	32,306	49,269
Nebraska	1,083	2,871	7,260	14,916	26,130
Nevada	50	238	1,669	7,212	9,169
New Hampshire	27	217	1,996	2,080	4,320
New Jersey	116	310	701	1,482	2,609
New Mexico	474	822	8,638	37,985	47,919
New York	358	1,352	4,569	14,258	20,537
North Carolina	1,398	3,661	5,932	9,001	19,992
North Dakota	984	1,898	4,581	6,568	14,031
Ohio	528	1,394	3,490	4,360	9,772
Oklahoma	1,683	4,119	7,564	15,483	28,848
Oregon	325	862	3,042	18,549	22,778
Pennslyvania	270	1,160	4,328	12,536	18,294
Rhode Island	5	18	54	294	371
South Carolina	629	1,635	6,128	4,307	12,699
South Dakota	1,090	4,403	7,602	13,328	26,423

Table 4.17 (cont.)

Potential for Cropland of 1977 Pasture, Range, Forest, and Other Land, by State (1000 acres)

State	High Potential	Medium Potential	Conversion Unlikely	Zero Potential	Total
Tennessee	1,428	2,351	3,626	10,428	17,833
Texas	3,534	10,727	46,960	65,280	126,501
Utah	73	447	1,166	12,347	14,033
Vermont	45	188	931	3,470	4,614
Virginia	546	1,605	5,732	9,489	17,372
Washington	506	1,049	3,247	15,669	20,471
West Virginia	64	388	1,302	10,493	12,247
Wisconsin	618	2,041	7,582	8,583	18,624
Wyoming	253	1,688	5,064	22,038	29,043
Carribbean	78	150	77	1,140	1,445
Total	36,215	90,774	268,422	587,902	983,313

Source: 1977 Soil Conservation Resources Inventory, U.S. Department of Agriculture, February, 1980.

LAND MANAGEMENT

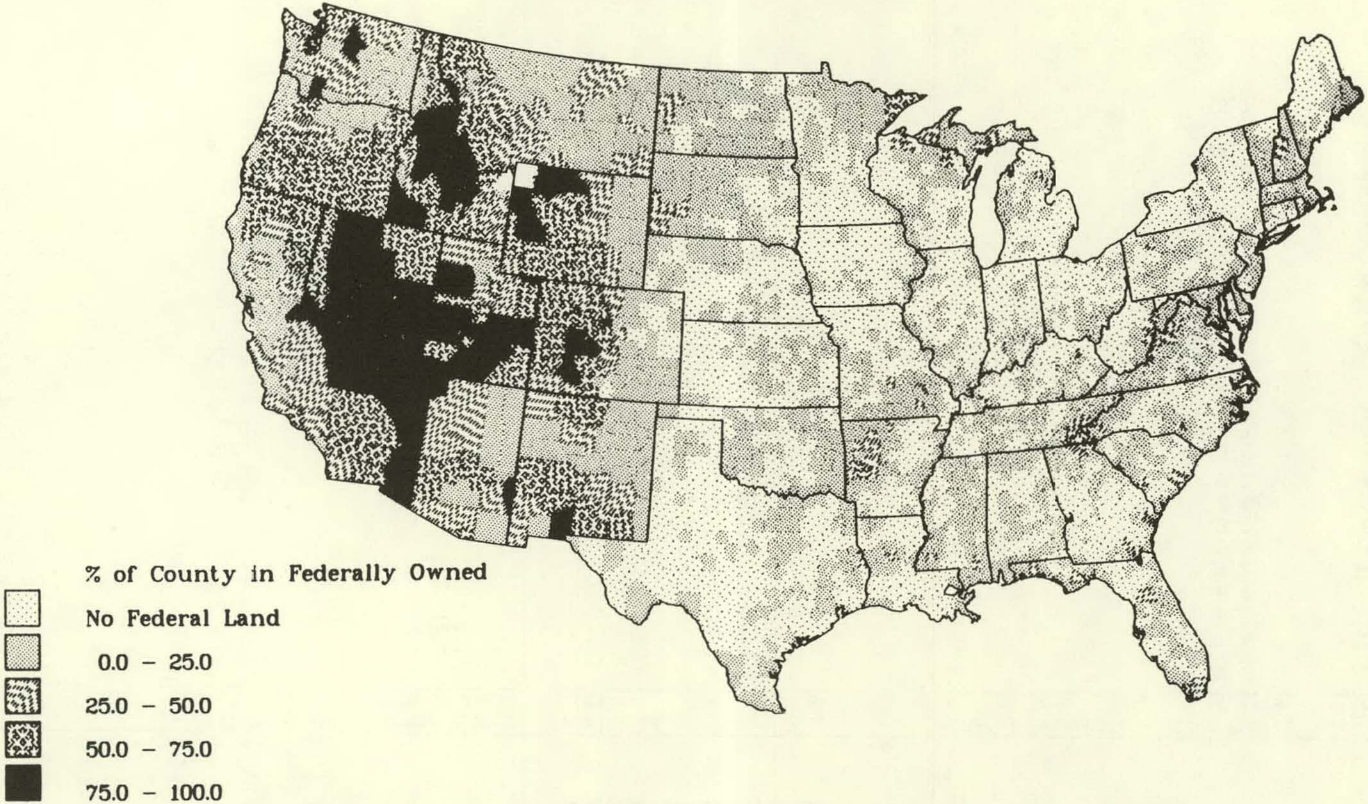
List of Tables

List of Figures

Figure No.		Page

Figure 4.53

Distribution of Federal Land



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Table 4.18

Public Lands By State

State	Federal Reserved % of Area	Other Public % of Area	Total Area (mi^2)	State	Federal Reserved % of Area	Other Public % of Area	Total Area (mi^2)
Alabama	3.8	1.3	51,609	Nebraska	0.7	1.6	77,227
Arizona	18.5	50.5	113,909	Nevada	10.6	31.4	110,540
Arkansas	10.2	2.2	53,104	New Hampshire	13.4	0.2	9,304
California	28.1	26.2	158,693	New Jersey	13.2	6.4	7,836
Colorado	23.7	20.7	104,247	New Mexico	13.4	29.2	121,666
Connecticut	0	0.0	5,009	New York	9.6	9.5	49,576
Delaware	0	2.4	2,057	North Carolina	0	3.0	52,586
Florida	6.9	5.4	58,560	North Dakota	0.2	8.1	70,665
Georgia	4.9	3.5	58,876	Ohio	0.6	0.2	41,222
Idaho	40.5	26.9	83,557	Oklahoma	0.9	4.2	69,919
Illinois	2.0	0.6	56,400	Oregon	27.9	30.5	96,981
Indiana	1.8	2.1	36,291	Pennsylvania	1.7	0.5	45,333
Iowa	0	0.6	56,290	Rhode Island	0	0	1,214
Kansas	6.6	1.4	82,264	South Carolina	6.9	3.3	31,055
Kentucky	5.7	2.8	40,395	South Dakota	3.4	14.3	77,047
Louisiana	1.6	5.0	48,523	Tennessee	6.5	4.0	42,244
Maine	0.4	7.1	33,215	Texas	1.5	1.0	267,339
Maryland	0	2.2	10,577	Utah	15.9	52.3	84,916
Massachusetts	0	2.4	8,257	Vermont	10.2	1.3	9,609
Michigan	14.5	13.8	58,216	Virginia	13.2	1.7	40,817
Minnesota	7.6	14.9	84,068	Washington	26.7	15.7	68,192
Mississippi	7.6	1.4	47,716	West Virginia	21.4	0.4	24,181
Missouri	6.6	1.3	69,686	Wisconsin	5.6	2.8	56,154
Montana	21.5	30.3	147,138	Wyoming	20.9	42.8	97,914
				United States	10.6	15.7	

Note: Includes only those public lands with areas greater than 8,000 acres.

Source Ramsey, William, *Some Considerations of Economic and Environmental Cost for Use in Power Plant Siting Screening Methodologies,* U.S. NRC, March, 1975.

Table 4.19

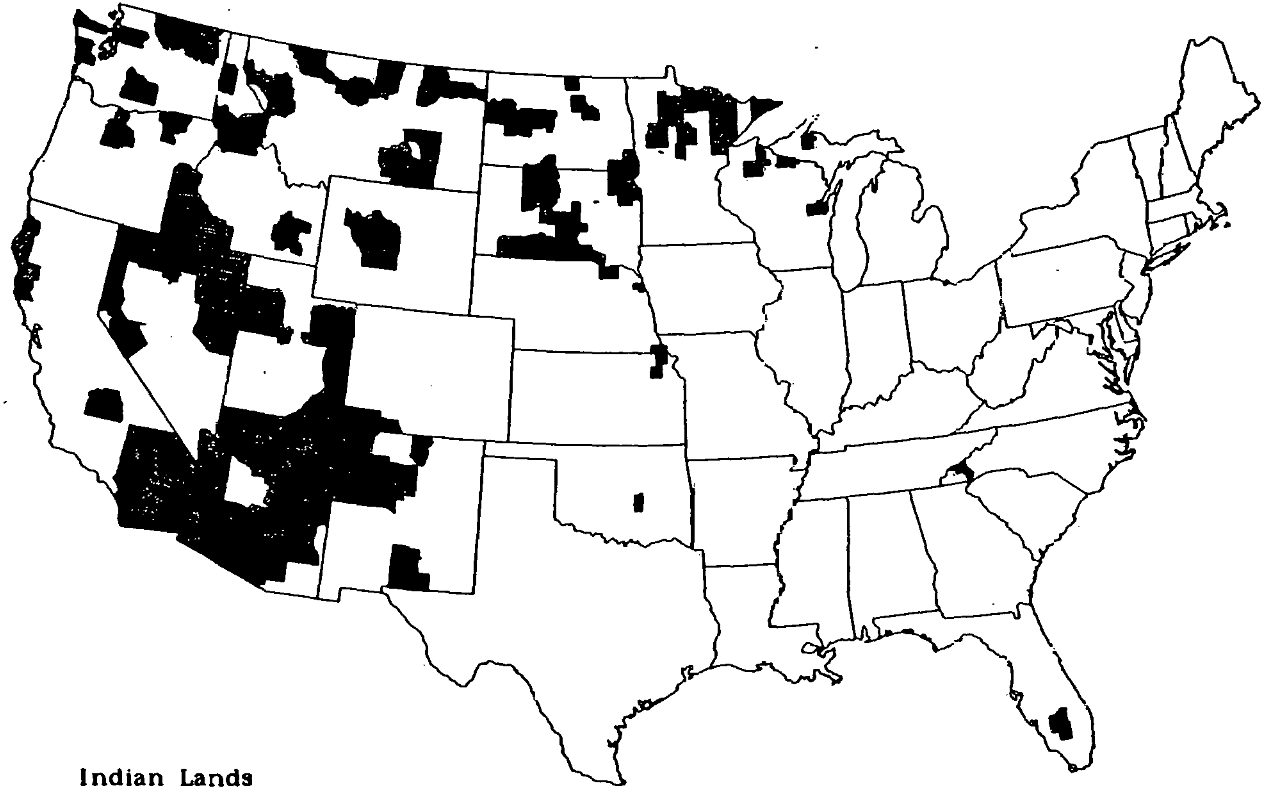
Federal Acreage Withdrawn from Mineral Uses as of June 1, 1980
(millions of acres)

Government facilities and installations not open to public entry	34.4[a]
National park service lands	25.1[b]
Fishlife and wildlife refuges	30.3[b]
Wilderness areas in national forests	12.9[c]
Wild and scenic rivers in national forests	0.3[c,d]
RARE II lands recommended for designation as wilderness	15.5[e]
RARE II lands under further study	10.5[e]
BLM potential wilderness study areas	57.0[e]
1978 designation of Alaskan national monuments	56.0[e]
20-year withdrawal of Alaskan lands	40.0[e]
TOTAL	282.0

[a]Source: *Federal Register,* Vol. 45, No. 98, Monday, May 19, 1980.
[b]As of June 30, 1976.
Source: U.S. DOI, Bureau of Land Management, *Public Land Statistics 1976,* U.S. GPO, Washington, D.C. (no date).
[c]As of Sept. 30, 1977.
Source: USDA, Forest Service, *Land Areas of the National Forest System as of September 30, 1977,* File 1380 (5400), February, 1978.
[d]Additional wild and scenic river acreage can be found outside of national forest lands.
[e]See text.

Figure 4.54

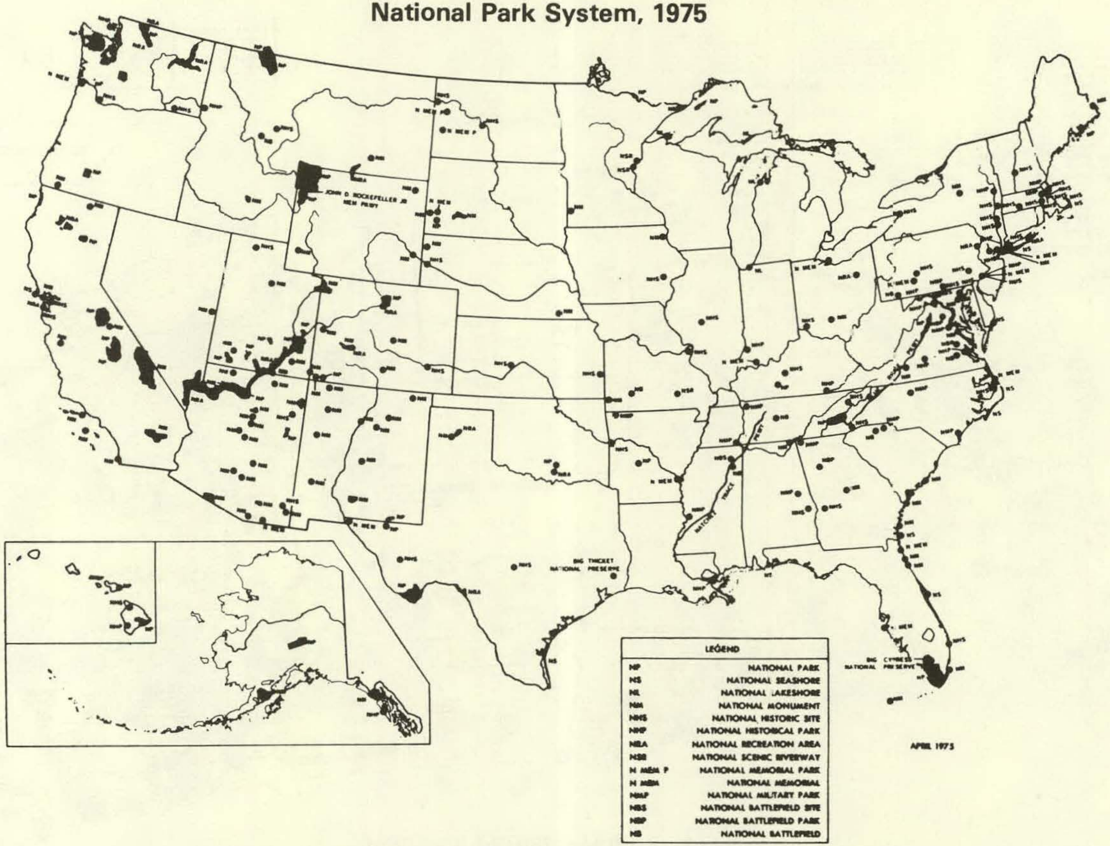
U.S. Counties Containing Indian Lands



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.55

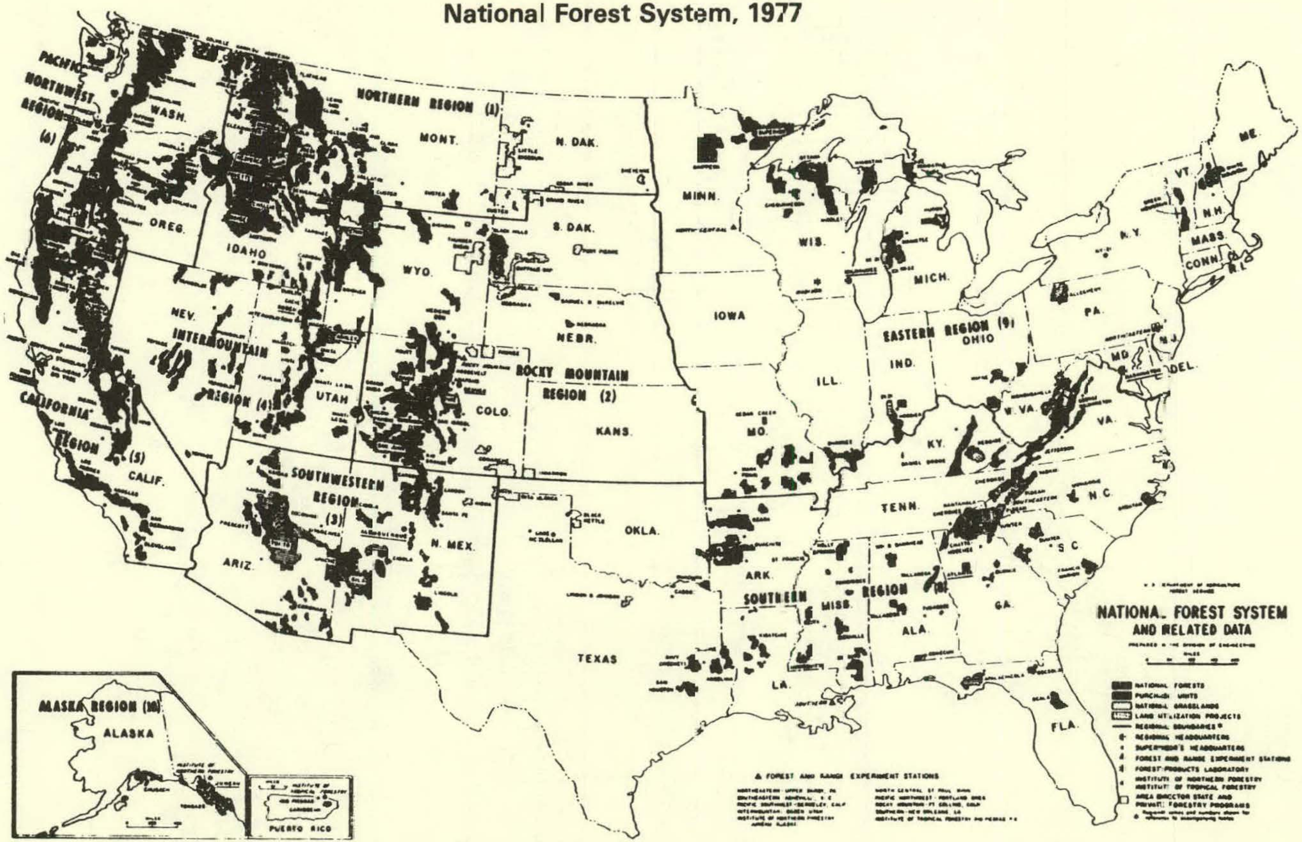
National Park System, 1975



Source: USDA Forest Service, *The Nation's Renewable Resources - An Assessment*, Report 21, 1977.

Figure 4.56

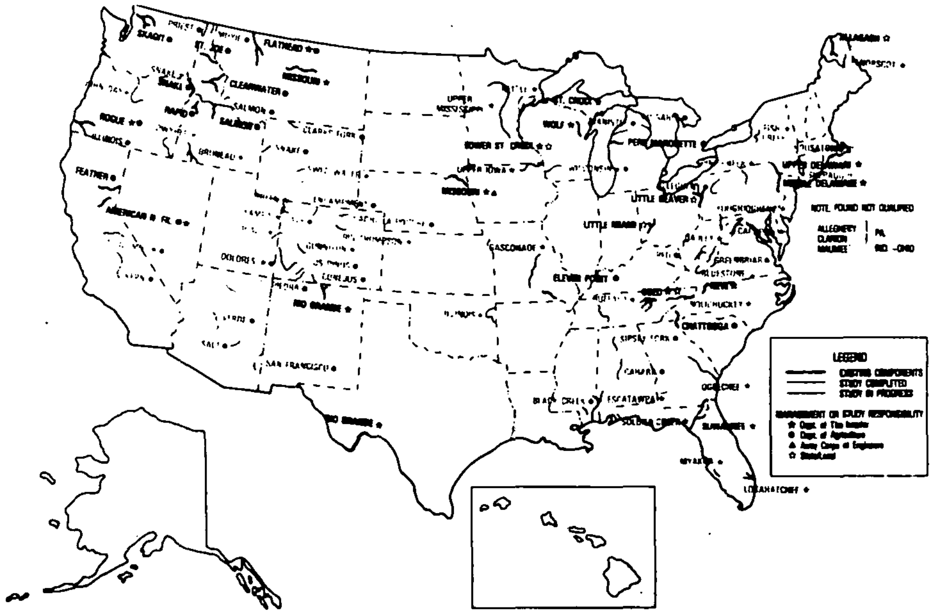
National Forest System, 1977



Source: USDA Forest Service, *Land Areas of the National Forest System*, File 1380 (5400), 1977.

Figure 4.57

National Wild and Scenic Rivers System, 1979

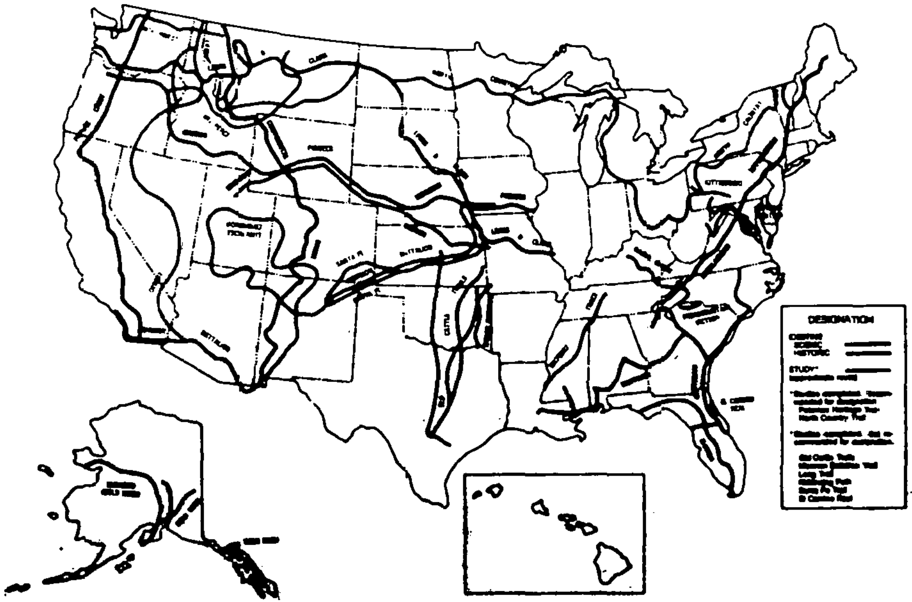


Source: U.S. Department of the Interior, Heritage Conservation and Recreation Service.

171

Figure 4.58

National Scenic and Historic Trails, 1979



Source: U.S. Department of the Interior, Heritage Conservation and Recreation Service.

Table 4.20

River Segments Included in the National Wild and Scenic Rivers System

River	Administering Agency	Wild	Miles by Classification: Scenic	Miles by Classification: Recreational	Total Miles	Total Acres *
Middle Fork Clearwater, Idaho (P.L. 90-542—10/2/68)	USFS	54	—	131	185	55,651
Eleven Point, Mo. (P.L. 90-542—10/2/68)	USFS	—	44.4	—	44.4	14,195
Feather, Calif. (P.L. 90-542—10/2/68)	USFS	32.9	9.7	50.4	93	19,873
Rio Grande, N. Mex. (P.L. 90-542—10/2/68)	BLM/USFS	51.75	—	1	52.75	16,880
	(USFS)	(43.90)	—	(0.25)	(44.15)	
	(BLM)	(7.85)	—	(0.75)	(8.60)	
Rogue, Oreg. (P.L. 90-542—10/2/68)	BLM/USFS	33	7.5	44	84.5	25,999
	(USFS)	(20)	—	(27)	(47)	
	(BLM)	(13)	(7.5)	(17)	(37.5)	
St. Croix, Minn. and Wis. (P.L. 90-542—10/2/68)	NPS/FS	—	181	19	200	62,695
Middle Fork Salmon, Idaho (P.L. 90-542—10/2/68)	USFS	103	—	1	104	32,000
Wolf, Wis. (P.L. 90-542—10/2/68)	NPS	—	25	—	25	5,516
Allagash Wilderness Waterway, Maine (Secretarial Designation—7/19/70)	State of Maine	95	—	—	95	22,840
Lower St. Croix, Minn. and Wis. (P.L. 92-560—10/25/72)	NPS	—	12	15	27	7,845
Little Miami, Ohio (Secretarial Designation—8/20/73)	State of Ohio	—	18	48	66	3,202.5
Chattooga, N.C., S.C., and Ga. (P.L. 93-279—5/10/74)	USFS	39.8	2.5	14.6	56.9	16,424
Little Beaver, Ohio (Secretarial Designation—10/23/75)	State of Ohio	—	33	—	33	2,637.4
Snake, Idaho and Oreg. (P.L. 94-199—12/31/75)	USFS	32.5	34.4	—	66.9	17,546

Table 4.20 (Cont'd.)

River Segments Included in the National Wild and Scenic River Systems

Rapid, Idaho (P.L. 94-199—12/31/75)	USFS	24	—	—	24	8,382
New, N.C. (Secretarial Designation—4/13/76)	State of North Carolina	—	26.5	—	26.5	1,900
Lower St. Croix, Minn. and Wis. s(Secretarial Designation—6/17/76)	States of Minnesota and Wisconsin	—	—	25	25	6,065
Misouri, Montana (P.L. 94-486—10/12/76)	BLM	72	18	59	149	131,838
Flathead, Mont. (P.L. 94-486—10/12/76)	FS/NPS	97.9	40.7	80.4	219	57,400
Obed, Tenn. (P.L. 94-486—10/12/76)	NPS/State of Tennessee	45.2	—	—	45.2	6,451
	Segments Added In 1978					
Pere Marquette, Mich. (P.L. 95-625—11/10/78)	USFS	—	66.4	—	66.4	13,000
Rio Grande, Tex. (P.L. 95-625—11/10/78)	NPS	95.2	96	—	191.2	30,592
Skagit, Wash. (P.L. 95-625—11/10/78)	USFS	—	99	58.5	157.5	34,650
Upper Delaware, N.Y. and Pa. (P.L. 95-625—11/10/78)	NPS	—	25.1	50.3	75.4	75,000
Middle Delaware, N.Y., Pa., and N.J. (P.L. 95-625—11/10/78)	NPS	—	35	—	35	[b]
American (North Fork), Calif. (P.L. 95-625—11/10/78)	USFS/BLM (USFS) (BLM)	38.3 (26.3) (12)	—	—	38.3	13,430
Missouri, Nebr. and S.D. (P.L. 95-625—11/10/78)	Interior/Corps of Engineers	—	—	59	59	14,941
Saint Joe, Idaho (P.L. 95-625—11/10/78)	USFS	26.6	—	46.2	72.8	21,803
Total		841.15	774.2	702.4	2,317.75	718,756.81

[a]Final boundaries for all areas not established. Thus, figure should be considered approximate.
[b]Located within the Delaware Water Gap National Recreation Area.

Source: U.S. Department of the Interior, Heritage Conservation and Recreation Service.

Table 4.21

Designated and Proposed Wilderness, 1964-76
(millions of acres)

	Designated		Proposed/Under Study		
Year	Annual Addition	System Total	Annual Addition	System Total	Grand Total
1964	9.244	9.244	37	37	46.24
1965	0	9.244	0	37	46.24
1966	0	9.244	0	37	46.24
1967	0	9.244	0	37	46.24
1968	.788	10.032	0	37	47.03
1969	.159	10.191	0	37	47.19
1970	.204	10.395	.21	37.21	47.60
1971	0	10.395	.55	37.76	48.15
1972	.631	11.026	.20	37.96	48.99
1973	0	11.026	0	37.96	48.99
1974	.354	11.380	.62	38.58	49.96
1975	1.336	12.716	.27	38.85	51.57
1976	1.738	14.454	.65	39.50[a]	53.95

[a]In addition, the 1976 BLM Organic Act includes approximately 174 million acres of BLM lands which are under consideration for Wilderness designation.

Source: U.S. Department of Agriculture, Forest Service, August 1, 1977.

Table 4.22

Areas Added to the National Wilderness Preservation System in 1976

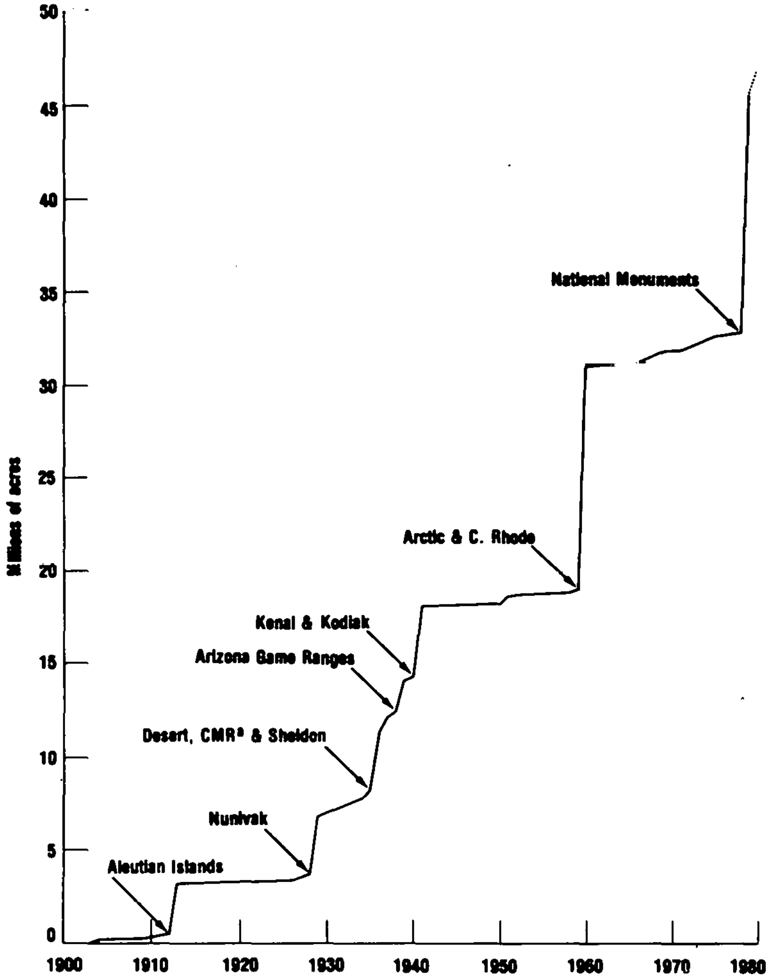
Wilderness	Agency	State	Public Law	Acreage
Agassiz	FWS	Minnesota	94-997	4,000
Alpine Lakes	FS	Washington	94-357	303,508
Badlands	NPS	South Dakota	94-567	64,250
Bandelier	NPS	New Mexico	94-567	23,267
Big Lake	FWS	Arkansas	94-557	2,600
Black Canyon of the Gunnison	NPS	Colorado	94-567	11,180
Chassahowitzka	FWS	Florida	94-557	23,360
Chiricahua	NPS	Arizona	94-567	9,440
Crab Orchard	FWS	Illinois	94-557	4,050
Eagles Nest	FS	Colorado	94-352	133,010
Fitzpatrick	FS	Wyoming	94-557	197,600
Fort Niobrara	FWS	Nebraska	94-557	4,635
Great Sand Dunes	NPS	Colorado	94-567	33,450
Haleakala	NPS	Hawaii	94-567	19,270
Hercules-Glades	FS	Missouri	94-557	12,315
Isle Royale	NPS	Michigan	94-567	131,880
J.N. "Ding" Darling	FWS	Florida	94-557	2,025
Joshua Tree	NPS	California	94-567	429,690
Kaiser	FS	California	94-557	22,500
Lacassine	FWS	Louisiana	94-557	3,300
Lake Woodruff	FWS	Florida	94-557	1,146
Medicine Lake	FWS	Montana	94-557	11,366
Mesa Verde	NPS	Colorado	94-567	8,100
Mingo	FWS	Missouri	94-557	8,000
Pinnacles	NPS	California	94-567	12,952
Point Reyes	NPS	California	94-567	25,370
Red Rock Lakes	FWS	Montana	94-557	32,350
Saguaro	NPS	Arizona	94-567	71,400
San Juan Islands	FWS	Washington	94-557	355
Shenandoah	NPS	Virginia	94-567	79,019
Simeanof	FWS	Alaska	94-557	25,141
Swanquarter	FWS	North Carolina	94-557	9,000
Tamarac	FWS	Minnesota	94-557	2,138
Ul Bend	FWS	Montana	94-557	20,890

	Added 1976		Total	
Agency	Areas	Acreage	Areas	Acreage
FS	5	669,833	92	12,605,405
NPS	13	919,268	17	1,120,213
FWS	16	155,156	52	718,087
Total	34	1,744,257	161	14,443,705

Source: U.S. Council on Environmental Quality, *Environmental Quality-1977,* Annual Report, U.S. GPO, Washington, D.C., 1977.

Figure 4.59

Growth in Acreage of National Wildlife Refuge System, 1900-78

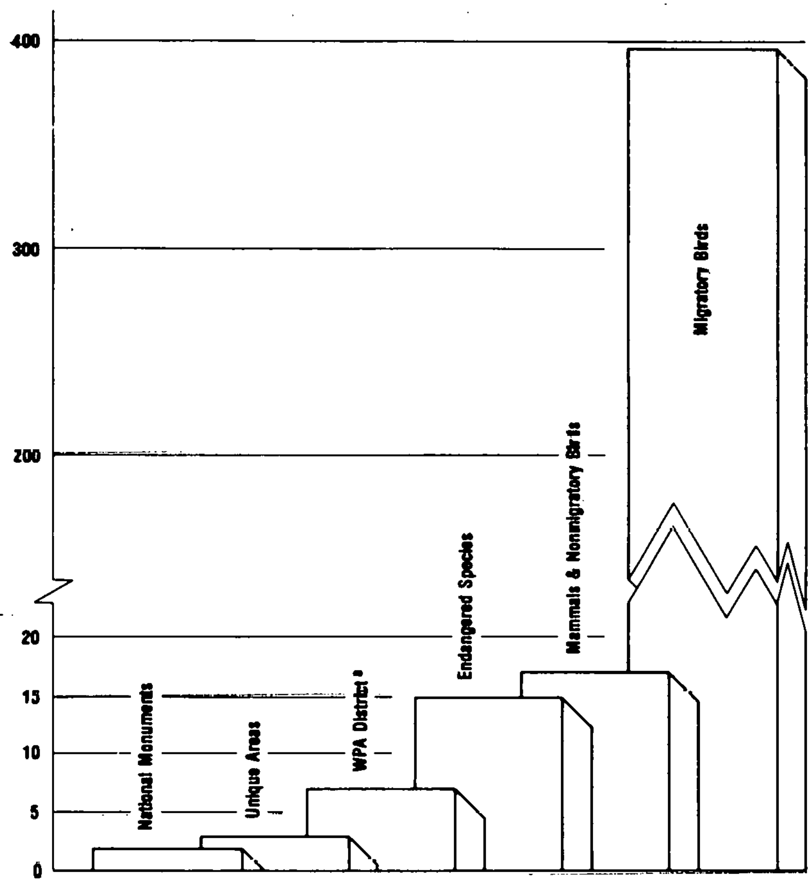


[a]CMR = Charles M. Russell Refuge.

Source: U.S. Department of the Interior, Fish and Wildlife Service.

Figure 4.60

Numbers, by Type, of National Wildlife Refuges, 1978

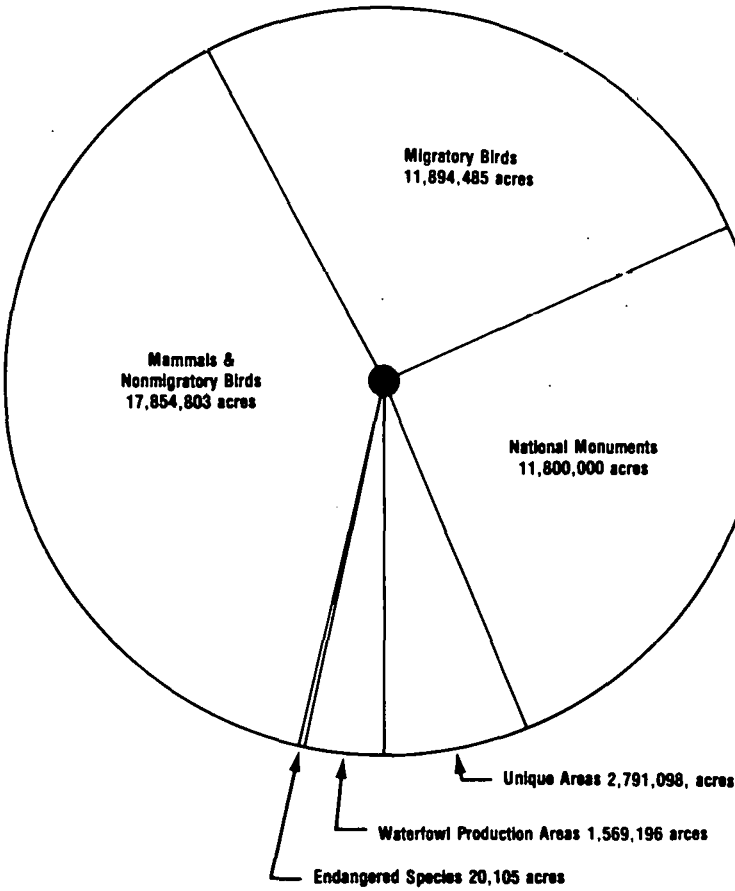


[a]WPA = Waterfowl Production Area.

Source: U.S. Department of the Interior, Fish and Wildlife Service.

Figure 4.61

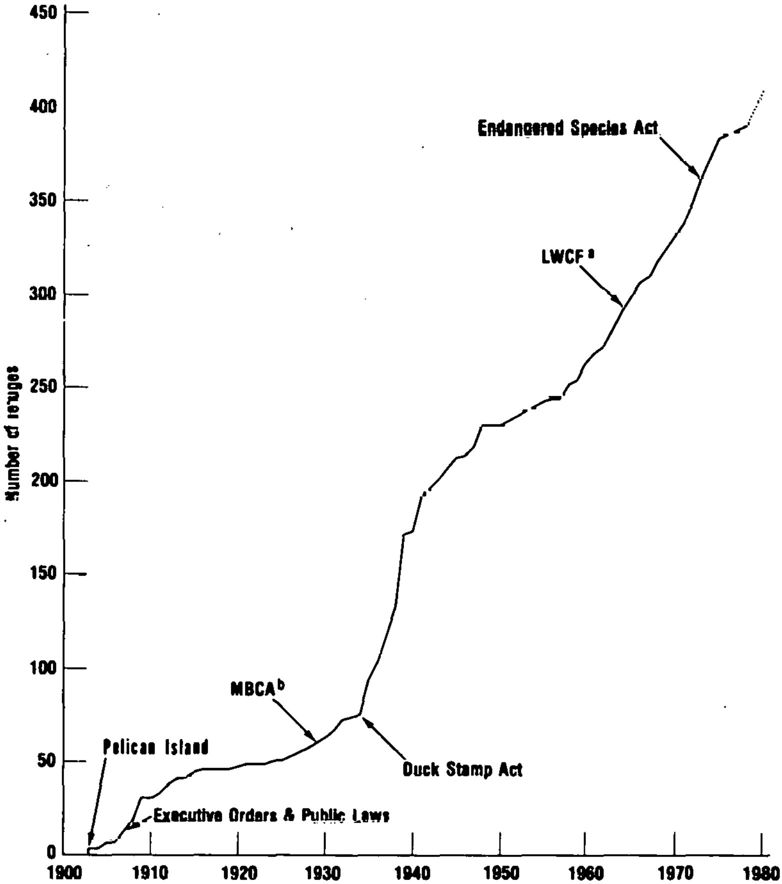
Acreage, by Type, of National Wildlife Refuges, 1978



Source: U.S. Department of the Interior, Fish and Wildlife Service.

Figure 4.62

Growth in National Wildlife Refuge System, 1900-78

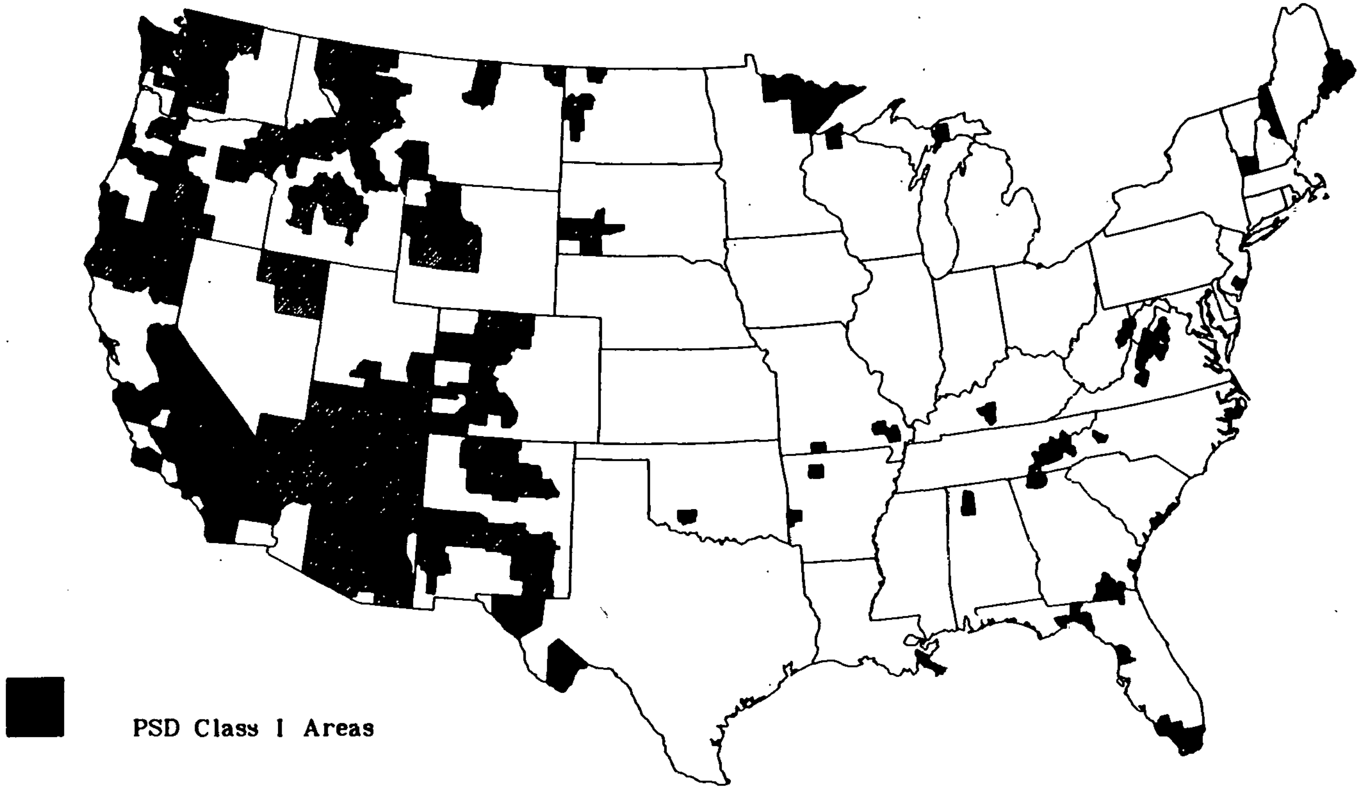


[a]LWCF = Land Water Conservation Fund.
[b]MBCA = Migratory Bird Conservation Act.

Source: U.S. Department of the Interior, Fish and Wildlife Service.

Figure 4.63

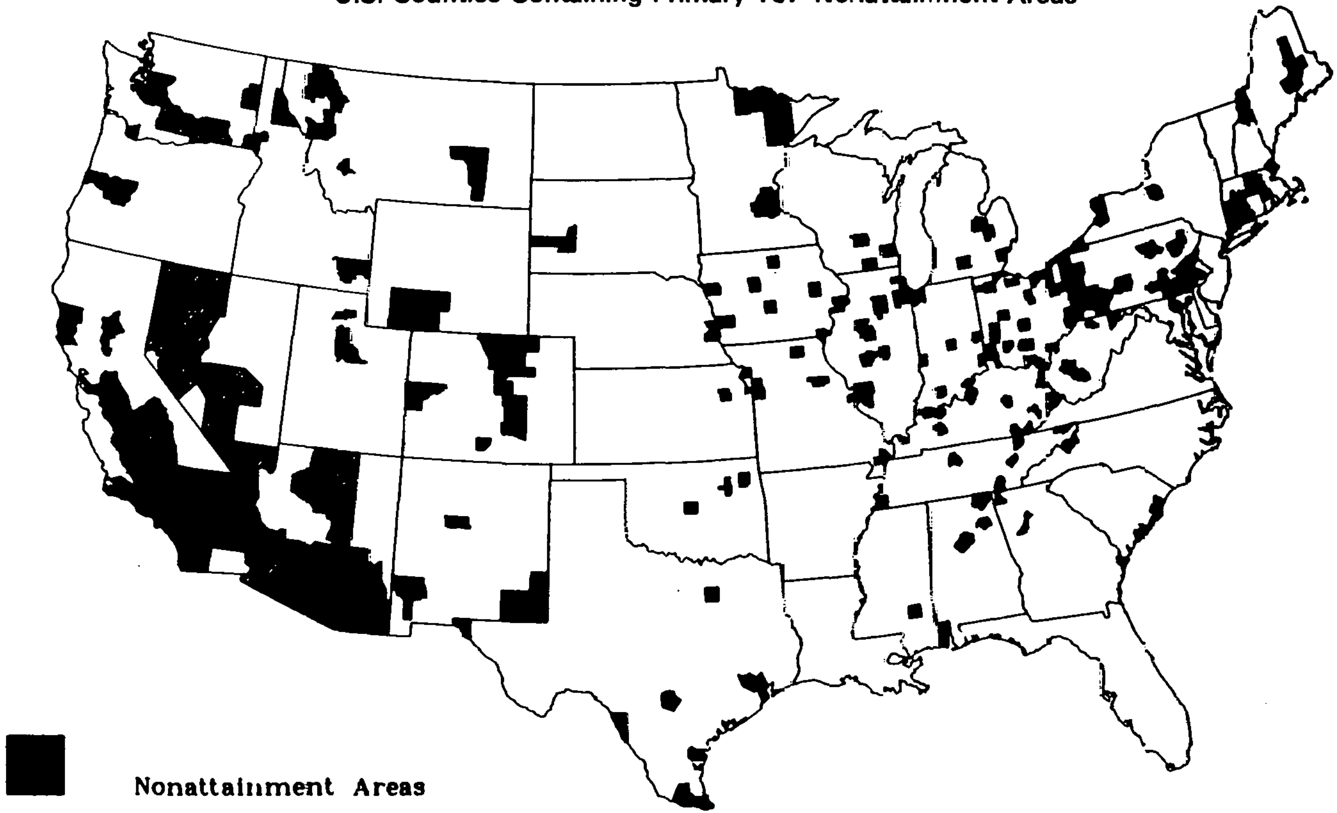
U.S. Counties Containing PSD Class I Areas



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.64

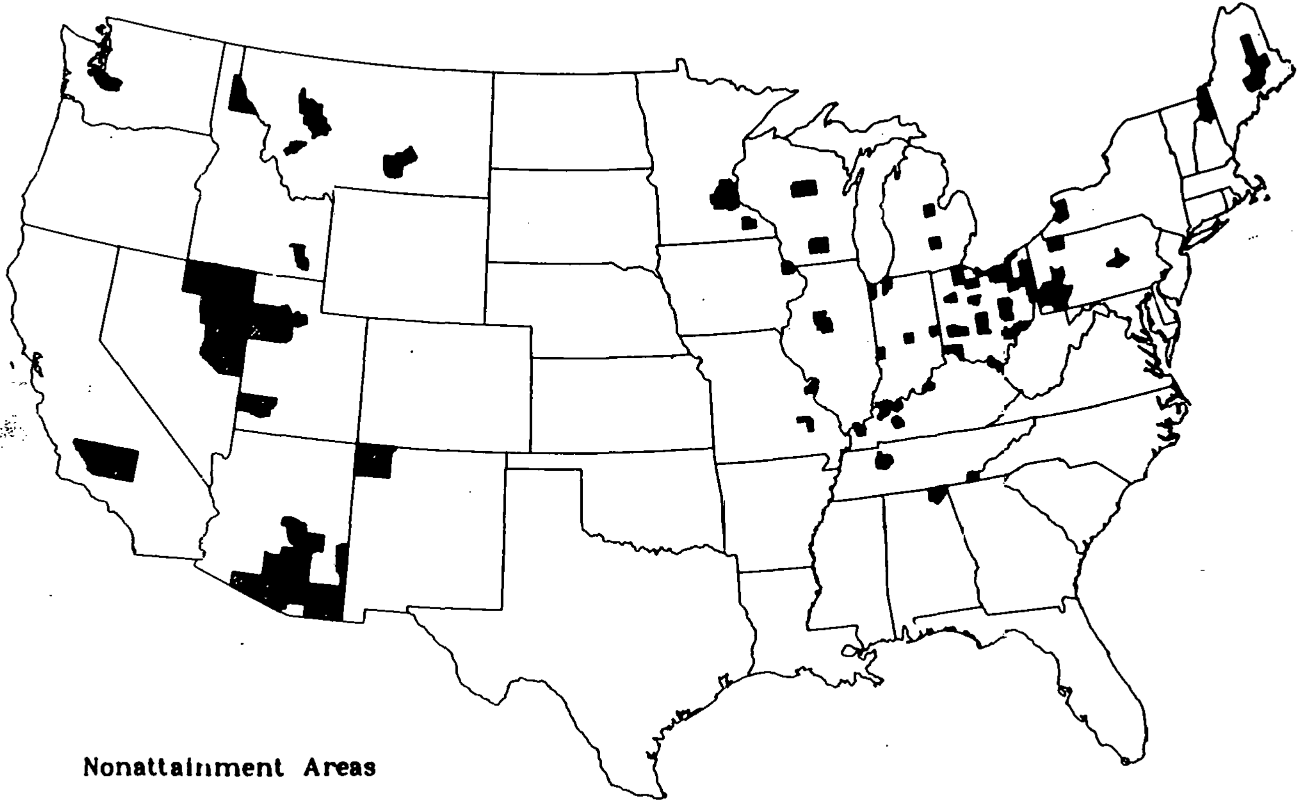
U.S. Counties Containing Primary TSP Nonattainment Areas



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.65

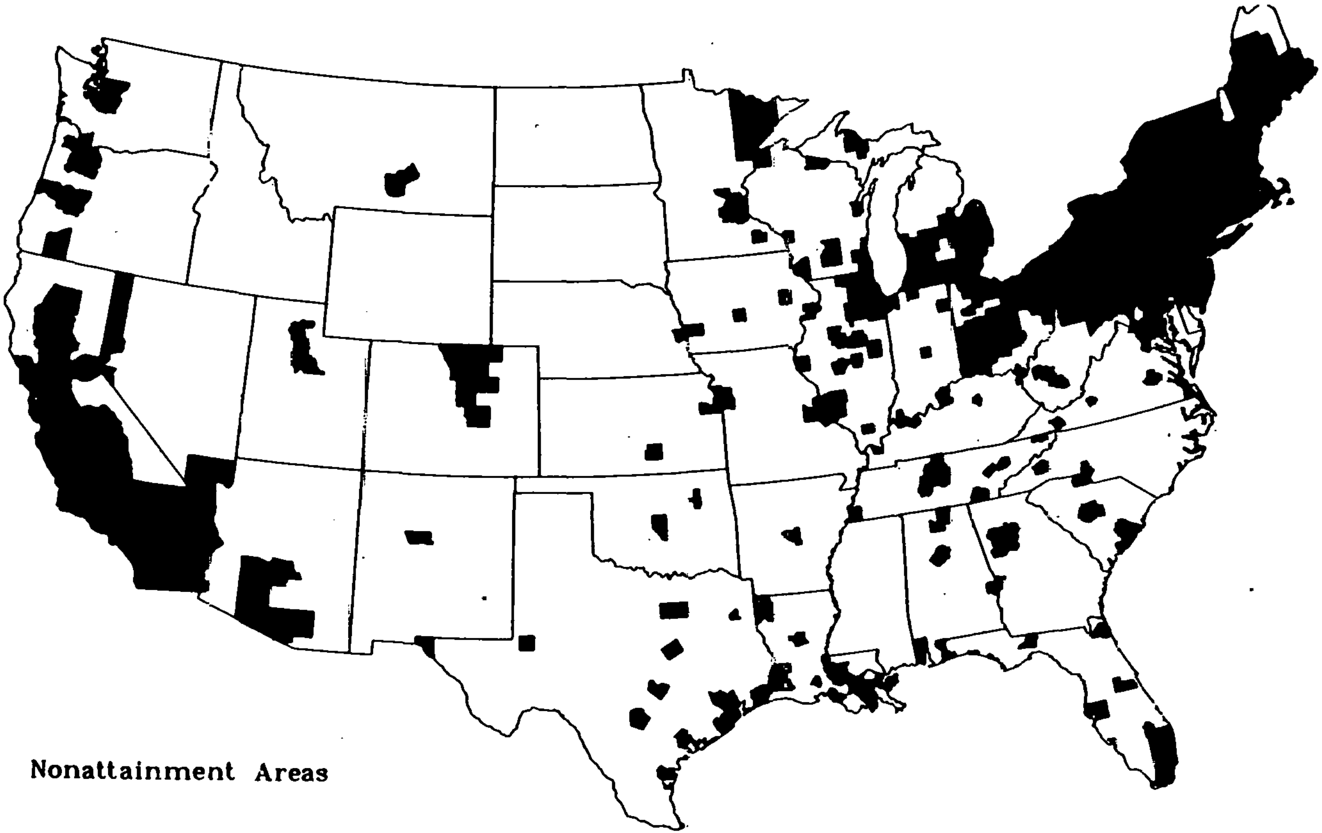
U.S. Counties Containing Primary SO_2 Nonattainment Areas



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.66

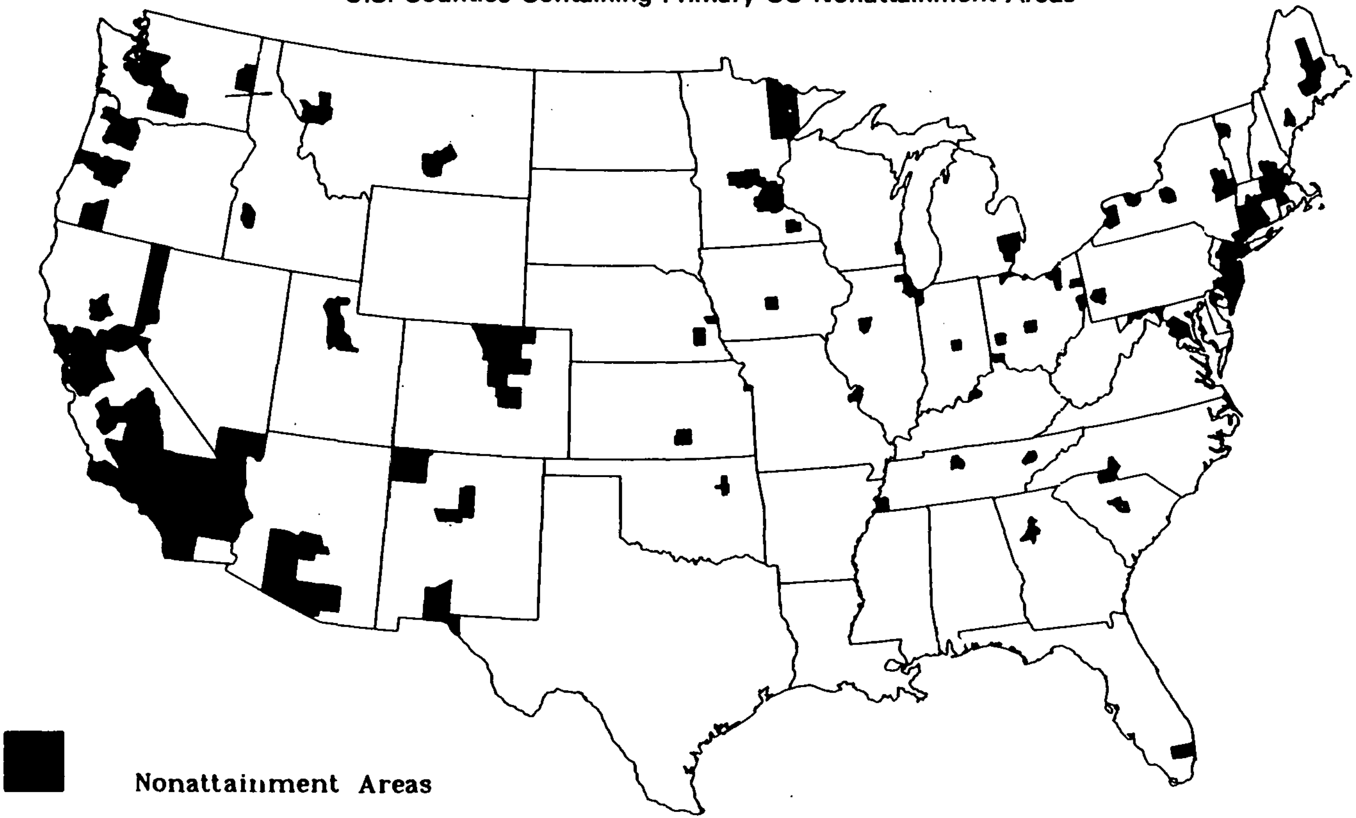
U.S. Counties Containing Primary O_x Nonattainment Areas



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.67

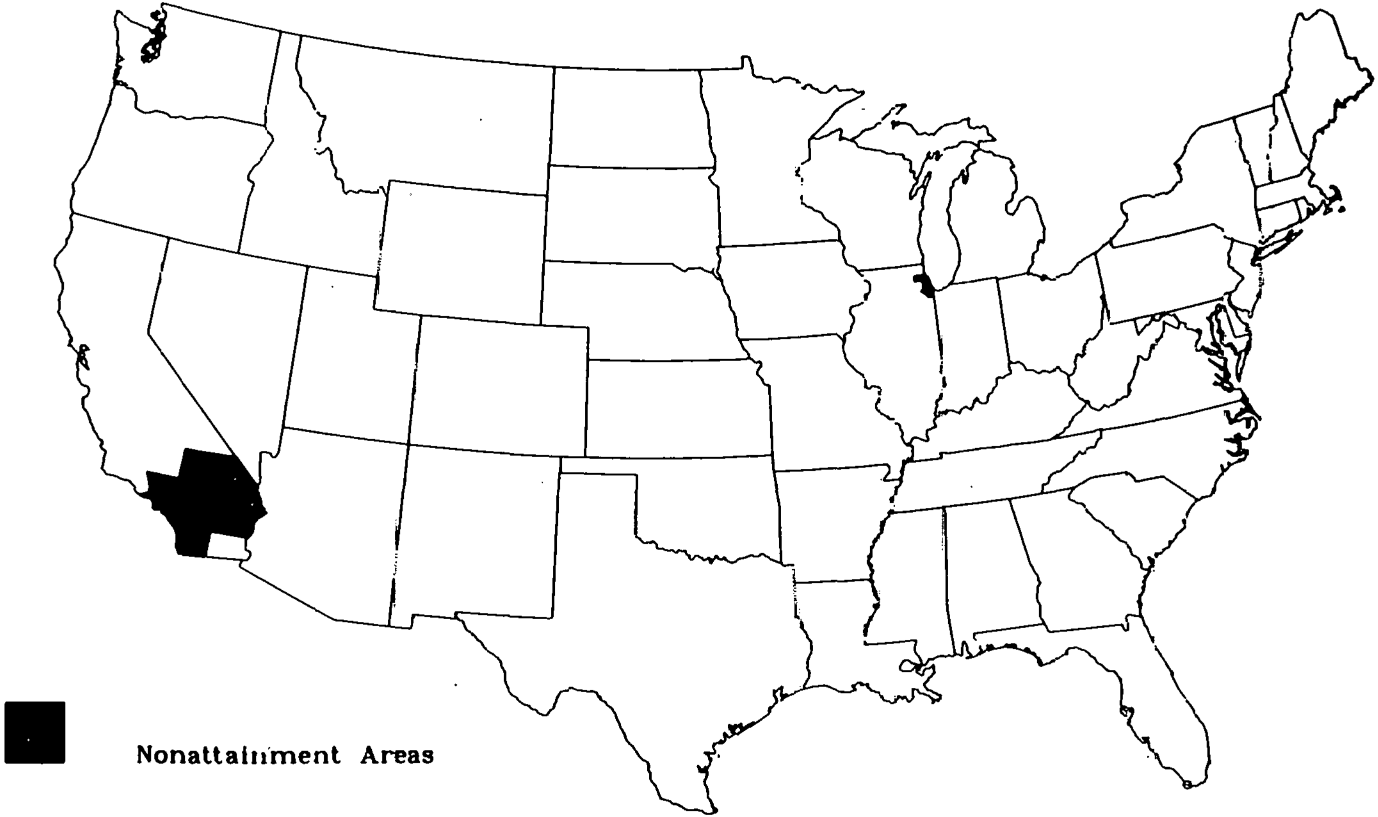
U.S. Counties Containing Primary CO Nonattainment Areas



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Figure 4.68

U.S. Counties Containing Primary NO_x Nonattainment Areas



Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Table 4.23

Provisions of State Power Plant Siting Laws

State	One-Stop Provision	Site Certification Authority	Size and Composition of Site Panel	Method of Acquisition	Annual Utility Forecast	State Approval of Forecast	Consideration of Alternate Sites Required	State Inventory of Sites
CT	Yes	Power Facility Evaluation Council	9 Governor Appointments	Eminent Domain	10-20 yr	No	No	No
MA	Yes	Electric Power Siting Council	9 Governor Appointments	Eminent Domain	10-yr	Yes	Yes	Yes
NH	Yes	Public Utilities Commission	13 Governor Appointments	Eminent Domain	None	N/A	Yes	No
NJ*	No	Commissioner of Environmental Protection	Coastal Area Review Board	Permit	None, 4-yr state plan	No	Yes	No
NY	Yes	Power Siting Board	5 Governor Appointments	Certification by Siting Board	10-yr	No	Yes	No
FL	Yes	Department of Pollution Control	5 Governor Appointments	Certification by Environmental Compatibility	10-yr	Yes	Yes	No
MD	Yes	Public Service Commission	Size of P.S.C.	Environmental Trust Fund	10-yr	No	Yes	Yes
AK	2 stop	Public Service Commission	Size of P.S.C.	Eminent Domain	2-yr	No	Yes	No
AZ	Yes	Arizona Power Plant Siting Committee	11 State Officials 7 others	Certification of Environmental Compatibility	10-yr	No	No	No
MT	Yes	Board of Natural Resources and Conservation	Size of Board	Application to Site Authority	10-yr	Yes	Yes	No

* Coastal Zone Only

Table 4.23 (Cont.)

Provisions of State Power Plant Siting Laws

State	One-Stop Provision	Site Certification Authority	Size and Composition of Site Panel	Method of Acquisition	Annual Utility Forecast	State Approval of Forecast	Consideration of Alternate Sites Required	State Inventory of Sites
NV	Yes	Public Service Commission	Size of P.S.C.	Permit	None	N/A	Yes	No
NM	Yes	Public Utilities Commission	Size of P.U.C.	Eminent Domain	None	N/A	No	No
WY	Yes	Industrial Siting Commission	9 Governor Appointments	Certification of Environmental Compatibility	20-yr	No	Yes	No
CA	Yes	Energy Resources Conservation and Development Commission	5 Governor Appointments	Application to Site Authority	5-10-20-yr	Yes	Yes	Yes
OR	Yes	Governor	9 Governor Appointments	Eminent Domain	10-yr	No	Yes	Yes
WA	Yes	Governor	16 Governor Appointments	Eminent Domain	None	N/A	Yes	No
MN	Yes	Environmental Quality Council	Size of Council	Eminent Domain	15-yr	No	Yes	Yes
SC	Yes	Public Service Commission	Size of P.U.C.	Eminent Domain	10-yr	No	No	No
OH	Yes	Power Siting Commission	5 Governor Appointments	Eminent Domain	10-year	No	Yes	No
KY	Yes	Public Service Commission	Size of P.S.C.	Certification of Environmental Compatibility	None	N/A	No	No

Source: Cirillo, R. R. et, al., *An Evaluation of Regional Trends in Power and Energy Transport,* Argonne National Laboratory, ANL/AA-9, July, 1977.

Table 4.24

State Programs for Preservation of Farmland, by Type of Program

State	Preferential property tax assessment	Preferential property tax assessment with deferred taxation	Preferential taxation with restrictive agreement	Circuit breaker state income tax credits	Inheritance and estate taxation	Land gains taxation	Agricultural districts	Agricultural zoning	Purchase of development rights	Transfer of development rights	Land use commissions	Land banking
Alabama		s										
Alaska		s							b	s		
Arizona	s											
Arkansas	s											
California			s			b		b				
Colorado	s											
Connecticut	s				s				s			
Delaware	s											
Florida	s											
Georgia												
Hawaii			s					s	b		s	s
Idaho	s											
Illinois		s				b						
Indiana	s											
Iowa	s										s	
Kansas		s			s							
Kentucky		s			s							
Louisiana	s											
Maine		s							s			
Maryland		s,b							s	b		
Massachusetts		s							s			s
Michigan			s	s	s							
Minnesota		s	b	b								
Mississippi												
Missouri	s											
Montana		s				b						
Nebraska		s										
Nevada		s										
New Hampshire			s						b			
New Jersey		s							s, b	b		
New Mexico	s											
New York		s			s		s			b		
North Carolina		s										
North Dakota	s			b								
Ohio		s					b					
Oklahoma	s											
Oregon		s				b		s			s	
Pennsylvania		s	s				b					s
Rhode Island		s										
South Carolina		s										
South Dakota	s											
Tennessee		s			s							s
Texas		s										
Utah		s										
Vermont		s				s						
Virginia		s				b	s		b			
Washington		s, b				b						s
West Virginia	s											
Wisconsin			s	s				s				
Wyoming	s											

Note: s = statute or program
b = bill

Source: Davies, Bob and Joe Belden, *A Survey of State Programs to Preserve Farmland,* (Washington, D.C.: Council on Environmental Quality, 1979).

Table 4.25

Summary of State Laws Affecting Management of Coastal Development (by type of activity or area affected)

State	Erosion-Prone Areas	Floodplains	Subsidence and/or Saltwater Intrusion	Energy Facility Siting	Priority to Water-Dep. Uses	Locating Dredge Disposal Sites	Offshore Oil & Gas; Sand & Gravel Extraction
Alabama	P	P	X		X		
Alaska	X	X	X	X	X		X
California	X		X	X	X		X
Connecticut					P	X	
Delaware	X				X		
Florida	X			X			
Georgia	X		X		X		X
Guam		X					X
Hawaii	X	X	X		X		X
Illinois		X				X	X
Indiana		X				X	X
Louisiana	P	P	P	X		P	P
Maine	X	X			X		X
Maryland	X	X		X	X		
Massachusetts	X	X		X	X	X	X
Michigan	X	X			X		X

Source: National Oceanic and Atmospheric Administration, Office of Coastal Zone Management, *The First Five Years of Coastal Zone Management,* U.S. Department of Commerce, Washington, D.C., March, 1979, Table IV, p. 31.

Table 4.26

Summary of State Protection of Significant Natural Resources Under CZMA

State	Wetlands	Flora & Faunal Habitats	Beaches & Dunes	Barrier Islands	Reefs
Alabama	X	P	P		
Alaska	X	X		X	
California	X	X	X		
Connecticut	X				
Delaware	X	X	X		
Florida	X	X	X		X
Georgia	X	X	X		X
Guam	X	X	X		X
Hawaii		X	X		X
Illinois	X		X		X
Indiana	X				
Louisana	X		P	P	
Maine	X	X		X	
Maryland	X	X	X		
Massachusetts	X	X	X		
Michigan	X	X	X		X
Minnesota	X				X
Mississippi	X		X	X	
New Hampshire		P	P	P	
New Jersey	X	X	P		
New York	X	X			
North Carolina	X	X	X	X	
N. Marianas					
Ohio	X	P	P		X
Oregon	X	X	X		X
Pennsylvania	X	P			
Puerto Rico	X	X	X		P
Rhode Island	X	X	X	X	
(Am.) Samoa					
South Carolina	X	X	X	X	
Texas	X		X		
Virgin Islands	X	X	X	X	X
Virginia	X		X		
Washington	X	X	X		X
Wisconsin	X	X	X		X

X = Pre-existing law or program incorporated in Coastal Management Program or new or expanded law or program directly attributable to CZM participation.

P = Proposed law or program to be part of CMP.

Source: National Oceanic and Atmospheric Administration, Office of Coastal Zone Management, *The First Five Years of Coastal Zone Management,* U.S. Department of Commerce, Washington, D.C., March, 1979, Table II, p. 20.

Table 4.27

Summary of State Protection of Historic and Cultural Resources Under CZMA

State	Required Dedication of Access	Open Beach Laws or Court Action	Protection/ Restoration of Historic and Cultural Resources	Protection/ of Scenic Areas/ Provision of Visual Access	Urban Waterfront Projects
Alabama	P		P	P	
Alaska	X		X		
California	X		X	X	
Connecticut			X		New Haven, Stamford, Norwalk
Delaware		X			Wilmington, Newcastle County
Florida					Miami, Sarasota
Georgia			X	P	Brunswick, St. Mary's
Guam		X	X		
Hawaii	X	X	X	X	Honolulu
Illinois			X	X	Chicago-Waukegan
Indiana					
Louisana					Moon Walk,
			X		Lincoln Park
Maine					Calais
				X	South Portland, Vinalhaven
Maryland	X		X		Cambridge Creek
Massachusetts			X	X	
Michigan			X	X	Detroit
Minnesota					Duluth
Mississippi					Gulfport
New Hampshire	P			P	Portsmouth,
	P			P	Exeter
New Jersey	X			X	Jersey City
New York			P	X	Buffalo
North Carolina			X		Wilmington
N. Marianas					
Ohio					
Oregon		X	X	X	
Pennsylvania	P		P		
Puerto Rico	X		X		San Juan
Rhode Island		X	X		
(Am.) Samoa					
South Carolina	X		X		
Texas		X			
Virgin Islands	X	X	X	X	
Virginia					Alexandria, Norfolk, Newport News, and Virginia Beach
Washington			X	X	Seattle
Wisconsin	X			X	Milwaukee, Kenosha

X = Pre-existing law or program incorporated into Coastal Management Program or new or expanded law or program directly attributable to CZM participation.

P = Proposed law or program to be part of CMP.

Source: National Oceanic and Atmospheric Administration, Office of Coastal Zone Management, *The First Five Years of Coastal Zone Management,* U.S. Department of Commerce, Washington, D.C., March, 1979, Table V, p. 39.

MEASURING FUTURE LAND USE IMPACTS

List of Tables

Table 4.28

Values Used In Calculating Area Affected By Coal Mining

Coal Region	Average Coal Density (tons/acre-ft)	Average Seam Thickness (feet)		Area Disturbed or Undermined (acres/million tons)	
		Deep	Surface	Deep Mining	Surface Mining
N. Appalachia, MD, OH, PA, N. WV	1800	5.0	4.2	227	171
Cent. Appalachia, E. KY, IN, VA, S. WV	1800	4.6	4.2	248	175
S. Appalachia, AL	1800	4.7	2.5	236	277
Central West, AR, IO, KS, MO, OK	1800	2.5	2.0	483	367
Midwest, IL, IN, W. KY	1800	6.2	4.7	183	148
Gulf, TX	1750	6.7	6.7	171	104
NE. Great Plains, NE. MT, ND	1750	12.1	12.1	94	52
NW. Great Plains, N. CO, SE. MT, WY	1770	14.3	21.4	93	34
Rockies, CO, UT	1800	7.4	8.3	162	76
Southwest, AZ, NM	1770	13.9	13.9	84	46
Northwest, WA	1770	8.0	8.0	141	88

Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Table 4.29

Estimated Land Requirements for Three Uranium Mining Methods[a]

Method	Acres/1000 Tons U_3O_8	Acres/Mine
Open-pit mining	158 - 316[b]	-
Underground mining	-	2 - 5[c]
Solution mining	111 - 222[d]	-

[a]Derived in Section 2.
[b]Lower number is for pit alone; higher number incudes topsoil storage, haul roads and other associated uses.
[c]Average mine size = 30 tons U_3O_8/year.
[d]Based on 25 - 50 acres of well field/year to produce 250 tons/year of yellowcake.

Source: Robeck, K., et. al., *Land Use and Energy,* Argonne National Laboratory, ANL/AA-19, September, 1980.

Table 4.30

Proposed Refinery Complexes: Location, Capacity, Land Area

Company	Location	Region	Crude Capacity (b/sd)	Land Area
Alaska Petrochemical	Valdel, AK	10	150,000	750
Apex Oil Company	Luling, LA	6	100,000	500
Barbour Energy	Brownsville, TX	6	150,000	750
Brunswick Energy Corp.	Brunswick County, NC	4	150,000	750
Dow Chemical	Brazoport, TX	6	180,000	900
Hampton Roads Energy	Portsmouth, VA	3	175,000	875
MacMillan Ringfree	Carson, CA	9	40,000	700
Mobil Oil Corp.	East of Rockies	8	150,000	750
Novex, Inc.	Houston, TX	6	30,000	150
Petromay Refining	Houston, TX	6	30,000	150
Petrounited, Inc.	Sunshine, LA	6	40,000	700
Pittson	Eastport, ME	1	250,000	1250
Solar Vistas Assoc.	Phoenix, AZ	9	3,000	15
Sooner Refining	Egan, LA	6	6,000	30
Tiber Petroleum Corp.	Harvey, PA	3	30,000	150
Refinery Corp.	Magnolia, LA	6	200,000	1000
UCO Oil	Martinez, CA	9	10,000	50
Ventech Refining	Knotz Springs, LA	6	22,000	110
Wallace & Wallace Chemical & Oil Corp.	Tuskegee, AL	4	150,000	750

Source: *Oil and Gas Journal,* May 19, 1980.

Table 4.31

Range of Land Use by Existing Fossil-fired Power Plants

MW	Fuel	Acres
500	Coal	500 - 1000[a]
1000	Coal	475 - 1000[b]
1000	Coal	330[c]
3000	Coal	200 - 1200[d]
3000	Oil	150 - 350[d]
1000	Oil	80[e]

[a]Source: U.S. Department of Energy, *Environment Characterization Information Report: Coal-Fired Power Plant,* Draft, April, 1980.

[b]Source: Levine, E.P., M.J. Senew, and R.R. Cirillo, *Comparative Assessment of Environmental Welfare Issues Associated with Satellite Power System Development,* Argonne National Laboratory, October, 1979.

[c]Source: Dvorak, A.J. et al., *The Environmental Effects of Using Coal for Generating Electricity,* Argonne National Laboratory, March, 1979.

[d]Source: U.S. Environmental Protection Agency, *Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category,* EPA-440/1-74-029a, October, 1974.

[e]Source: Cirillo, R.R., T.D. Wolsko, et al., *An Evaluation of Regional Trends in Power Siting and Energy Transport,* Argonne National Laboratory, ANL/AA-9, July, 1977.

Table 4.32

Power Plant Land Consumption Factors Used in Calculating Future Land Requirements

Fuel	Plant Size Range, MW	Site Size
Coal	500	300 acre
	500 - 1000	500 acre
	1000 - 2000	1000 acre
Oil	All	0.08 acre/MW (minimum 10 acres/site)

Source: Calculated from "Range of Land Use for Fossil-fired Power Plants," and "Trends in Site Sizes for Fossil Fueled Power Plants."

Table 4.33

Trends in Site Sizes for Fossil-Fueled Power Plants

Region	Site Size, MW			
	1974		New Sites	
	Median	Maximum	Median	Maximum
New England (CT, ME, MA, NH, RI, VT)	150	1650	400	450
Middle Atlantic (NJ, NY, PA)	450	2300	850	2500
South Atlantic (DE, DC, FL, GA, MO, NC, SC, VA, WV)	500	2900	1300	3700
East North-Central (IL, IN, MI, OH, WI)	320	3050	1050	2600
East South-Central (AL, KY, MS, TN)	550	2550	1000	2650
West North-Central (IA, KA, MN, MO, NB, ND, SD)	100	2350	700	3000
West South-Central (AR, LA, OK, TN)	250	2250	850	3000
Mountain (AZ, CO, ID, MT, NV, NM, UT, WY)	150	2200	800	3000
Pacific (CA, OR, WA)	200	2100	500	500
National	250	3050	850	3700

Source: Cirillo, R.R., T.D. Wolsko et al., *An Evaluation of Regional Trends in Power Plant Siting and Energy Transport,* Argonne National Laboratory, ANL/AA-9, July, 1977.

Table 4.34

Cooling System Land Requirements

	Nuclear	Fossil Fuel
Once-Through	1	1
Natural Draft Cooling Towers	15	10
Mechanical Draft Cooling Towers	68	45
Spray Canals	150	100
Cooling Ponds	3000	2000

Source: Environmental Technology Assessment, *State of Illinois, Power Facility Siting in the State of Illinois, Part II - Impacts of Large Energy Conversion Facilities*

Table 4.35

Land Use Requirements for the Conversion of Alternative Feedstocks to Alcohol

Facility	Feedstock Requirements	Alcohol Production (10^6 gal/yr)	Land Requirements Facility (acres)	Land Requirements Feedstock (acres)
Corn Fermentation (ethanol)	25,000 bbl/day	20	80	100,000[a]
Corn and Wheat Residue (ethanol)	1,562 dt/day	25	120[b] 140[c]	
Wood Methanol	1,000 dt/day	56	218	40,000[d]
Wood Ethanol	1,000 dt/day	33	159	40,000[d]

[a]Assumes 90 bu/acre.
[b]Acid hydrolysis.
[c]Enzymatic hydrolysis.
[d]Feedstock derived from energy farm.

Source: Dale, L., R. Opiela, and J. Surles, *Alcohol Production from Agriculture and Forest Residues,* Argonne National Laboratory, ANL-EES-TM-88, May, 1980.

Table 4.36

Land Requirements for 110 MW Production Generation Units at Geothermal Facilities

Resource Type	Wells/Unit	Acres/Well	Acres/ Generating Unit	Total Acres/Unit
Dry Steam (The Geysers)	15[a]	40[c]	5	605[a]
	35 - 80[b]	20[d]	5	705 - 1,605[b]
Hot water	100	10 - 40	30	1,030 - 4,030
Hot dry rock	11	10 - 40	15	125 - 455

[a]Initial requirement.

[b]Over 30-year lifetime of generating unit.

[c]SOURCE: EPA-600-7-79-0607, U.S. GPO, Washington, D.C., March, 1979

[d]Average density over 30 years; derived from data in: Reed, M.J. and G.E. Campbell, Environmental Impact of Development in The Geysers Geothermal Field, USA, Second UN Symposium on the Development and Use of Geothermal Resources, San Francisco, California, Vol. II, May 20-29, 1975.

Table 4.37

Solid Wastes From Coal-Fired Utilities[c]

	Tons per 10^{12} Btu Output Energy			
	Eastern Coal[a]		Western Coal[b]	
	Without Scrubber	With Lime Scrubber	Without Scrubber	With Lime Scrubber
Bottom Ash	2201.4	2201.4	2441.1	2441.1
Fly Ash	8676.4	8676.4	8735.2	8735.2
Scrubber Sludge	0	15247.0	0	2511.0

[a]Based on a North Central Appalachian coal with a heat content of 11,500 Btu per pound, 2.3 percent sulfur content, and 9.2 percent ash content, and assuming a 34.13% thermal efficiency.
[b]Based on a Western Rocky Mountain Province coal with a heat content of 10,000 Btu per pound, 0.6 percent sulfur content and 7.7 percent ash content, and assuming a 34.13% thermal efficiency.

[c]Source: U.S. Department of Energy, *Environmental Data-Energy Technology Characterization: Coal,* DOE/EV 0061/3, Washington, D.C., January 1980.

Table 4.38

Rates of Solid Waste Generation and Disposal Area Requirements, Utility Sector

Region	Ash (10^6 tons/yr/GW)	Land Required for Ash Disposal (acres/yr/GW)	FGD Sludge, (10^6 tons/yr/GW)	Land Required for Sludge Disposal (acres/yr/GW)
1	0.68	13.08	1.20	45.80
2	0.47	8.94	0.38	14.53
3	1.72	32.76	1.00	38.33
4	2.14	40.92	1.53	54.67
5	1.31	24.98	1.31	49.28
6	1.53	29.21	0.48	18.42
7	1.12	21.34	1.28	48.92
8	1.64	31.40	0.39	15.02
9	1.01	19.21	0.22	8.41
10	2.18	41.59	0.33	12.68

Source: Derived from data given in Le, T., P.M. Meier and H. Tostoker, *National Coal Utilization Assessment, The Soilid Waste Impacts of Increased Coal Utilization,* Brookhaven National Laboratory, Upton, New York, BNL 24786, 1978.

Table 4.39

Area Requirements for Disposal of Solid Wastes from Industrial Fossil Fuel Combustion[a]

Fuel Burned	Solid Waste 10^6 tons (dry) Ash	FGD Sludge	Total	Lifetime Land Requirement, acres
1975				
Coal, 10^{12} Btu	0.004836	0.003160	0.007996	4.589
1990				
Coal, 10^{12} Btu	0.005626	0.003030	0.008656	4.966
Oil, 10^{12} Btu	0	0.003488	0.003488	3.996

[a]These data were derived from Le, T., P.M. Meier and H. Tostoker, *National Coal Utilization Assessment, The Solid Waste Impacts of Increased Coal Utilization,* Brookhaven National Laboratory, Upton, New York, BNL 24786, 1978.

Table 4.40

Calculating Area for Oil Shale Solid Wastes for 50,000 bpd Surface Retorting Facility

	Spent Shale (tons/day)	Acreage of Spent Shale 20′ seam	Acreage of Spent Shale 40′ seam	Acreage of Spent Shale 80′ seam
All mined shale disposed of above ground	360,000	3300 ac./yr.	1700 ac./yr.	800 ac./yr.
70% mined shale of mined shale returned to mine	131,000	1200 ac./yr.	600 ac./yr.	300 ac./yr.

Assumptions:

1.1 tons of spent shale is produced in surface retort per barrel of oil produced.

Compaction of the spent shale produces a material density of 90 pounds per cubic foot.

30% of shale from MIS would be mined.

Sources:

U.S. DOI-FES, "Colony Development Operation, 1978," In: Kevin Markey, *The Costs of Oil Shale,* Friends of the Earth.

Brown, A., et. al, *Water Management in Oil Shale Mining,* Vol. I - main text, U.S. DOC, PB 276 085, 1977.

Table 4.41

Oil Shale Solid Wastes Produced by the Colony Development Operation at Grand Valley, Colorado

Source of Solid Waste	Annual Production (tons)	Major Constituent
Pyrolysis unit		
Processed shale	19,418,000	Processed shale
Clarifier sludge from wet scrubbers-preheat system	313,900	Raw shale dust
Ball circulation system	23,725	Processed shale dust
Processed shale moisturizing system	15,695	Processed shale dust
Crushing unit		
Primary crusher	9,152	Raw shale dust
Final crusher	118,625	Raw shale dust
Shale storage silo	27,375	Raw shale dust
Upgrading units (hydrotreaters)		
Naphtha	75	Spent HDN catalyst
Naphtha	60-80	Proprietary solid
Gas oil	230	Spent HDN catalyst
Gas oil	300-500	Proprietary solid
Hydrogen unit		
Hydrodesulfurizer	18.3	Spent HDS catalyst
Guard bed	6.7	Spent ZnS catalyst
Shift converter (High temperature)	10	Spent Fe-Cr catalyst
Shift converter (Low temperature)	16.7	Spent Cu-Zn catalyst
Sulfur unit		
Claus unit	80	Spent alumina catalyst
Gas treating unit		
DEA filter	214.5	Diatomaceous earth
DEA filter	214.5	Deactivated carbon
Coker unit	292,000	Green coke
Water Treatment	219	Lime and alum flocculants
	9	Proprietary coagulant aid

Source: *Surface Mining of Non-Coal Minerals,* "Appendix II: Mining and Processing of Oil Shale and Tar Sands," National Academy of Sciences, 1980.

5. Glossary

Acre-foot: the quantity of water required to cover 1 acre to a depth of 1 foot; equal to 432,560 cubic feet or 325,851 gallons.

Air quality standards: the prescribed level of pollutants in the outside air that cannot be exceeded legally during a specified time in a specified geographical area.

Alluvial valley floors: unconsolidated, stream-laid deposits with water availability suffi cient for subirrigation or flood irrigational activities.

Appropriation doctrine: the system of water law adopted by (and dominant in) most western states. The basic tenets of the appropriation doctrine are (1) that a water right can be acquired only by diverting the water from a watercourse and applying it to a beneficial use and (2) in accordance with the date of acquisition, an earlier acquired water right shall have priority over other later acquired rights. The first in time of beneficial use is the first in right, and the right is maintained only by use. Water in excess of that needed to satisfy existing rights is viewed as unappropriated water, available for appropriation by diversion and application to a beneficial use. (See riparian doctrine.)

AQMA: air quality maintenance areas set up by SIPs to prevent significant deterioration of a given area.

Aquifer: a saturated underground body of rock or similar material capable of storing water and transmitting it to wells or springs.

Barrel (oil): a volumetric unit of measurement equivalent to 42 U.S. Standard gallons.

bbl/d: barrels per day.

bcf: billion cubic feet.

Best available control technology: the most advanced control technology that can be used for new sources of pollution. Required for nonattainment regions by the Clean Air Act.

Best known technology: for water pollution control is a shorthand term to describe those techniques and methods known by the NWC staff to be under consideration in the spring of 1972 when the Commission's estimates of cost of various pollution control measures were prepared. Does not necessarily bear any relationship to the term "best available technology" as used in the Federal Water Pollution Control Act Amendments of 1972.

Biota: the flora and fauna of a region.

BLM: Bureau of Land Management, a federal agency.

bpd: barrels per day.

British thermal unit (Btu): the amount of heat required to raise the temperature of 1 pound of water 1 degree F at its point of maximum density.

b/sd: barrels per stream-day.

CEQ: U.S. Council on Environmental Quality, established by NEPA.

Class I: for air quaility, a "pristine" area allotted minimal PSD increments.

Class II: for air quality, an area with PSD increments sufficient for moderate industrial growth.

Class III: for air quality, an area with PSD increments allowing maximum growth.

Coastal zone: as defined by the Coastal Zone Management Act of 1972, PL 92-583, coastal waters, land under waters, and adjacent shoreland, islands, and transitional areas of the participating states; for Great Lake states, extends to Canadian border; for other states, seaward to outer limits of U.S. territorial water; extends landward as necessary to control shorelands.

Carbon monoxide (CO): a colorless, odorless, highly toxic gas that is a normal byproduct of incomplete fossil fuel combustion. CO, one of the major air pollutants, can be harmful in small amounts if breathed over a certain period of time.

CZMA: Coastal Zone Management Act.

DOE: Department of Energy, a federal agency.

DOI: Department of the Interior, a federal agency.

dwt: deadweight ton.

Effluent: a discharge from a pollution source that is relatively self-contained, generally referred to in regard to discharges into waters but can also mean discharges into air.

Environmental impact statement (EIS): a detailed statement setting forth the environmental effects and considerations anticipated by a proposed action, policy or project which has been determined to be a "major federal action significantly affecting the environment" under the provisions of the National Environmental Policy Act.

Eminent Domain: a right of a government to take private property for public use by virtue of the superior dominion of the sovereign power over all lands within its jurisdiction.

Emission standard: the maximum amount of a pollutant legally permitted to be discharged from a single source, either mobile or stationary.

Endangered: any species, sub-species, or sub-population of animal which is threatened with extinction resulting from very low or declining numbers, alteration and/or reduction of habitat, detrimental environmental changes, or any combination of the above. Continued survival in this state is unlikely without implementation of special measures.

EPA: Environmental Protection Agency, a federal agency.

Exclusionary zone: designated by the Nuclear Regulatory Commission on site-specific basis; area surrounding a nuclear reactor for which plans on evacutation of all personnel in event of an emergency must be submitted.

FGD: flue gas desulfurization.

Floodplain: as defined by Executive Order 11988, lowland and relatively flat areas adjoining inland and coastal waters, including offshore islands, subject to a one percent or greater chance of flooding in a given year.

FLPMA: Federal Lands Policy Management Act.

Flue gas: gas resulting from combustion of a fuel.

Fly ash: fine, solid particles of noncombustible material residue carried from a bed of solid fuel by combustion gas.

Gasification of coal: the conversion of solid coal into a gaseous form by various chemical reactions with steam, a synthetic fuels technology.

Hazardous waste: as defined by the Resource Conservation and Recovery Act of 1976, PL 89-272, a solid waste or combination of solid wastes which, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (1) cause, or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

Hydrocarbons (HC): a type of air pollution including organic acids, aldehydes, unsaturated hydrocarbons, and aromatics.

Head-of-hollow fills: filling of a small indentations in land contour; the top surface of the fill, when computed, is at approximately the same elevation as the adjacent ridge line and no significant drainage occurs into the fill area.

Hydrogen sulfide (H_2S): a type of air pollution.

Kerogen: the organic oil-yielding material present in oil shales. It is not a definite compound but a complex mixture varying from one shale to another.

Kilowatt-hour (kWh): the amount of energy equal to 1 kilowatt for 1 hour. It is equivalent to 3,412 Btu.

Light water reactor (LWR): reactor using ordinary water as a coolant instead of heavy water.

Liquefication of coal: the conversion of solid coal into condensed aromatic liquids by thermal fracture of carbon-carbon and carbon-oxygen bonds, a synthetic fuels technology.

Long-wall mining: the ore seam is removed in one operation along a working face that may be several hundred yards long. The mine roof collapses as the working face advances through the ore body.

mmcf: million cubic feet.

Modified in-situ: a portion of oil shale is mined, remainder is fractured with explosives to create a highly permeable zone through which hot liquids can be circulated.

NAAQS: National Ambient Air Quality Standards prescribed in the Clean Air Act Amendments of 1977, Pl 95-95.

NEPA: National Environmental Policy Act (1969).

NFS: National Forest Service, a federal agency.

Nonattainment areas: areas which contain more sulfure dioxide, particulates, nitrogen dioxide, oxides, carbon monoxide, and oxidants than the NAAQS prescribe. These areas are managed by SIPs.

NO_x: either nitrogen dioxide or nitrogen oxide, also referred to as nitric oxides.

NSPS: New Source Performance Standards limiting all new sources of pollution and set by SIPs.

NRC: Nuclear Regulatory Commission, a federal agency.

OCS: Outer Continental Shelf.

Oil shale: a sedimentary rock containing solid organic matter from which oil can be obtained when the rock is heated to a high temperature.

Once-through process: the withdrawal of water from a water body for use in cooling or processing and subsequent return of that water, usually at a higher temperature or other altered condition, into the same body of water from which it came. Contrasts with water recycling processes.

Overburden: material of any nature which overlies a coal deposit, excluding topsoil.

O_x: total oxidants.

Particulate: liquid or solid material in the air, either organic or inorganic, including dust, fly ash, dirt, smoke, soot, and metallic fume.

PSD: prevention of significant deterioration.

PSD increments: in those areas where air is cleaner than the NAAQS, additional air pollutants are limited to specified amounts (PSD increments) of TSP and sulfur dioxide, calculated relative to a baseline air quality, managed by SIPs.

Rad: radiation absorbed dose, the basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.

Radwaste: radioactive waste; liquid, solid, or gaseous waste resulting from mining of radioactive ore, production of reactor fuel materials, reactor operation, processing of irradiated reactor fuels, and related operations, and from use of radioactive materials in research, industry, and medicine.

RARE II: Roadless Areas Review and Evaluation, Survey II, conducted by the NFS for areas over 5,000 acres that may warrant preservation as wilderness areas.

RCRA: Resource Conservation and Recovery Act.

Reclamation: as defined by the Department of Interior's Office of Surface Mining and Reclamation Enforcement, actions taken to restore mine land to a postmining use as approved by the regulatory authority.

Retorting: raw oil shale is heated to obtain crude shale oil.

Riparian doctrine: the system of water law historically recognized by the eastern states. The riparian doctrine protects landowners adjacent to lakes and streams from withdrawals or uses that unreasonably diminish water quantitiy or quality. Under the riparian doctrine, individuals have the right to make reasonable use of the stream waters flowing by lands they own so long as the use does not substantially diminish either the quantity or the quality of the water passing to landowners downstream. Where diversions or uses have been unreasonable, they either have been enjoined or riparian owners adversely affected have been compensated for interference with their rights. (See appropriation doctrine.)

Room-and-pillar mining: some material (e.g., coal, shale) is removed to form large rooms, and some is left in place, as pillars to support the mining roof.

SCS: Soil Conservation Service, a federal agency.

SIP: State Implementation Plan for prevention of significant air quality deterioration as required by the Clean Air Act Amendments of 1977 (PL 95-95).

SMCRA: Surface Mining Control and Reclamation Act.

Sole source aquifer: as regulated by EPA in implementing the Safe Drinking Water Act, PL 93-523, a sole or principal drinking water source which, if contaminated, would create a significant hazard to public health.

Solution mining: the extraction of soluble minerals from subsurface strata by injection of fluids, and the controlled removal of mineral-laden solutions.

SO_2: sulfur dioxide, a heavy, pungent, colorless gas formed primarily by the combustion of fossil fuels. SO_2 damages the respiratory tract as well as vegetation and materials and is considered a major air pollutant.

SO_3: sulfur trioxide, a form of air pollution.

SO_x: sulfur oxides; either sulfur dioxide or sulfur trioxide.

Standard Metropolitan Statistical Area (SMSA): an integrated economic and social unit with a large population nucleus. There are over 245 SMSAs in the United States.

tcf: trillion cubic feet.

Threatened species: any species or subspecies of wildlife not in immediate jeopardy of extinction, by vulnerable because it exists in such small numbers or is so extremely restricted throughout all or a significant portion of its range that it may become endangered.

TSP: total suspended particulates.

Wetlands: as defined by Executive Order 11990, areas inundated by surface or ground water with a frequency to support vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction.

USDA: Department of Agriculture, a federal agency.

USGS: United States Geological Survey, a federal agency.

U_3O_8: uranium oxide, the international standard for the form in which uranium concentrate is marketed.

Uranium: a metallic element, highly toxic and radioactive, which ignites spontaneously in air and reacts with nearly all nonmetals; used in nuclear fuel and as the source of U-235 and plutonium.

Yellowcake: product of uranium mills that is 90 percent uranium oxide; one ton of ore produces four pounds of yellowcake.

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