A Technology Assessment of Coal Slurry Pipelines

March 1978

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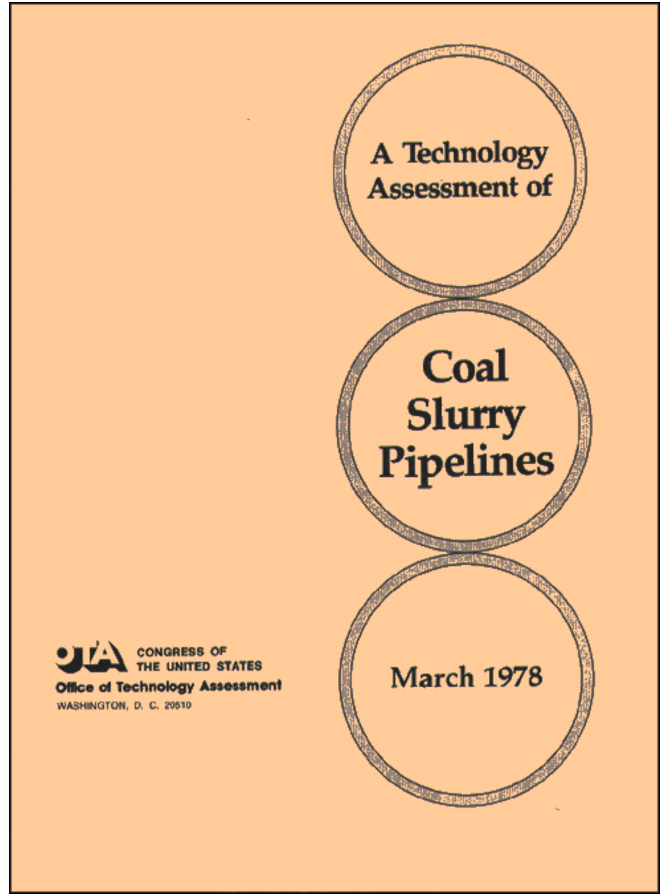
A Technology Assessment of

Coal Slurry Pipelines

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CONGRESS OF THE UNITED STATES
Office of Technology Assessment
WASHINGTON, D. C. 20510

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Congress of the United States
OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, D.C. 20510

March 2, 1978

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U.S. House of Representatives
Washington, DC 20515

Honorable Warren G. Magnuson
Chairman, Committee on Commerce,
Science and Transportation
United States Senate
Washington, DC 20510

Gentlemen:

On behalf of the Board of the Office of Technology Assessment, we are pleased to forward the results of the assessment of coal slurry pipelines requested by your committees.

This assessment will aid in congressional deliberation over proposed coal slurry pipeline legislation, and we hope it will contribute to resolving larger questions of transportation policy, water resource allocation, and social costs and benefits of energy development.

Sincerely,

Edward M. Kennedy
Chairman

Sincerely,

Larry Winn, Jr.
Vice Chairman

Enclosure

Foreword

This assessment analyzes the costs and potential economic, social, and environmental impacts of coal slurry pipelines, and it represents the results of a project undertaken in mid-1976 at the request of the Senate Committee on Energy and Natural Resources; the Senate Committee on Commerce, Science, and Transportation; and the House Committee on Interstate and Foreign Commerce. In addition to aiding in congressional deliberation on several bills that propose granting Federal eminent domain to coal slurry pipeline enterprises, the study should contribute to resolving broader questions of transportation policy, western water allocation, and regional conflicts over energy development.

The pages that follow include a discussion of the possible effects on society of coal slurry pipeline development, a comparison of pipeline and unit train costs, and an analysis of relevant legal and regulatory issues. Findings address conditions under which slurry pipelines may be attractive in terms of cost and the influence of transportation regulatory policy. Also evaluated are the potential impacts of Slurry pipeline development on the rail industry, consequences of pipeline water use as contrasted with community impacts of increased coal train traffic, and implications of the power of eminent domain at the Federal, as opposed to State, level.

This report is another in the series of energy assessments that are being provided to the Congress for its consideration in the development of national energy policy.

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NOTE The Advisory Panel provided advice, critique, and assistance throughout this assessment, for which the OTA staff IS deeply grateful The Advisory Panel, however, does not necessarily approve, disapprove, or endorse all aspects of this report OTA assumes full responsibility for the report and the accuracy of Its content

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L Summary

1. Summary

Considerable public controversy currently surrounds legislative proposals at both the Federal and State levels that would grant the power of eminent domain for right-of-way acquisition to coal slurry pipeline enterprises and impose certain restrictions and requirements upon their activities. Against this background, the Chairmen of the Senate Committee on Energy and Natural Resources, the Senate Committee on Commerce, Science, and Transportation, and the House Committee on Interstate and Foreign Commerce, requested this assessment of the potential economic, environmental, and social implications of coal slurry pipeline development. The analysis presented here is intended to contribute to the information available to Congress on which to base any determination concerning Federal eminent domain legislation for coal slurry pipelines, and to provide an analytical framework against which a public agency might evaluate the potential effects on the economy, society, and environment of specific individual pipeline proposals and their alternatives.

Four interrelated studies provide a basis for systematically evaluating the transport of coal by pipeline compared to railroad. The first establishes hypothetical baseline forecasts to the year 2000 of volumes of utility steam coal to be transported from nine producing regions to each consuming State based on demand growth, environmental regulation, and coal-use assumptions. The second study provides rail and pipeline cost estimates and plausible market scenarios, which have been used to predict the possible impact of slurry pipeline development on the total social cost of electric power, the cost and quality of service in the railroad industry, employment levels, and other economic measures. A third investigation identifies and evaluates the water resource, environmental and social impacts of transporting hypothetical quantities of coal by pipeline as contrasted with the corresponding effects of moving the same amounts by rail. The fourth examines the legal and regulatory provisions relevant to rail and pipeline competition, water rights, environmental protection, and eminent domain. Finally, the coal volume forecasts have been subjected to a sensitivity analysis to determine what effect the findings of the economic study might have on the original projections.

Major findings of the assessment are summarized below. They should be read with the understanding that they are based upon simplifying assumptions and considerable speculation about the future.

- Based on the analysis performed in this assessment, coal slurry pipelines do represent under some specific circumstances the least costly available means for transporting coal measured in economic terms. Whether this is true of any particular pipeline can only be determined by detailed evaluation of the conditions specific to the route.
- The current regulatory framework does not guarantee that choices between slurry pipelines and rail will necessarily minimize the cost to society of transporting coal. With the power of eminent domain, coal pipelines would enjoy significant regulatory advantages over railroads. These advantages would stem from the differences between regulated tariffs and cost of service, the ability of pipelines to serve selected customers, and the prohibition of long-term contracts between railroads and their shippers.
- The development of a substantial slurry pipeline industry is likely to diminish the growth in future revenues of competing railroads, primarily in the West, unless rates paid by remaining shippers are adjusted to compensate. However, average

rail tariffs, adjusted for inflation, are declining and are likely to continue to do so for the next 20 years based on the market and cost assumptions of the analysis. Even if railroads were to respond to pipeline competition by modifying their rate structure to preserve the net income they would otherwise have realized without pipelines, the rate of decline in tariffs would be lessened but not reversed.

- The introduction of coal slurry pipelines is not likely to affect materially the rate of coal resource development and use on a national scale. It may, however, affect the regional pattern of coal mining and distribution in such a way as to expand the use of western coal to greater distances from this area of origin.
- Pipelines employ less labor than does rail over their respective useful lives, but if a substantial pipelines industry were to develop, enough people would probably be employed in construction and supplying industries to offset cumulative employment impacts in the rail industry for the rest of the century. Since railroad employment may decline due to productivity improvements before the year 1990 in any event, job losses due to pipeline competition could contribute to layoffs as opposed to reduced rates of hiring in the railroad industry during that period. In addition, agriculture may be affected locally by future water availability impacts of slurry pipelines, as well as by the cost and quality of service by railroads. Railroads can also have direct adverse impacts on agriculture in the form of possible disruption of ranching operations.
- Sufficient unused quantities of suitable water are physically present although not necessarily legally available for the operation of several slurry pipelines from western coal-producing areas. Substantial institutional barriers impede in voluntary displacement of present water rights, but other possible future uses of remaining supplies could be foreclosed by pipeline development. When levels of use exceed users' rights, as is the case during years of relative abundance of water, new appropriations may also displace present uses.
- Under the prior appropriation system for water allocation in many Western States, slurry pipelines, like any new applications of water, are accorded a lower priority relative to existing rights. They therefore may not be able to acquire water even if they were to represent a more economically productive use. The Federal Government has substantial power to control water resource allocation for pipelines, notwithstanding State provisions, if it should choose to exercise it. Even without an explicit choice to exercise that power, Federal certification of a pipeline project based on a finding that it served the public interest could supersede State water allocation authority under some circumstances.
- The environmental choice between coal pipelines as opposed to increased rail traffic primarily involves weighing the water use and temporary construction activity impacts of slurry pipelines against the noise, land-use disruption, railroad crossing accidents, and inconvenience resulting from increased train traffic. All other impacts examined are relatively insignificant or roughly equivalent for both modes.
- Several Federal statutes serve to protect the environment against potential adverse impacts of both railroads and pipelines, as do a variety of Federal and State laws and programs designed to improve safety at rail-highway grade crossings, usually in part at public expense. Federal environmental impact statements, however, are generally not required for increases in rail traffic, as opposed to extensions in routes. They are also not necessarily required for slurry pipeline construction, since building such a pipeline is possible at present without major Federal action. Usually, however, Federal or State environmental statements will be necessary

for pipelines, especially if Federal certification is required as a condition for the power of eminent domain.

- Not all States have statutes granting the power of eminent domain to slurry pipelines. Those that do require that the pipelines serve a public purpose within the State, and more recent statutes limit use of State water for pipelines and subject them to State regulation as common carriers.

- The development of a coal slurry pipeline industry would be possible in the absence of the power of eminent domain at the Federal level. All other pipeline systems except natural gas were built largely with State eminent domain authority. On the other hand, Federal legislation in this area would facilitate coal slurry pipeline development by removing the need to direct routes, possibly at prohibitive cost, around States without eminent domain provisions, and by eliminating the requirement that the public in each State along a pipeline route benefit from the operation. Federal preemption, however, would limit States' powers to influence the form of Slurry pipeline development.

A judgment concerning the desirability of slurry pipelines as a form of coal transportation will depend on the subjective weights that one assigns to the factors discussed above. The overall issue, however, extends beyond the question of whether coal slurry pipeline development by itself would have a favorable impact on society. The judgment will therefore also depend on one's views concerning broader problems, of which the coal slurry pipeline controversy is only one aspect, These include: 1) the current railroad regulatory structure, 2) the present systems for allocating water resources in the West, and 3) the availability of mechanisms by which conflicting regional differences over energy development can be reconciled.

In the absence of eminent domain provisions at the Federal or State level, coal slurry pipelines are less likely than otherwise to compete successfully with established railroads. On the other hand, if Federal eminent domain legislation were passed without provisions for equalizing the regulatory restrictions on each mode, pipelines would enjoy significant advantages over railroads. One lies in the interstate Commerce Commission's prohibition of long-term contracts with shippers in the rail industry. Such contracts, if permitted, could facilitate investment in specific improvements to provide more economical service when a shipper is willing to be bound by rate and volume provisions in return. Financing of pipeline enterprises would not be possible without long-term contractual arrangements, probably containing escalation clauses to cover unforeseen cost increases. Also, common carrier obligations of railroads to provide uneconomical service are probably more stringent than they would be for coal slurry pipelines. Although the situation may change as a result of the Rail Revitalization and Regulatory Reform Act, the allowed return on rail investment is lower than what is permitted for pipelines now carrying other commodities. In this context, however, slurry pipelines simply represent another competing mode of transportation to be considered in the larger debate concerning the merits of regulatory reform for the railroad industry.

The second larger question is related to the allocation of western water resources among competing uses. If everyone agreed that the present institutional mechanisms always led to the best choices, a significant area of contention would be absent from the controversy over coal slurry pipelines and over many other forms of energy resource development as well. Mine-mouth power generation and coal gasification and liquefaction, for example, require even more water than do slurry pipelines to process a given amount of coal. Some residents of western coal-producing States therefore see expansion of this type of activity as a potential threat to their limited water supplies. The prior appropriation system of water rights, on the other hand, subordinates new uses to present ones, making water acquisition for energy development difficult. Improving the process by which water-use priorities are established could therefore eliminate some of the conflict over slurry pipelines.

Finally, other elements of the dispute over coal slurry pipelines reflect conflicting regional interests regarding coal development generally. Producing areas are expected to suffer adverse impacts, like the inconvenience associated with expanded train traffic or increased competition for water, while the benefits accrue to other parts of the Nation in the form of lower electric rates or reduced dependence on gas or oil. In this respect, coal slurry pipelines represent only one of the many factors in the balance Congress must strike as it fashions future energy legislation.

II. Introduction

IL Introduction

President Kennedy suggested in early 1962 that coal slurry pipelines might represent a way of transporting coal more economically, thereby improving the depressed condition of the coal mining industry. Since that time, a substantial measure of public debate has centered on the desirability of applying this technology as an alternative to transportation by rail. Two such pipelines have been built and put into operation in this country. One was closed after the introduction of competing unit trains and the approval by the Interstate Commerce Commission (ICC) of a separate rate structure for this more efficient form of rail service. Another has been carrying coal for 6 years and has demonstrated that a coal slurry pipeline of the size required to serve a large electric generating station is economically feasible.

A slurry pipeline involves the pumping of finely ground coal suspended in water or other liquid medium through a pipe over a long distance. At the terminus the coal and liquid are separated and the coal is prepared for combustion or other use. The primary rail competitor of slurry pipelines is the unit train, a complete train of dedicated cars operating on a regularly scheduled movement between a single origin and a single destination. It contrasts with ordinary carload movements in which many commodities are combined and recombined in one train as they are transported from many origins to many destinations.

Most of the current public controversy surrounds legislative proposals at both the Federal and State levels to grant the power of eminent domain for right-of-way acquisition to coal slurry pipeline enterprises and to impose certain restrictions and requirements upon their activities. Against this background the Chairmen of the Senate Committee on Energy and National Resources, the Senate Committee on Commerce, Science, and Transportation, and the House Committee on Interstate and Foreign Commerce requested this assessment of the potential economic, environmental, and social implication of coal slurry pipeline development and the implications of legislating Federal eminent domain authority.

At least three major sets of policy questions must be addressed to arrive at a legislative conclusion. The first involves the desirability from social, economic, and environmental standpoints of developing a coal slurry pipeline industry. The second is related to the extent to which the present regulatory and institutional arrangements would have to be altered to provide for the allocation of coal traffic between pipelines and railroads in a way that would represent the least cost to society. The third concerns the balance of Federal and State control over such areas as water resource allocation, land ownership, and local environments, and how conflicting regional interests might be resolved.

The purpose of this assessment is to clarify these issues in order to assist Congress in making a judgment concerning the general desirability of coal slurry pipelines and the utility of eminent domain legislation as a means of facilitating their development. The study should also provide an analytical framework against which a public licensing or regulatory agency might evaluate specific individual pipeline proposals and their alternatives.

Resolution of the foregoing questions and development of an analytical framework for evaluating specific pipeline projects require a comparison analysis of the costs, impacts, and institutional and legal setting of the two modes. The desirability of mining, transporting, and using coal is not addressed here. A forthcoming OTA study on coal utilization will examine many of these questions. In addition, modes with which long distance slurry pipelines would not be likely to compete significantly, including trucks, belt conveyors, and barges have not been considered in detail. Finally, the transportation market in this analysis is confined to steam coal for use by domestic electric utilities, which constitute the principal customers that could receive large enough volumes of slurry coal for economical pipeline operation.

Four interrelated studies contributed to the analysis. One examined the legal regulatory provisions relevant to rail and pipeline competition, water rights, environmental protection, and eminent domain. Another established baseline forecasts to the year 2000 of volumes of utility steam coal to be transported from nine producing regions to each consuming State based on hypothetical demand growth, environmental regulation, and coal-use assumptions. A third study provided rail and pipeline cost estimates and plausible traffic scenarios, which were examined to predict the impact of slurry pipeline development on the cost of electric power, the cost and quality of service in the railroad industry, employment levels, and other economic measures. A fourth investigation identified and evaluated the water resource, environmental and social impacts of transporting hypothetical quantities of coal by pipeline as contrasted with the corresponding effects of moving the same amounts by rail. Finally, the coal volume forecasts were subjected to a sensitivity analysis to determine what effect the findings of the economic study might have on the original projections. Complete reports on these individual studies comprise the second volume of this report.

In the legal and regulatory study, the existing legal systems, including relevant statutes, regulatory policies, and judicial precedents, were discussed with particular attention to contrasting the framework for coal slurry pipelines with the regulatory environment for other similar or competing transportation modes. Issues examined included the implications of common carrier status, rate setting, and contractual arrangements between carriers and shippers. In addition, provisions of water law were explored to determine what access a pipeline operator would have to water sources under a variety of conditions and how much control could be exercised over the use of water for slurry pipeline purposes by State agencies as opposed to the Federal Government. Provisions of environmental law related to pipeline and rail construction and operation were also investigated, as were precedents for and implications of granting the power of eminent domain for acquisition of transportation right-of-way at the Federal and State level.

Assessing the potential economic and environmental consequences of coal slurry pipeline development necessitated forecasting the coal transportation market in which coal pipelines would compete. Although large industrial facilities, gasification plants, and foreign countries represent possible future customers for slurry coal, this assessment concentrated on coal for steam production by domestic electric utilities, since they represent the predominant present users which could receive coal in quantities that would take advantage of pipeline economies, A model of utility industry behavior at the powerplant level provided estimates of how much coal would be purchased from what sources to meet both hypothetical demand growth and environmental requirements at the lowest cost. These results were aggregated to arrive at total projected coal flows from nine producing regions to 48 consuming States at 5-year intervals through the year 2000.

With this measure of demand for transportation as a starting point, the economic analysis sought to establish relative cost relationships for railroads and pipelines and to hypothesize a plausible share of the traffic which pipelines might capture if their development were not constrained by institutional or legal factors. Potential savings to customers served by pipelines could then be estimated, as well as the impacts of diverting the traffic in question from the railroad industry. The impacts of pipeline development were evaluated as they would affect the cost and quality of rail service, availability of water for other uses, demands on related industries and markets, levels of employment, and regional economic development. Simplifying assumptions were necessary to carry out the market, cost, and impact analyses. Those related to markets and costs are summarized at the end of chapter IV. The impact analysis also depends on major assumptions, detailed in chapter V and in the appendix, including an approximately 2.9 percent annual rate of growth in both rail revenue traffic and GNP, as well as continuation of present trends in some elements of rail costs.

To complement the economic analysis, a simultaneous study encompassed the environmental impacts of constructing and operating coal pipelines, as contrasted with the corresponding effects of moving the same volumes of coal by railroad. With regard to pipelines, particular attention was focused on water use and disposal and construction impacts. Principal impacts unique to railroads included traffic accidents and interruption at grade crossings, train-caused fires, diesel emissions, and land-use interference. Energy and materials use, occupational health and safety, and social impacts and perceptions were explored for both modes.

The coal-flow forecasting model mentioned earlier embodied preliminary assumptions about the cost of transportation, and additional analysis was therefore necessary to determine what effect findings from the economic analysis related to rail and pipeline costs might have on the coal transportation demand projections. This later work also incorporated some improvements in the model and included data from the President's National Energy Plan, which became available after the first set of coal flows were derived.

In order to facilitate consideration of legislative options, a number of specific policy issues are identified and analyzed. These comprise the subject of the third chapter. Chapter IV includes descriptions of coal slurry pipelines and unit trains followed by the coal flow forecasts, cost comparisons, and traffic assumptions on which the economic and environmental analyses are based. Economic impacts are treated in chapter V and the appendix, and chapter VI covers environmental and social impacts. The last chapter contains the results of the legal and regulatory analysis. As mentioned above, Volume I I consists of complete reports on the research results contributing to the assessment.

A predominately technical analysis such as this one takes inadequate account of human perceptions of, and attitudes toward, the facts presented. Ultimately, the impacts of technology are, directly or indirectly, impacts on people. Opportunities for citizen participation and public comment based on this material would contribute an important perspective.

III. Issues and Findings

III. Issues and Findings

The request to OTA for an assessment of coal slurry pipelines is a consequence of proposed legislation which would grant such pipelines Federal eminent domain powers. This question and the controversy surrounding this proposal presuppose certain more basic policy issues. Should the Federal Government adopt a policy of facilitating the development of coal slurry pipelines? Does the present regulatory and institutional environment encourage the allocation of coal traffic on the basis of the true cost to society? If not, should steps be taken to try to achieve that result? Is such a policy compatible with an effort to protect State jurisdiction over matters such as water resource allocation, land ownership, and local environmental quality? The following specific issues and findings were formulated to elucidate these underlying policy questions as well as the more specific legislative issue of eminent domain.

In much of this analysis, the critical questions often extend beyond slurry pipeline development as an issue unto itself. These questions are also not new. For example, the effect of the regulatory environment on the ability of railroads to compete with pipelines is only a part of a larger problem concerning the way in which railroads are regulated generally. Also, potential water use by slurry pipelines is controversial partly because water resources in arid portions of the West are managed arguably neither by a completely rational and explicit planning process nor by the usual market mechanism which applies to other natural resources. Finally, some of the differences of opinion over slurry pipelines are reflections of regional conflicts over energy development generally. Hopefully, this assessment will contribute some to the resolution of these larger questions, as well as the specific issues related to the coal slurry pipeline debate.

Issue 1

Do slurry pipelines represent a less costly way to move coal?

If one ignores regulatory distortions and larger social costs, slurry pipelines can, according to this analysis, transport coal more economically than can other modes under certain circumstances. The following conditions tend to favor pipelines on any particular route:

- High annual volumes of coal shipped.
- Long distances to be traversed.
- High anticipated rates of inflation.
- Low real interest rates.
- Large closely spaced mines.
- A secure market of several large customers located in such a way as to permit them to receive coal from a single pipeline.
- Terrain characteristics favorable to pipeline excavation and construction.
- Availability of sufficient water at low delivered cost.
- Low cost of electric power for pipeline pumping relative to that of diesel fuel for railroad locomotives.
- Circuitous rail routes, poor track, or other conditions unfavorable to railroads.
- Inefficient rail operations, including short or slow trains.
- Absence of a parallel navigable waterway.

The choice of pipeline transportation over rail represents in part a decision to incur capital costs, which can be amortized at a predictable rate, rather than operating costs, which are subject to inflation. This common business decision involves weighing the real interest rate one must pay on invested capital against the uncertain inflation component of future operating expenses. Comparisons of rail and pipeline economics in this analysis are based on total life cycle costs, and they take the greater exposure of rail expenses to inflation into account. However, managers of electric utilities, which represent potential customers for slurry pipelines, perceive an advantage in greater stability as well as lower overall levels in transportation tariffs.

The necessity to predict future construction costs, labor productivity, and inflation rates adds a major element of uncertainty to the relative costs of the two modes. In fact, the range of uncertainty associated with predictions of rail and pipeline costs in a given case is often as great as the difference between them. Pipeline financing requires long-term purchase contracts with customers, which embody significant risk given the difficulty in forecasting the future. Since the costs of errors in judgment will probably be borne largely by the public and not necessarily by the utility investors, regulatory agencies governing utilities should therefore scrutinize long-term contracts for pipeline transportation with great care.

If pipeline economics do result in savings, the benefit will accrue to the coal mining, electric utility, and pipeline industries. Regulatory mechanisms can cause savings in the transportation and utility sectors to be passed on to consumers. The mining industry is not similarly constrained by regulation, but competition may limit increases in mining revenues.

Since economic conditions favoring pipelines or railroads are present to varying degrees at different times and locations, and since the determination of cost advantages entails considerable speculation about the future, Congress therefore faces the challenge of formulating legislation sufficiently flexible to allow choices to be made which suit specific conditions. (For further discussion of costs, see *Coal Transportation Market,* chapter IV.)

Issue 2

To what extent does the regulatory structure surrounding each mode influence the apparent relative economic attractiveness of railroads and slurry pipelines?

Common carrier status and Interstate Commerce Commission (ICC) rate regulation place railroads at a disadvantage relative to less stringently regulated pipelines. Even if pipelines were required to be common carriers in name and subjected to the Interstate Commerce Act (ICA), they would still behave like contract carriers in practice due to the practical requirements imposed by the economics and mechanics of their operation. This has three consequences.

First, pipelines could capture coal traffic from railroads even where the incremental rail cost is lower. Rail rates contain an element of fixed system costs and losses which result from the requirement to maintain certain unprofitable services, e.g., low-volume branch lines. This creates a distortion in relative rates, permitting selection of pipeline transportation in some cases where rail represents a lesser cost to society.

Second, rate regulation which does not allow a “market” return on direct rail investment will not permit facility improvements that would reduce total costs. “Real” costs as estimated in this study are not as low as those that railroads could achieve with an improved ability to attract needed investment.

Third, prohibitions against long-term contracts with shippers impede railroads from undertaking otherwise economical investments that would only pay for themselves over a period of time.

Pipelines do not have the same fixed cost structure or obligation to continue unprofitable service, except as provided in contracts. Moreover, pipeline rate regulation would probably provide for a return on investment substantially higher than ICC has historically allowed on direct rail investment, as exemplified by the recent San Antonio Rate Case (Docket #36180). (This ’issue is discussed more fully in chapter VI 1.)

Issue 3

Will development of coal slurry pipelines adversely affect the health of

the railroad industry in such a way as to jeopardize the quality or cost of service to remaining shippers?

Under an assumption that pipelines carry a share of coal traffic increasing to approximately 200 million tons per year by the end of the century, western railroads will experience slower increases in coal revenues than they would otherwise have expected. Although any reduction in revenue could represent a threat to the financial health of a particular railroad, the potential impact of coal slurry pipelines on the railroad industry appears to be substantially less than that of either a possible adverse regulatory policy or a decline in the present rate of improvement in productivity.

The likely effect on railroad customers will depend upon several conditions. The analysis performed in this assessment suggests that average rail road costs decline as the system expands to provide new service. If such is the case, the critical questions are a) whether or not the railroads would pass on these savings to other shippers, and b) how large the savings would be if pipelines did not enter the market. If savings are not passed on to rail shippers, slurry pipeline competition will affect the profitability of the rail industry and possibly the quality of service it provides, but not the rates paid by its customers.

Under current regulations, however, rail cost savings will probably accrue, at least in part, to shippers through reduced rates of growth in tariffs relative to general inflation. The most probable effect on rail customers from pipeline competition will, therefore, be a lessening of the present rate of decline in average tariffs per ton-mile adjusted for inflation.

Shippers faced with higher relative rail tariffs might adapt by switching to another mode of transportation. As a consequence, rate impacts will probably be felt more strongly by captive rail customers. Also, such changes in transportation mode are not certain to reduce total social costs.

The foregoing discussion presumes that pipeline development would occur gradually and would involve only new coal movements and not those already carried by rail. Rapid diversion of rail traffic after substantial resources have been invested to expand service would clearly have an additional adverse impact on the rail industry.

Finally, some argue that more competition would promote increased productivity and technological improvement in the rail industry. The magnitude of this effect depends on the level of competitive forces already present and on the incentives built into the regulatory structure. Added competition may also influence investor confidence in railroad enterprises, making capital formation to implement improvements more difficult. (Chapter V focuses largely on this issue.)

Issue 4

Will capacity limitation of other modes necessitate the development of coal slurry pipelines to carry projected coal volumes?

The capacity of rail systems can be expanded faster than can coal mining or electric power generation using coal, provided the necessary investments in local rail facilities are made. The same is true of slurry pipelines. Supplier industries and capital markets are adequate to meet the development needs of either mode, although, continued low net incomes in the rail industry may impede the capital formation needed to finance rail expansion.

The choice between transportation modes will not be determined by their respective capacity limitations. Sufficient investment in either can keep transportation capabilities abreast of foreseeable needs. The real question is which type of investment (rail or pipeline) makes the most sense economically, socially, and environmentally. Similarly, the amount of coal to be mined and consumed on a national scale will not be affected as much by transportation capacity or cost, especially in the West, as by the environmental and social costs of large-scale mining and combustion, the expense associated with converting utility and industrial boilers from oil or gas to coal, price trends in world oil markets, and the national priority placed upon reducing dependence on foreign energy supplies.

The pattern of distribution of coal from producing areas to points of use, however, is sensitive to transportation costs. Thus, relative reductions in coal freight rates in the West will encourage the use of western coal at greater distances from where it is mined. (This issue is addressed in a forthcoming OTA assessment of future coal utilization.)

Issue 5

What other economic factors represent relative advantages or disadvantages of coal slurry pipelines?

Three areas of economic impact resulting from reliance on slurry pipelines or railroads remain to be considered. These involve employment, agriculture, and impacts on the distribution of income. Under the transportation scenarios considered in this study, the total cumulative employment by slurry pipelines and railroads until the year 2000 is roughly equivalent with or without slurry pipeline development. Pipelines over their useful life are less labor intensive than railroads, but during the construction period labor requirements for pipelines are high. Under the scenarios examined here, construction activity will continue until 2000 with substantial employment in this sector and in supplying industries as a result. Even without the competition of pipelines for new coal traffic, railroad employment is expected to remain at a constant level, or even decline, until 1990. If slurry pipelines capture a significant portion of the coal transport market during this period, especially if they do so after railroads have expanded their operations to carry new coal traffic, the decline in railroad employment may outstrip attrition and result in actual layoffs. This effect, however, is not likely to be great on a national scale.

Agriculture may be affected locally by future water availability impacts of slurry pipelines, as well as by the cost and quality of service by railroads. Train traffic can also have direct adverse impacts on agriculture in the form of possible disruption of ranching operations.

After computing overall costs, questions of equity remain. Not all will benefit or be burdened equally by a decision in favor of one or another coal transport mode. A slurry pipeline may lower the shipping costs of utilities while raising them for noncoal rail users. Pipeline construction will benefit construction labor at the expense of railroad labor. Some industries will benefit from an expansion of coal unit trains while the communities through which they pass will experience the disruptive effects of such expansion. Balancing the conflicting interests involved is a subjective and political process. (These considerations are also covered in chapter V.)

Issue 6

What will be the impacts of water use for coal slurry pipeline development? How might such impacts be mitigated?

The allocation of water for any use can potentially have a significant impact upon: 1) the physical environment by diminishing surface stream flows or depleting ground water supplies; and 2) the future economic and social well-being of the populace in the water source area as choices must be made between competing water uses in the future.

Physical environmental impacts are largely a function of the ratio of pipeline water requirements to the size of physically available surface and ground water flows. In none of four hypothetical pipeline routes analyzed would the water needed be a large enough percentage of the total supply to have a significant impact on stream water quality. In the most extreme hypothetical case examined, that of pipelines carrying 125 million tons of coal per year from eastern Wyoming, the proportion would be 3 percent of available surface flows.

Economic and social impacts depend upon

the degree to which pipeline water demands infringe upon alternate uses for the same water. Sufficient water is physically, although not necessarily legally, available in three western coal-producing areas studied to service both existing uses at present levels and a substantial number of coal slurry pipelines as well. However, pipelines do compete directly with other possible *future* uses. These include alternative forms of energy development involving inter alia facilities for coal mining, electric power generation, and shale oil. Consequently, a decision to construct a coal slurry pipeline will require consideration now of alternative uses for water in the future. When levels of use exceed users' rights, as is the case during years of relative abundance of water, new appropriations may displace present, as well as future, uses.

The water-related impacts of coal slurry pipelines can be mitigated if sources of water can be found which are usable for slurry but not for most other purposes. There are three promising possibilities: irrigation return flows; primary or secondary sewage effluent; and most important, saline ground water. In each instance the water may need some purification for use as a slurry medium but this appears to be a manageable requirement. Sewage effluent will not be available in sufficient quantities in many areas to serve as more than a supplementary water source, and the sizes and locations of saline ground water sources are generally not well known. An additional means of mitigating the pressure on limited water resources is to recycle the recovered slurry water by return pipeline. The limiting factors are the high but not necessarily prohibitive cost of such a self-contained system and the fact that not all of the water can be readily separated from the coal.

It should be emphasized that coal slurry pipeline water use represents only a small part of a large set of issues surrounding water resource allocation in the West. The National Water Commission in 1973 described the situation as follows:

> Water differs from other resources in that to a large extent its allocation among different uses is made outside a market price system. Legal and administrative institutions based more often than not on tradition rather than economic efficiency, play a basic role in water allocation, Therefore, public policy must be relied upon to be a major determinant in the flexible allocation of water resources to achieve improved patterns of productive uses.[1]

Further discussion of water use impacts is contained under *Water Use by Pipelines* in chapter VI.

Issue 7

How does water law affect the viability of coal slurry pipelines? Specifically, who exercises control over water required for coal slurry pipelines, and how might Federal or State authority be affected by legislation?

State law governs access to surface and ground waters within the State subject to two major limitations: 1) waters shared with other States, such as a river or lake that crosses State boundaries, and 2) water controlled by the Federal Government.

State governments exercise some control over access to water for coal slurry pipelines in a variety of ways. Water resource management policy determines the rate at which ground water sources are exploited, i.e., whether they are mined or whether extraction is confined to a rate not exceeding natural replenishment. States can withhold water from use for purposes of conservation and planning for future needs. Even if adequate water supplies are physically available, any potential user must qualify under State law as a "beneficial use" in terms of the public interest. The courts have yet to resolve definitively the question of whether coal slurry pipelines are a beneficial use. Other State-imposed obstacles to providing water for slurry include "use preference" policies, which could conceivably

[1]National Water Commission, *Water Policies for the Future,* Washington, 1973, p. 319

result in preemption of the water supply of a pipeline by other users after the pipeline is operational, and prohibitions on the exportation of water out of State. The latter type of provision, however, is of uncertain constitutionality.

The Federal Government has ample power under the Constitution to assure adequate water supplies to a coal slurry pipeline, State restrictions notwithstanding. That authority derives primarily from the commerce and property clauses of the Constitution. The former has been interpreted to give the Federal Government authority over all navigable water and the latter over water from Federal projects. Moreover, there is judicial precedent in support of the preemption doctrine, i.e., where there is a declared Federal interest in a policy, State law cannot be permitted to contravene that policy.

Despite these sweeping powers, Federal officials have traditionally administered Federal law in a way that tends to preserve State controls over the distribution of water. Slurry legislation presently pending before Congress does not alter this situation. Control over water supplies is unchanged in some proposed bills, and in others the use of federally controlled water for slurry pipelines is expressly forbidden. However, the First Iowa HydroElectric *Cooperative v. Federal Power Commission* case suggests that the courts may rule that Federal certification of a coal slurry pipeline will negate State attempts to restrict unallocated water to the project even though Federal statutes seem to reserve control over water to the States. To the extent the law is uncertain, the proponent of a coal slurry pipeline who has been unable to obtain rights to State water may seek to force such access through litigation in the Federal courts.

If these matters are to be clarified, Congress must address three issues through legislation. First, it must be decided to what extent, if any, water under Federal control should be made available for coal slurry purposes. If it is decided that such water should be provided, that intent should be made unambiguously clear to the administrators of Federal projects through legislation. Second, Congress is in a position to decide the extent to which control of water resources for a pipeline survives the enactment of legislation authorizing Federal certification and regulation of pipelines. Pending legislation leaves little scope for State regulation of pipelines. If the intent of Congress is to preserve meaningful State regulation then the legislation should spell out what State administrators may do to control water for pipeline use. Third, Congress can determine the degree to which the Federal Government will defer to State law in distributing water from Federal sources.

The basic problem facing Congress is whether it is desirable and possible to reduce the uncertainty surrounding water supplies for coal slurry pipelines while protecting to a substantial degree existing State jurisdiction over water sources. (For further discussion of water law, see *Water Law,* chapter VI I.)

Issue 8

What are the principal relative social and environmental impacts aside from economic benefits of railroads and pipelines as coal carriers? To what extent can adverse impacts be mitigated?

Water requirements and possibly some transient effects of construction constitute the principal source of adverse environmental and social impacts associated with coal slurry pipelines (see Issue 6 above), For railroads the major negative impact is social — the disruptive effect of increased unit train traffic upon the lives of individuals living or working near the tracks. That disruption can take a variety of forms: increased exposure to train noise, interruption of commuting and other automobile traffic, additional accidents at grade crossings, and interference with cattle movements on range land.

Some of the adverse impacts that result from increased unit train activity can be mitigated. Grade separations permit the safe movement of vehicle and pedestrian traffic across tracks. Cattle passes may facilitate the movement of herds from one range to another. New highway and rail construction can be planned so as not to intersect if at all possible. New tracks can be laid to avoid residential areas, and land alongside existing track can be zoned nonresidential. These "solutions" are not without their drawbacks. Some, like vehicle grade separations, are expensive, and the costs are often borne in part by the public. The utility of grade crossings for cattle is uncertain. Some impacts must simply be accommodated, e.g., the nonresidential zoning of town land alongside the tracks may be necessary where no practical means are found to reduce exposure to train noise. To a significant degree, whether the impacts of increased unit train traffic prove manageable will depend on the extent to which railroad companies and the communities and landowners along the tracks are able to cooperate and work together to deal with those problems that arise.

Other environmental and social impacts associated with either coal slurry pipelines or unit trains, e.g., air pollution, construction impacts, revegetation, and occupational health and safety, are not particularly serious or are roughly equivalent for the two modes. (Environmental impacts are covered in chapter VI with a specific section on Community *Disruption by Railroads.)*

Issue 9

What present Federal or State environmental protection laws are relevant to potential adverse impacts of railroads or slurry pipelines?

The major Federal environmental protection laws relevant to coal slurry pipelines and unit trains are the National Environmental Policy Act (N EPA), and the Federal Water Pollution Control Act (FWPCA). Also applicable, but less important in this instance, are the Clean Air Act (CAA), the Noise Control Act (NCA), the Resource Conservation and Recovery Act (RCRA), the Safe Drinking Water Act (SDWA), and for protection of construction and operation personnel, the Occupational Safety and Health Act (OSHA).

Under the requirements of NEPA any major Federal action significantly affecting the environment must be preceded by an Environmental Impact Statement (E IS). It is technically possible at present to construct and operate a slurry pipeline without a Federal EIS, since no major Federal action or certification is required to initiate service. Increased train traffic, the basic source of rail-related environmental problems, also does not require an EIS. However, a number of activities in connection with the construction and operation of both coal slurry pipelines and unit trains may involve Federal action requiring an EIS. These include construction or-l Federal lands, crossing "navigable waters" or "waters of the United States" (which includes most of the Nation's surface waters), and discharge of wastes into waters of the United States. Regulatory agencies granting certificates of Public Convenience and Necessity for extension or abandonment of service must also file EISs. Where Federal action is not involved, pipeline and rail activities will require a State E IS in some instances,

The waters of the United States are protected against pollution discharges from coal slurry pipelines or unit trains under FWPCA. The FWPCA does not cover ground water, which will be partially protected by regulations to be promulgated by the Environmental Protection Agency (EPA) under the SDWA and the RCRA. For example, SDWA regulations will govern the underground disposal of waste water, and RCRA leaching of waste water, from preparation of the coal slurry or from dewatering facilities and possible holding ponds. Railroad and pipeline construction activities will be subject to Federal regulations concerning nonpoint source pollution and erosion runoff.

The Clean Air Act as amended provides for comprehensive control of air pollution. Under CAA, EPA has promulgated national primary and secondary ambient air quality and stationary source standards and is implementing regulations for a variety of pollutants. These are indirectly applicable to coal slurry pipelines in that they affect powerplants which supply electricity to pumping stations. They are not applicable to locomotive emissions. Standards concerning particulate matter will apply to coal dust emissions associated with the preparation of coal for transport by pipelines or rail and the operation of unit trains. Construction of a pipeline or rail line will, in some States, be subject to standards and regulations concerning fugitive dust. Locomotive emissions may be regulated under State implementation plans.

Other impacts associated with the construction and operation of one or the other of the two transport modes and subject to Federal regulation include train noise under NCA, and railroad crossing safety under OS HA. Finally, under some Federal environmental protection statutes private parties could bring suit to remedy pipeline- or rail-induced environmental damage by compelling EPA or other appropriate regulatory agency to enforce the applicable statute. Several Federal and State programs are aimed at improving safety and reducing inconvenience at railroad highway grade crossings, partially at public expense. Provisions of the 1976 Federal Highway Act (23 USC 140, 203) are examples. (See Environrnental *Law,* chapter VII.)

Issue 10

What present Federal and State laws are applicable to land acquisition for a coal slurry pipeline right-of-way? What legal precedents are provided by other commodities and transport modes?

The power of eminent domain is inherent in the authority to govern and is limited only by the principles of just compensation to the owner of the expropriated property, the territorial jurisdiction of the government concerned, and the requirement that any grant of eminent domain authority must serve a beneficial public purpose. Statutory limitations may be imposed in connection with particular grants of eminent domain authority. Congress has the power to formulate legislation granting rights-of-way over Federal public lands, national forest lands, and through powers of eminent domain, over private and State lands for pipelines engaged in interstate commerce.

At present no Federal legislation grants eminent domain authority for coal slurry pipelines. Among States west of the Mississippi, six have enacted eminent domain provisions for that purpose. Others have no statutes which could be interpreted as including such authority, and in the rest a slurry pipeline company could not be sure it had the power of eminent domain until the issue was litigated. Recent State legislation granting eminent domain to slurry pipelines limits their use of State water and subjects them to State regulation as a common carrier. The pipeline must be deemed to fulfill a “public purpose” within a State to qualify for a grant of eminent domain power from any State.

The issue of eminent domain for coal slurry pipelines arises in large part because railroads and other landowners, under whose land pipelines would have to cross, have declined to grant the necessary rights-of-way. In those instances where a railroad holds fee title to its own right-of-way, it can presently prevent a slurry pipeline from crossing the tracks. Where the railroad holds only an easement, it cannot. In the Western States much of the early railroad rights-of-way were acquired under the Pacific Railroad Acts of 1862 and 1864, and the type of right-of-way acquired thereunder is in dispute. Recent court judgments tend to suggest that the railroads received only a limited fee which would not empower them to prevent crossing by a slurry pipeline, but further litigation will be required for a definitive resolution of the matter. Even if the right to cross railroads is achieved, slurry pipelines will still have to negotiate rights-of-way from other landowners, not all of whom will necessarily be sympathetic.

A precedent for a Federal grant of eminent domain power to a transportation enterprise exists in the 1947 Amendment to the Natural Gas Act, which gave such authority to interstate natural gas pipelines. On the other hand, the vast network of interstate oil pipelines (with one brief exception) together with ammonia fertilizer pipelines and railroads have been built with only State eminent domain authority.

A comparison of interstate coal slurry pipelines with interstate natural gas pipelines indicates that although the granting of Federal eminent domain to gas pipelines does not mandate such a grant to coal pipelines, it does furnish a legal precedent if Congress finds such a grant to be in the national interest.

On the other hand, comparison of coal slurry pipelines with oil pipelines suggests that State eminent domain authority may not be as effective in meeting needs of the former as it has been for the latter. (This area is discussed further under Eminent Domain in chapter VII.)

Issue 11

What would be the direct consequences of and alternatives to granting coal slurry pipelines eminent domain powers under Federal as opposed to State law?

Congress has four basic options with regard to eminent domain for coal slurry pipelines. The first is to avoid granting authority and leave the matter to the States. A number of States have already enacted legislation granting slurry pipelines the power of eminent domain. In order to qualify for this benefit, most States require that the prospective pipeline operator obtain a license or certificate of public convenience and necessity, be designated a common carrier or public utility serving a beneficial public purpose, and accept State regulation regarding rates and access to State water.

From the perspective of the pipeline operator, this first option presents several difficulties. Under the best of circumstances it will require negotiations with several State governments, each with somewhat different requirements. More seriously, a slurry pipeline may have difficulty meeting the beneficial public purpose test in the State in which it originates and in those through which it passes since the coal is not made available to markets in those States. Consequently, the pipeline may not qualify for a grant of eminent domain authority under State law even if such legislation is on the books. Finally, there is no guarantee that every State on the route of a planned pipeline will enact the desired legislation. If a pipeline must be constructed without the benefit of eminent domain authority, it will be much more difficult if not impossible to acquire the needed right-of-way. Some landowners may resist any passage or demand exorbitant prices. The result will probably be delays, increased costs, and less efficient routing.

The second option is to provide eminent domain authority under Federal law. Such a grant of Federal authority would be valid in all States and would exempt slurry pipelines from State licensing or certification requirements. In their place would be one certificate of public convenience and necessity issued by a Federal agency. At the same time State regulations not in conflict with constitutional provisions or Federal statutes could still be applied to the pipeline. Compared to the first option, this approach should facilitate the construction of slurry pipelines by reducing both delays and costs.

The third option involves a conditional grant of Federal eminent domain power. Such authority would be granted to a pipeline only if State eminent domain authority were not available. The States would be allowed a period of time in which to grant eminent domain authority to slurry pipelines on such conditions as might be deemed necessary to protect the interests of the State. Only if a State failed to act, or if State legislation proved inapplicable to a particular pipeline, would Federal eminent domain authority be provided.

The fourth option would be to grant the power of Federal eminent domain for individual pipeline projects through specific legislation. This approach would be cumbersome, but it would allow Congress to determine, in each case, the degree to which the national interest is served.

If it is determined that coal slurry pipelines should be built, either Federal or State eminent domain authority would appear to be a necessity. If the objective is to encourage their rapid development, Federal legislation has some clear advantages. However, if the intent is to reserve for the States the power to protect their interests as they perceive them, then pre emption by a Federal statute would be undesirable.

IV. Coal Slurry Pipeline and Unit Train Systems

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Assessing the costs and benefits of rail and pipeline alternatives required first, the establishment of coal transportation market projections and second, the development of cost relationships and traffic scenarios for the two modes. Since the extent and pattern of transportation activity depend on the cost and configuration of the system, these two steps cannot be separated entirely, and the market projections were later tested for sensitivity to transportation costs. This chapter contains a brief description of the competing technologies followed by the results of the two analyses just mentioned.

TECHNOLOGY DESCRIPTION

Pipelines

Slurry pipelines have been proposed as a method for moving large volumes of coal over great distances. Two such pipelines have been built in this country, one is in operation, and several are in different stages of planning (see figure 1), The economic and environmental advantages and limitations are a matter of considerable dispute. In the absence of waterways, however, pipelines are claimed to be potential competitors for coal traffic in volumes of more than approximately 5 million tons per year over distances greater than about 200 miles, particularly where rail facilities are circuitous or in poor condition.

The process involves three major stages: 1) grinding the coal and mixing it with a liquid (generally water) to form the slurry, 2) transmission through the pipeline, and 3) dewatering the coal for use as a boiler fuel, for storage, or for transloading to another mode of transportation. These steps are diagramed in figure 2, and some characteristics of selected coal and other mineral slurry pipeline systems are presented in table 1.

Slurry Preparation

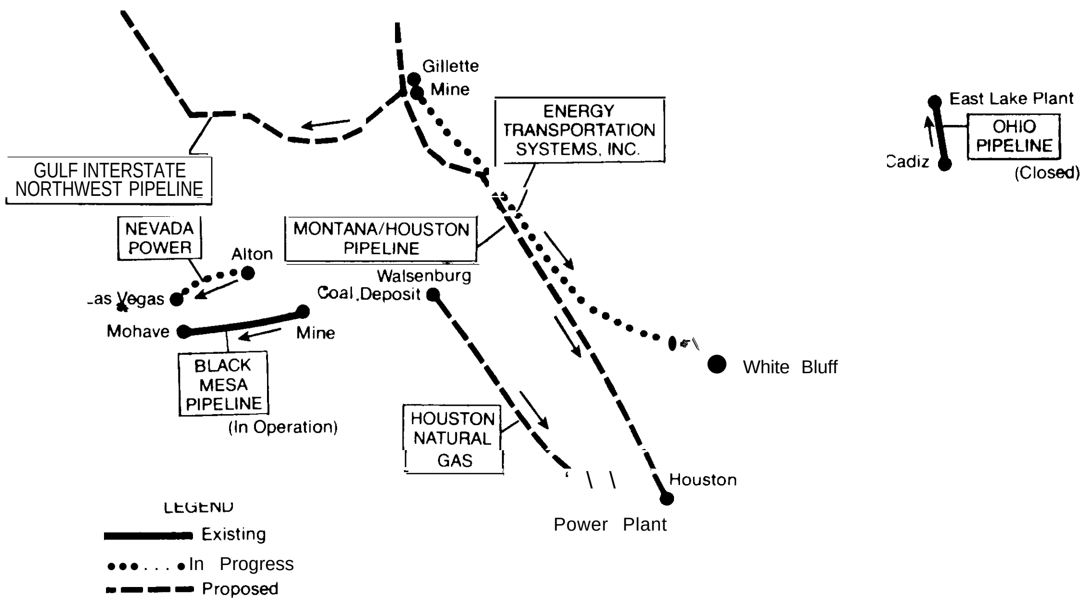
Coal is assembled from a mine or group of mines at a single point where mixing, cleaning, or other beneficiation may take place, and where the slurry is prepared. Preparation begins with impact crushing followed by the addition of water and further grinding to a maximum particle size of one-eighth inch. More water is then added to form a mixture that is about 50 percent dry coal by weight, and the resulting slurry is stored in a tank with mechanical agitators to prevent settling.

The optimum size distribution of the coal and proportion of water is dependent on design tradeoffs that are peculiar to the specific application, and water requirements are reduced to the extent of the initial moisture content of the coal. Water is also not necessarily the only slurry medium, and oil as well as methanol derived from the coal itself have been proposed.

Transmission

The slurry from the agitated storage tanks is introduced into a buried steel pipe and propelled by reciprocating positive displacement pumps located at intervals of approximately 50 to 150 miles, depending upon terrain, pipe size, and other design considerations. The slurry travels at a velocity just under 6 feet per second, but the precise speed also depends on the coal particle size distribution, pipe diameter, and economic factors. Ideally, the

Figure 1—Present and Proposed Coal Slurry Pipelines



Source: Slurry Transport Association.

flow is maintained at a rate which minimizes power requirements while maintaining the coal in suspension. Once started, the flow must continue uninterrupted, or the coal will gradually settle and possibly plug the pipe. Considerable technical controversy surrounds the likelihood of this event and the possibility that the pipeline can be restarted after given periods of time. To prevent this type of settling, the operating pipeline at Black Mesa has ponds into which to empty the pipe in the event of a break or other interruption.

The potential economic advantage of this technology lies in the fact that the volume of coal that can pass through a pipeline increases approximately as the square of the pipeline diameter, while construction, power, and other operating costs do not rise in as high a proportion. Therefore, if throughput volumes are high enough to take advantage of this economy of scale, and if the pipeline is long enough to recover the cost of gathering, preparing, dewatering, and delivering the coal at the termini, the pipeline can compete with unit trains.

Dewatering and Delivery

At the downstream end of the pipeline, the slurry is again introduced into agitated tank storage, from which it is fed into a dewatering facility. Dewatering is accomplished by natural settling, vacuum filtration, or by centrifuge, and then the finely ground coal still suspended in the water can be separated by chemical flocculation. After additional drying by the application of heat, the coal can then be stored, transported further by other modes, or introduced directly into grinding equipment at a powerplant and injected into the boilers. The reclaimed water can be used in an electric generating station's cooling system to condense steam, or it could theoretically be recycled in a return pipeline.

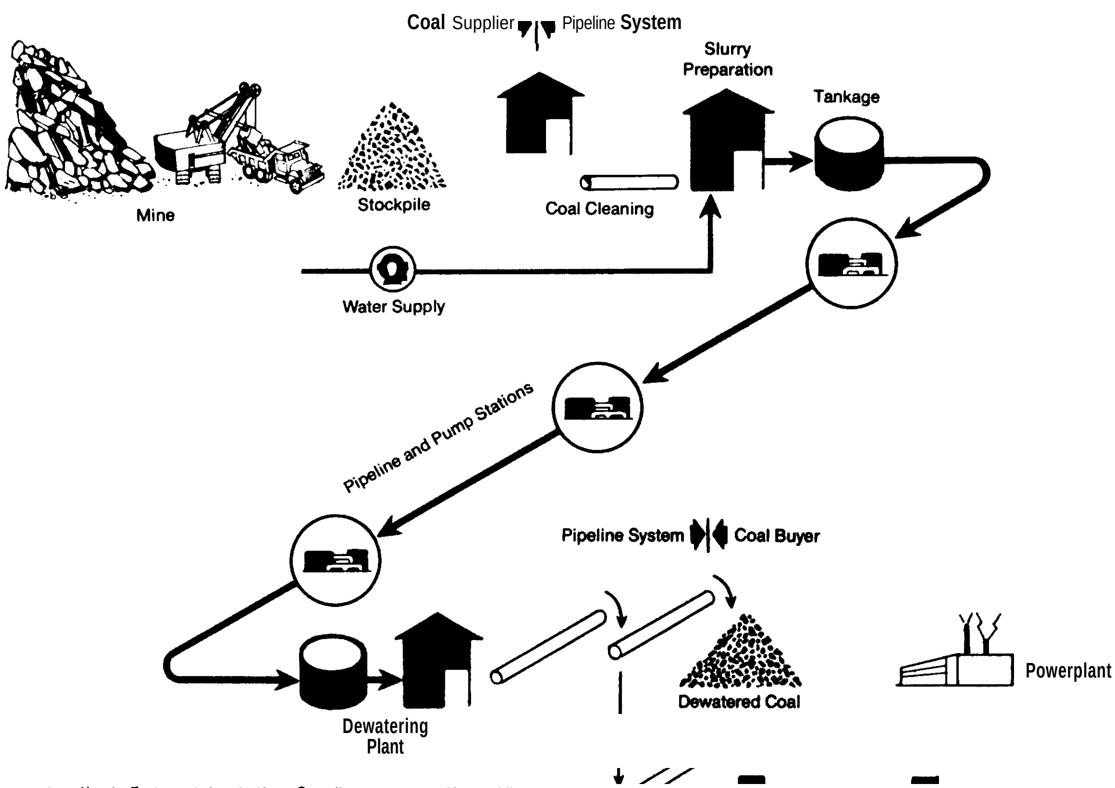
Possible variations on this stage, which are not covered by this assessment, include introduction of coal slurry as a feedstock for gasification or liquefaction facilities designed to take into account the fact that the coal is already ground and mixed with water, or the use of a combustible slurry medium like oil or methanol so that dewatering would not be necessary and the slurry could be used as a boiler fuel directly.

Unit Trains

The principal economic competitors with coal pipelines are unit trains. This type of train, also designed to take advantage of scale economies, generally carries a single commodity in dedicated service between two points in sufficient volume to achieve cost savings. The cars are designed for automated loading and unloading, and the train is operated according to procedures which avoid switching and time-consuming delays in freight yards.

A typical coal unit train consists of six 3,000 horsepower locomotives and 100 hopper cars with carrying capacitates of 100 tons each. Roughly two such trains per week are therefore required to deliver 1 million tons of coal per year. Speeds vary considerably depending on track conditions, but 20 to 50 miles per hour is a common range. Trains generally travel more slowly loaded than empty.

Figure 2–Schematic of Slurry Pipeline System



Source John M Huneke, Testimony before the House Committee on Interior and Insular Affairs on Coal Slurry Pipeline Legislation, Washington, D C Sept. 12, 1975

COAL SLURRY. — Aerial view of the Black Mesa Slurry Preparation Plant and Pumping Station near Kayenta, Ariz.

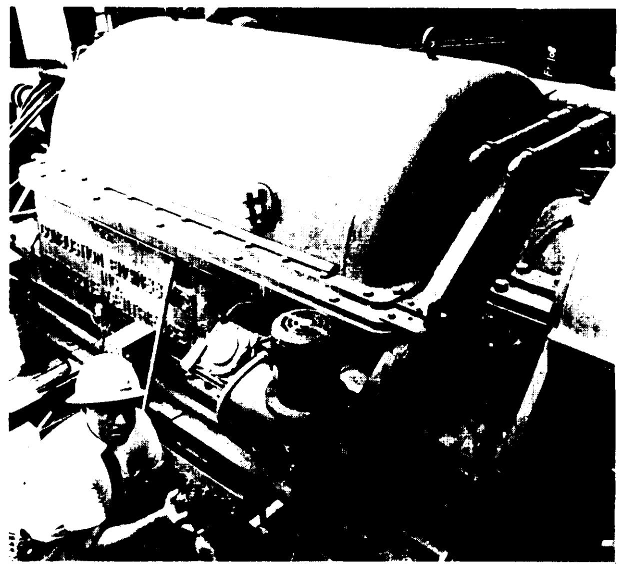


Photo: Courtesy of Southern California Edison Company

CENTRIFUGES. – Southern California Edison Company employee in foreground holds lump of coal which is finely ground at Black Mesa, Ariz., before it goes through 273-mile slurry pipeline mixed with water (50-50%) and slurried to huge circulating facilities — holding tanks — at Mohave Generating Station. From holding tanks the coal/ water solution is sent into one of 40 centrifuges (20 for each generating unit) where the coal is dewatered before it goes into boiler furnaces.

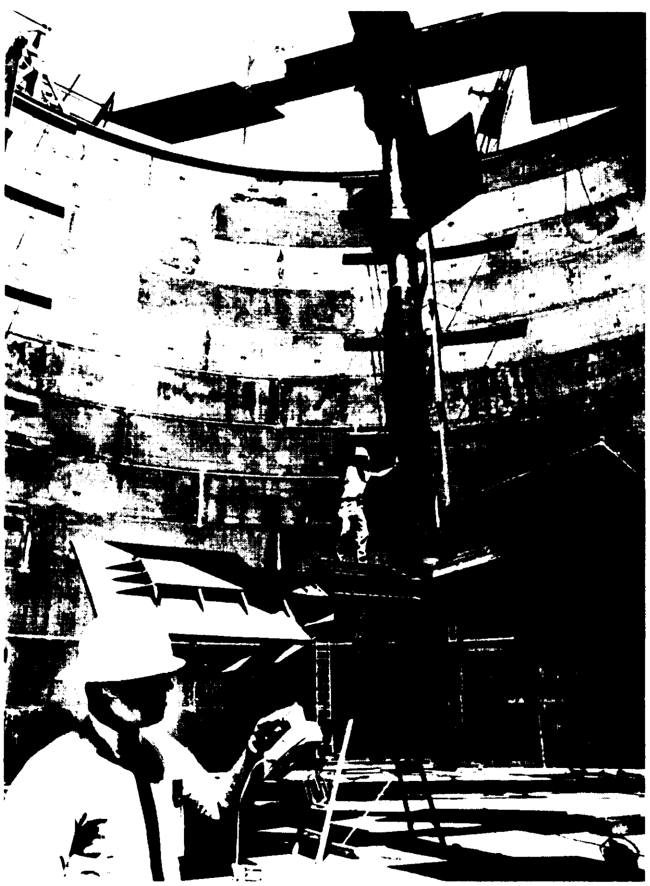


Photo: Courtesy of Southern California Edison Company

4

GIANT MIXERS. – Inside one of the huge mixing tanks, personnel at the Mohave Power Project display a kitchen-size electric mixer to give some comparison with the world's largest mixing blades — used to keep powder-fine coal in water solution (slurry). A battery of smaller centrifuges later expel the water from the coal before the fuel is used to create electricity for three Southwest States, Nevada, Arizona, and California.

COAL MINING. – A thick seam of coal exposed by stripping, done by the big dragline, is being loaded into the Dart hauler by a front-end loader.

Photo: United States Department of Energy

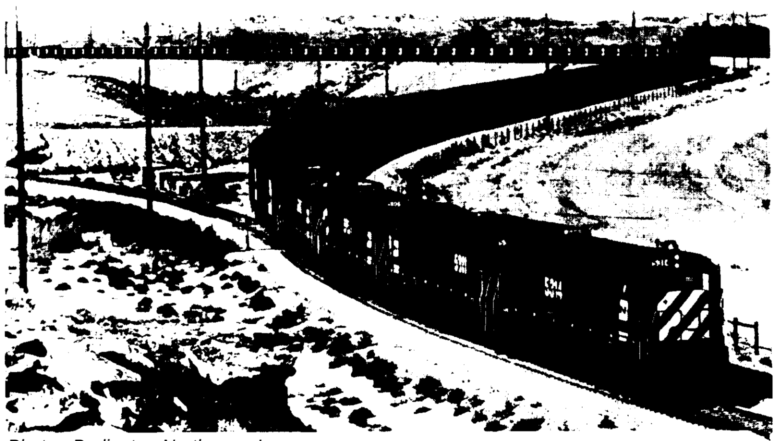


Photo. Burlington-Northerrn, Inc.

COAL UNIT TRAINS. – Like the one depicted in this photo, typically utilize 6 locomotives and 100 hopper cars. The trains are frequently more than a mile long.

COAL. – Sub-bituminous coal underlies some 25,000 square miles of Montana and Wyoming.

Table 1. Summary of Selected Worldwide Commercial Slurry Pipelines

Slurry material	System or location	Length (miles)	Diameter (inches)	Annual throughput (million tons/year)	Initial operation
Existing					
Coal	Consolidation	108	10	**1.3**	1957
	Black Mesa	273	18	**4.8**	1970
Limestone	Calaveras	17	7	1.5	1971
	Rugby	57	10	1.7	1964
	Trinidad	6	8	0.6	1959
	Colombia	17		0.4	1944
Copper Concentrate	Bougainvillea		6	1.0	1972
	West Irian	69	4	0.3	1972
	KBI Turkey	38	5	1.0	——
	Pinto Valley	11	4	0.4	1974
Magnetite Concentrate	Tasmania	53		2.3	1967
	Waipipi (land)	4	8	1.0	971
	Waipipi (offshore)	1.8	12	1.0	971
	Pena Colorada	30	8	**1.8**	974
Gilsonite	Am. Gilsonite	72	6	0.4	957
Tails	Japan	44	12	0.6	968
Nickel refinery tailings	West. Mining	4.3	4	0.1	970
In Progress					
Coal	**Nevada** Power Utah/Nev.	180	24	10.0	
	Energy Trans. Systems, Inc. Wyo./Ark.	1,036	38	25.0	
Magnite and Hematite	Sierra Grande	20	8	2.1	
	Brazil	250	20	12.0	
	Mexico	17	10	1.5	
Planned					
Coal	Houston Nat. Gas Colo. to Tex.	750	22	9.0	
	Gulf Interstate N.W. Pipeline	800	30	16.0	
Phosphate	Australia	200	16-22	4.0-6.0	
Sulfur/hydrocarbon	Canada	800	12-16	—	
Magnetite and hematite	Africa	350	18	6.6	
	Brazil	240	20	12.0	
	India	36	20-22	10.0	
	Mexico	17	10	1.5	
	Australia	44	8	0.9	

[a]No longer in operation.

Source: John M. Huneke, Testimony before **the House Committee on Interior and Insular Affairs on Coal Slurry Pipeline Legislation, Washington, D. C., Sept. 12,1975.**

Since these trains are frequently more than 1 mile in length, one of the problems associated with their use is the interruption of traffic at crossings, especially where they arrive frequently and travel slowly. Also, trains of all kinds produce substantial amounts of noise, and they contribute to community and land-use disruption as well as to a component of highway traffic accidents. However, compared to pipelines, railroads offer advantages in terms of flexibility of operation and absence of water requirements at the coal source.

To benefit from this improved service, a customer must ship quantities sufficient to justify economically a dedicated train and often must invest in rapid loading and unloading facilities *to* meet turnaround time requirements. Also, it is sometimes to the customer's advantage to own the railroad cars as well.

COAL TRANSPORTATION MARKET

As the use of coal for powerplant fuel accounts for approximately 65 percent of all domestic coal use, changes in demand for utility coal will have major ramifications for the coal industry as a whole and the industries involved in its transport. The complexity of the problem is increased by the uncertainties faced by electric utilities. In addition to questions of economic viability, expansion potential, and electrical demand, the utilities must also consider future pollution-control requirements that are directly relevant to their selection of fuel type for new plant construction. As nuclear and coal-fired powerplants are approaching equivalence in life cycle costs, stringent pollution-control requirements can play a significant role in the nuclear/coal tradeoff. Pollutant-emission limitations also affect the type of coal to be burned once the decision to build a coal-fired plant is made. As coal types are geographically localized, intentions to burn specific coals add a spatial dimension to the utility demand for coal.

To determine what patterns of coal use utilities are likely to pursue under various scenarios of electrical demand growth, generating plant configuration, and environmental regulation, this study employed a utility simulation model developed under the sponsorship of the Environmental Protection Agency (EPA). The model simulates the behavior of the electric utility industry on a State-by-State basis when economic, technical, and environmental parameters are specified. For this analysis, several scenarios have been employed to bound the range of likely utility response to various levels of electrical demand and pollution-control requirements. Detailed tables and maps have been prepared that specify the type, amount, origin, destination, and year of coal demand for the utilities in response to each scenario.

Significant variations in production at the regional level can be attributed to anticipated changes in pollution-control requirements as well as to overall demand growth rates. Under current regulations, States must have plans to improve and maintain ambient air quality to levels specified by National Ambient Air Quality Standards (NAAQS). In addition, emission limitations are expressly provided for the construction of new sources in operation after 1977. Utility response to these requirements have been, up to now, a process of deciding whether to use low-sulfur coals or flue-gas desulfurization equipment. This strategy encourages the use of low-sulfur western coals able to meet the emission limitations established by the New Source Performance Standards (NSPS). However, changes in the application of New Source Performance Standards that would mandate the use of flue-gas desulfurization equipment capable of removing 90 percent of released sulfur dioxide (SO_2) on all new plants regardless of the sulfur content of the burned coal would sharply curtail the demand for western coals as higher sulfur "local" coals would not have to be transported as far to the powerplant site. This effect is most dramatic in the case of midwestern coals. A partial list of factors influencing coal usage appears below.

Major Factors Influencing Coal Usage

Factors affecting the level of usage:

- Rate of growth of national energy consumption (especially electricity).
- Costs of competing fuels (especially imported oil and uranium).
- Distribution of electricity demand over time (peak vs. average power demand).
- Availability of capital, equipment, and mining manpower for expansion of mining capacity.

Factors affecting the distribution of usage:

- Regional differences in energy demand growth.
- Emission I imitations on sulfur oxides.
- Regional differences in costs of competing fuels.
- Rate of retirement of oil- and gas-fired powerplants.
- Relative costs of surface and deep mining.
- Availability and costs of transportation.
- Innovations in combustion and pollution-control technologies.
- Federal and State policies toward further development of coal reserves in the West.

Coal Sources

The model recognizes nine coal supply regions, listed in table 2, and three types of coal: bituminous, sub-bituminous, and lignite. Figure 3 is a map displaying the areas within the regions which are currently being mined or which are likely to be mined in the foreseeable future.

Utility Simulation Model

This model simulates the response of the electric utility industry to postulated energy demands, economic conditions, and environmental regulations— the complete set of which specify a "scenario'' -on a national scale. Eight scenarios were executed to provide insights into the sensitivity of the model to changes in variables and to reflect improvements brought about during the course of the assessment. One was selected as the basis for market assumptions in the subsequent economic analysis. Details of the model and the results of all of the scenarios are presented in Volume II, and what follows are the salient features and assumptions along with the selected set of results.

Table 2. Coal Supply Regions

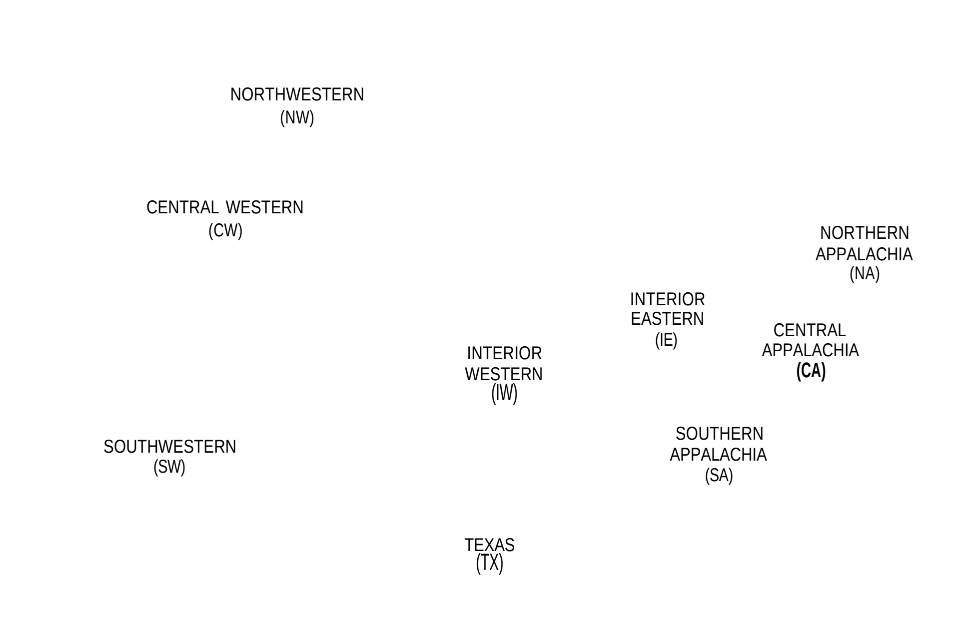
Supply region	Code	States encompassed
1. **Northern Appalachia . .**	**NA**	**PA, MD, OH**
2. **Central Appalachia . . .**	**CA**	**WV, VA, KY (east)**
3. **Southern Appalachia. .**	**SA**	**TN, AL**
4. **Interior Eastern. . . . . .**	IE	IN, IL, KY(west)
5. **Interior Western . . . . . .**	**IW**	**IA, KS, MO, OK,AR**
6. **Northwestern . . . .**	**NW**	**MT, ND**
Central Western	**CW**	**WY, UT, CO**
8. **Southwestern. . . . .**	**SW**	**AZ, NM**
9. **Texas. . . . .**	**TX**	**TX**

Source: Teknekron, Inc., *Projection of Utility Coal Movement Patterns: 1980-2000, 1977.*

Coal Assignments

Coal is assigned to each generating unit on the basis of least cost to the utility, taking into account applicable sulfur-emission standards, coal heating and sulfur content, and mining and transportation costs. Four categories of available coals are assigned to each State. Three of the categories are the least expensive coals available to the State that can meet applicable sulfur-emission requirements without the use of flue-gas desulfurization. The emission limitations are specified for these three categories according to: 1) applicable State Implementation Plan (SIP) limitations for nonmetropolitan areas, 2) applicable State Implementation Plan limitations for metropolitan areas, and 3) emission limitations for new units under New Source Performance Standards (NSPS). The fourth category of coal is simply the least expensive coal available to the State without regard to its sulfur content. The actual assignment is made in a two-step procedure.

Figure 3–Coal Supply Regions



Source Tekoekron Inc

First, the sulfur-emission limitation in effect is determined for each unit depending on its location and the year that it went into service, Secondly, costs are compared to determine if it is more economical to burn the appropriate low sulfur coal without additional cleanup or to use flue-gas desulfurization equipment with the cheapest coal available. All coal-fired units within a given State that are subject to the same sulfur-emission limitations burn the same kind of coal, Neither blending of coals from different supply regions nor cleaning of significant amounts of coal are considered. Table 3 identifies the assigned coals in each of the four categories for each State by class, sulfur content, and delivered price, The class of the assigned coals are identified by the two letter code for the region of origin (see table 2 for codes), rank (bituminous (B), sub-bituminous (S B), or lignite (L)), and whether they are cleaned (C) or uncleaned (UC). Thus for example, the concatenated designation “SA/B/UC” for the nonmetropolitan SIP complying coal for Alabama specifies a Southern Appalachian, bituminous, uncleaned coal. This assignment procedure, which identifies only one coal source for a given State and set of environmental restrictions, represents an important limitation. It causes the model to predict large concentrated flows of coal from single producing areas to consuming States, so individual results at the State level are not as reliable as hose corresponding to larger regions,

Coal Prices

The prices developed in table 3 are expressed in 1975 dollars and are composed of three major elements. These include an f.o.b. mine raw coal price, a transportation cost from the region of origin to the State of consumption, and an additional component representing localized severance taxes or market premiums. The f.o.b. mine prices used as a base are calculated from National Economic Research Associates (N ERA)[1] data and con-

[1] National Economic Research Associates, Inc , Costs *of SO_x Control for the Steam Electric Power Industry,* June 1975

Table 3. Assigned Coals, by State, "No Cleaning" Scenarios (1975)

	Non metropolitan SIP complying coal			Metropolitan SIP complying coal			NSPS complying coal			Cheapest available coal		
State	Class	Sulfur (percent)	Price (cents/ 10° Btu)	Class	Sulfur (percent)	Price (cents/ 10°Btu)	Class	Sulfur (percent)	Price (cents/ 10° Btu	Class	Sulfur (percent)	Price (cents/ 10° Btu
Alabama. .,	SA/B/UC	1.7	51.3	CA/B/UC	1.2	93.7	CW/SB/UC	0.64	80.7	SA/B/UC	1.7	51.3
Arizona. ., ...	SW/SB/UC	0.6	27.2				SW/SB/UC	0.73	27.2	SW/SB/UC	0.87	27.2
Arkansas . . . . .,	SA/B/UC	1.3	65.0				CW/SB/UC	0.64	65.1	IE/B/UC		63.0
California.	CW/SB/UC	0.95	63.0	CW/SB/UC	0.5	63,0	CW/SB/UC	0.64	63.0	CW/SB/UC	0.95	63.0
Colorado	CW/SB/UC	0.85	42.8				CW/SB/UC	0.64	42.8	CW/SB/UC	0.95	42.8
Connecticut .,		None			None			None		NA/B/UC	2.5	68.5
Delaware . . . .,	NA/B/UC	3.0	65.5	CA/B/UC	1.0	61.1		None		NA/B/UC	3.0	68.0
Florida ... ., ., .,		None			None			None		SA/B/UC	1.7	75,8
Georgia . . . ., .,	IE/B/UC	3.0	62.6	IE/B/UC	3.0	62.6		None		IE/B/UC	3.6	62.6
Idaho	CW/SB/UC	1.0	36.2				CW/SB/UC	0.64	36.2	CW/SB/UC	1,0	36.3
Illinois . . . . .,	IE/B/UC	3.6	541	CW/SB	0.96	63.0	CW/SB/UC	0.64	63.0	IE/B/UC	3.6	54.1
Indiana. . . . ., .	CW/SB/UC	0.64	69.5				CW/SB/UC	0.64	69.5	IE/B/UC	3.6	54.1
Iowa ., ., ...	IE/B/UC	3.0	59.8				CW/SB/UC	0.64	56.3	IW/B/UC	3.7	52.6
Kansas, . . .	CW/SB/UC	0.95	51.8				CW/SB/UC	0.64	51.8	CW/SB/UC	0.95	51.8
Kentucky. .,	CA/B/UC	2.2	51.3	CA/B	0.77	65.8	CA/B/UC	0.77	65.8	IE/B/UC	3.6	54.3
Louisiana. ., ...	SA/B/UC	1.7	65.0	SA/B/UC	1.7	65.0	CW/SB/UC	0.64	78.3	SA/B/UC	1.7	65.0
Maine. ., . . .	NA/B/UC	2.5	80.2	NA/B/UC	2.5	80.2		None		NA/B/UC	2.5	80,2
Maryland	CA/B/UC	1.0	58.5	CA/B/UC	1.0	58.8		None		NA/B/UC	2.5	53.9
Massachusetts.		None			None			None		NA/B/UC	2.5	71.3
Michigan	NW/SB/UC	0.73	78.5				NW/SB/UC	0.64	78.5	IE/B/UC	3.7	66.5
Minnesota. .	NW/SB/UC	0.73	56.3	NW/SB/UC	0.73	56.3	NW/SB/UC	0.64	56.3	NW/SB/UC	0.73	56.3
Mississippi	SA/B/UC	1.7	59.5	SA/B/UC	1.7	59.5	CW/SB/UC	0.64	78.3	SA/B/UC	1.7	59.5
Missouri, ., ...	CW/SB/UC	1.2	63.0				CW/SB/UC	0.64	63.0	IW/B/UC	37	36.1
Montana . . .,	NW/SB/UC	0.73	31.7				NW/SB/UC	0.64	31.7	NW/SB/UC	0.73	31,7
Nebraska.	CW/SB/UC	0.95	40.8				CW/SB/UC	0.64	40.8	CW/SB/UC	0.95	40.8
Nevada. ., ., ., . .		None					CW/SB/UC	0.64	49.8	CW/SB/UC	0.95	49.8
New Hampshire . .	NA/B/UC	1.8	68.5	NA/B/UC	18	68.5		None		NA/B/UC	2.5	68.5
New Jersey	CA/B/UC	10	77,0		None			None		NA/B/UC	5.6	62.6
New Mexico . . .	SW/SB/UC	0.87	32.6				SW/B/UC	0.77	50.8	SW/SB/UC	0.87	31.2
New York. . . .	CA/B/UC	1.6	80.0		None			None		NA/B/UC	2.5	62.6
North Carolina . .	CA/B/UC	1,0	72.5	CA/B/UC	10	72.	CA/B/UC	0.64	89.5	CA/B/UC	2.1	72.5
North Dakota.	NW/L/UC	1,0	30.9				NW/SB/UC	0.64	44.6	NW/L/UC	1.1	0.9
Ohio : : : : :	NA/B/UC	2.6	54.1	CW/SB/UC	0.64	78.3	CW/SB/UC	0.64	78.3	NA/B/UC	3.7	54.1
Oklahoma	CW/SB/UC	1.1	58.3				CW/SB/UC	0.64	58.3	IW/B/UC	3.7	57.0
Oregon. ., .,	NW/SB/UC	0.73	65.3	NW/SB/UC	0,73	65.3	NW/SB/UC	0.64	65.3	NW/SB/UC	0.73	65.3
Pennsylvania, .,	NA/B/UC	2.4	54.1					None		NA/SB/UC	2.5	54.1
Rhode Island		None			None			None		NA/B/UC	2.5	68.5
South Carolina .,	SA/B/UC	1.7	621	SA/B/UC	1.5	62.1		None		SA/B/UC	1.7	62.1
South Dakota	CW/SB/UC	0.95	33.1				CW/SB/UC	0.64	33.1	CW/SB/UC	0.95	33.1
Tennessee.	SA/B/UC	1.7	53.9	CW/SB/UC	0.64	77.2	CW/SB/UC	0.64	77.2	SA/BUC	1.7	539
Texas,	TX/L/UC	1.2	43.3				CW/SB/UC	0.64	74.0	TX/L/UC	1.2	43.3
Utah.	CB/SB/UC	0.95	38.7				CW/SB/UC	0.64	38.7	CW/SB/UC	0.95	38.7
Vermont.		None			None			None		NA/B/UC	2.5	68.5
VlrgInia	CA/B/UC	17	51.1					None		CA/B/UC		51.1
Washington. .	NW/SB/UC	073	59.0	NW/SB/UC	073	60.0	NW/SB/UC	0.64	59.0	NW/SB/UC	0.73	59.0
W. Virginia	CA/B/UC	14	51.3	CA/B/UC	1.0	51.3	CA/B/UC	077	66.0	CA/B/UC	2.1	51.3
Wisconsin	IE/B/UC	3.6	63.0				NW/SB/UC	064	65.3	IE/B/UC	3.6	25.1
Wyoming, . ..		None					CW/SB/UC	064	25.1	CW/SB/UC	0.95	25.1

Notes: No entries under "Complying Met SIP" means there is only one is available, Sulfur content "as fired". Prices in 1975 dollars,
SIP in that State, arbitrarily considered to be non-met "NONE" means Sources: Teknekron, Inc. *Projections of Utility Coal* Movement *Patterns*
the limitation is so stringent that no coal which can meet it without FGD 1980-2000.

verted to 1975 dollars. The transportation cost is based on an assumed straight-line distance and a transportation rate as described below. A severance tax of 30 percent of f.o.b. mine price is added to the price of Montana coals (NW/SB class). A premium ("economic rent" of $0.15/106 Btu) is added to the delivered price of Appalachian coals complying with emission limitations equivalent to, or more stringent than, the New Source Performance Standards.

Time-dependent feedback relationships between the prices of coal and oil and rates at which the utilities use these fuels are not included in the analysis. Regional difference in coal prices, heating value, and sulfur content are accounted for in all the scenarios but an unlimited supply of coal at current (real) prices is assumed.

Coal Transportation

The model entails no constraints on the transport of coal. Transport costs were calculated by multiplying the straight-line distance from the center of the relevant supply region to the center of the consuming State by generalized transportation tariffs developed by NERA[2] (0.8 cents per ton-mile for coal originating in the West, 1.2 cents for coal originating in the Midwest and East).

Generating Mix

All existing generating units of investor-owned utilities, including nuclear, hydro, and fossil-fuel fired units are included in the data base, as are plants of the Tennessee Valley Authority (TVA) and municipal systems in Nebraska. Excluded utilities owned by public agencies amount to 15 percent of total generating capacity. New units currently planned by the industry for the period 1975-85 are also included, except that they are not brought "online" until the model determines that they are needed. If assumed electricity demand growth rates are lower than those implied by the utilties' plans filed with the Federal Power Commission (FPC), the model defers the startup date for an announced plant by one or more years beyond that indicated by the utility. The model sites new plants beyond 1985 (or later in the cases where new announced plants have been deferred), with the mix between coal and nuclear specified exogenously.

Demand for Electricity

Starting with actual electricity sales in 1973, a national average growth in peak and average power demand is specified exogenously to the model. This average rate is made to vary by region of the country to reflect normalized variations in population growth rates. Average power-demand growth is 5.4 percent per year in the selected scenario, while growth in peak demand is 5.9 percent per year.

Scenario Description

Energy Alternatives

Each energy alternative specifies both Government energy policy and the utilities' response to that policy by expressing the following factors quantitatively:

- Energy Policy
  - Influence of Government management of supply and demand.
  - Availability and price of fuels.
  - Regulations for powerplant fuel conversions.
  - Effect of natural gas curtailment.
- Utility Response
  - Schedule for additions to capacity by fuel type and State.
  - Schedule for conversions of gas- and oil-fired plants to coal.

The principal elements combined to specify a given alternative are the effect of Government demand-management policies on the rate of growth in demand for electricity, the additions to capacity by fuel type to meet demand and the oil-to-coal, gas-to-coal, and gas-to-oil conversions to be carried out. Under the selected scenario, the growth rates of 5.4 and 5.9 percent for average and peak demand reflect no Government policy for demand management.[3] Fuel mixes for capacity additions are those forecast by the nine regional reliability councils.

Coal prices have been discussed earlier, but the model includes other fuels as well. Oil prices are assumed to remain constant in real terms, while natural gas prices rise from current values to the Btu-equivalent price of oil in 1981, as reflected by current trends. Uranium prices are formed from a complex projection of utilities' current contracts and the estimates of future uranium prices, resulting in a significant rise in (real) price into the 1990's.

The curtailment of natural gas, in both the interstate and intrastate markets, significantly affects the future of the electric utility industry in the primary gas-burning States. ' The industry must replace the curtailed capacity by

[2] Ibid

[3] Federal Energy Administration, National Energy Outlook, February 1976

[4] Texas, Oklahoma, Louisiana, Kansas, Florida, and California (Texas alone burned 45 percent of all 1975 gas deliveries to steam-electric plants Louisiana was second with 11 percent)

utilizing existing alternative fuel-burning capability, by rebuilding boilers to burn oil or coal, or by building additional new capacity over that which would be built without natural gas curtailments. All the energy alternatives incorporate the following set of plausible conditions:

1. All gas plants with only coal as an alternative capability burn coal.
2. Al gas plants with only oil as an alternative capability burn oil.
3. Gas plants that can burn either coal or oil switch to these fuels in proportion to current consumption of coal and oil by powerplants in the affected State.
4. All gas plants with no alternative firing capability burn gas until 985 and then are gradually phased out over the 10-year period from 985 to 1995.

The last category includes 32 percent of the Nation's gas plants and 40 percent of the Texas, Louisiana, Oklahoma, and California gas capacity. This degree of curtailment agrees closely with utility plans filed with the FPC.

Additions to generating capacity in the selected scenario are an extension of currently scheduled additions to generating capacity as shown in table 4, disaggregated by Electric Reliability Council region. The regions are illustrated in figure 4. A more detailed examination of the schedule for fossil-fueled steam capacity shows a breakdown into 80.9 percent coal-fired, 17.5 percent oil-fired, and 1.6 percent gas-fired, with all the gas-fired capacity scheduled to come online by the end of 1978. For simplicity in scheduling out to later years, the apportionment of new fossil steam capacity is 81 percent coal and 19 percent oil.

The utilities have also reported their intentions to add capacity in the decade from 1986 through 1995. These data, also obtained from the nine National Electric Reliability Councils, are summarized in table 5. Since the data were not further broken down, the same 81 percent coal/19 percent oil split in these fossil-fueled steam generation units is assumed.

Considering only the steam capacity planned after 1985, the division between coal, oil, and nuclear in capacity additions is approximately as follows:

- Coal . . . 33 percent
- Oil . . . . . 8 percent

Fossil = 41 percent

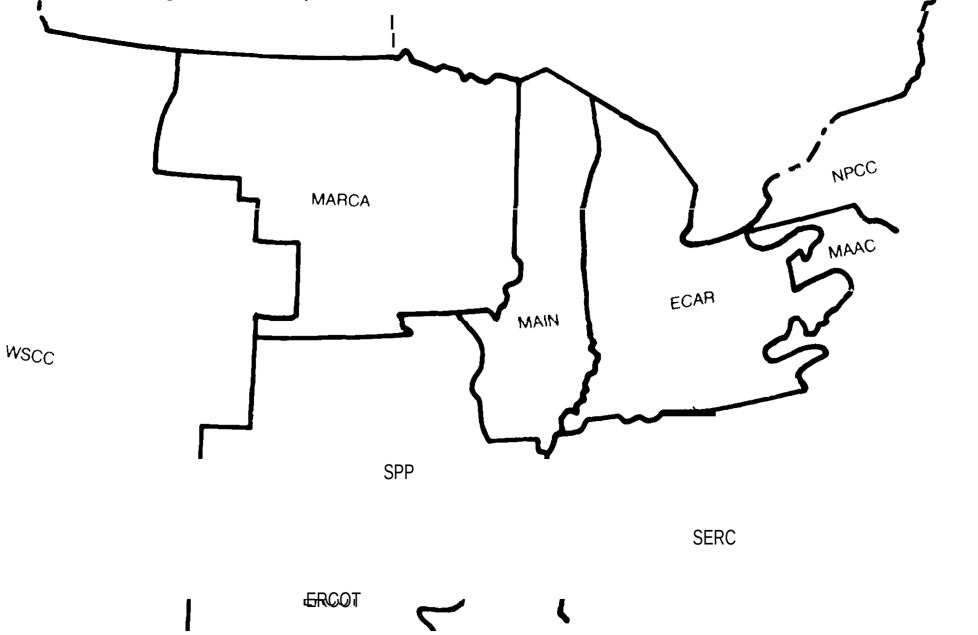
- Nuclear. . 59 percent

Table 4. Scheduled Additions to Capacity, for the Decade 1976-85, as of April 1,1976, as Reported by Nine Regional Reliability Councils

Council	Total additions (MW)	Nuclear		Fossil		Hydro, other	
		MW	%	MW	%	MW	%
NPCC. . .	26,137	20,043	76.7	4,175	16.0	1,917	7.3
MAAC . .	21,863	16,755	76.7	5,079	23.2	28	0.1
ECAR. . .	42,461	19,743	46.5	22,582	53.2	136	0.3
SERC . . .	72,021	49,997	69.4	18,761	26.0	3,262	4.5
MAIN . . .	22,987	13,266	57.7	8,386	36.5	1,335	5.8
SWPP. . .	34,752	12,255	35.3	20,851	60.0	1,644	4.7
ERCOT. .	17,739	4,945	27.9	12,433	70.1	360	2.0
MARCA .	13,968	2,396	17.1	11,316	81.0	254	1.8
WSSC . .	53,918	23,330	43.3	18,738	34.7	11,849	22.0
Totals	305,846	162,730	53.2	122,321	40.0	20,785	6.8

Source: National Electric Reliability Council.

Figure 4—Regional Reliability Councils of the National Electric Reliability Council



Source Teknekron Inc

Table 5. Planned Additions to Capacity for the Decade 1986-95, as of April 1,1976, as Reported by Nine Regional Reliability Councils

Council	Total additions (MW)	Nuclear MW	Nuclear 0/0	Fossil MW	Fossil %	Hydro, other MW	Hydro, other 0/0
NPCC. . .	37,710	28,954	76.8	3,175	8.4	5,581	14.8
MAAC . .	31,545	16,173	51.3	14,299	45.3	1,073	3.4
ECAR . . .	86,500	44,115	51.0	39,790	46.0	2,595	3.0
SERC . . .	35,021	19,927	56.9	11,172	31.9	3,922	11.2
MAIN . . .	51,570	28,234	55.0	23,336	45.0	0	0
SWPP. . .	75,844	40,752	53.7	35,090	46.3	0	0
ERCOT. .	44,000	23,900	54.3	19,220	43.7	880	2.0
MARCA .	18,591	8,180	44.0	9,760	52.5	651	3.5
WSCC . .	85,000	50,065	58.9	24,055	28.3	10,880	12.8
Totals	465,781	260,300	55.6	179,897	38.6	25,582	5.5

Source: National Electric Reliability Council.

All post-1985 steam capacity is assigned in the above proportion and the mix of capacity planned to 1985 remains unaltered.

A coal conversion plan for existing and announced fossil steam units embodied in the selected scenario is as follows:

- Federal Energy Administration (FEA) conversion orders under the Energy Supply and Environmental Coordination Act (ESECA), for the conversion of oil and gas plants to coal plants, are not approved by E PA, and no such conversions take place.
- Gas plants that can convert only to coal do **SO.**
- All new oil-fired fossil steam units coming online after 1980 burn oil.
- Gas plants that can burn either coal or oil switch to these fuels in proportion to the consumption of coal and oil by powerplants in the affected State.

In summary, the energy alternative represented by the selected scenario is a relatively high demand, high nuclear one, particularly in the years beyond 1985. The high rate of demand growth and the low proportion of coal to nuclear plants tend to balance each other to produce an intermediate projection of coal use. A recapitulation of the main energy features of the scenario follows.

- Growth in demand for electric energy
  — 5.4 percent per year
- Growth in peak power demand
  — 5.9 percent per year
- Additions of new steam capacity after 1985
  –33 percent coal
  –8 percent oil
  —59 percent nuclear
- Conversion policy
  – FEA conversion orders under ESECA, for the conversion of oil and gas plants to coal plants, are not approved by EPA and no such conversions take place.
  –Gas plants that can convert only to coal do **SO.**
  —All new oil-fired fossil steam units coming online after 1980 burn oil.
  —Gas plants that can burn either coal or oil switch to these fuels in proportion to the consumption of coal and oil by powerplants in the affected State.

Environmental Alternatives

When incorporated into a scenario, each of several environmental policy alternatives will elicit a different response from the utilities, because of the intimate relationship between regulation and the behavior of the industry. The alternatives considered emphasize limitations on emissions from coal-fired plants as well as plant-siting restrictions. Utility response concerns the type of coal used, the pollution-control strategy employed, and the location of the post-1985 plants.

The chosen scenario illustrates the impact of a Non-Significant Deterioration (NSD) policy reflecting recent amendments to the Clean Air Act. This alternative is characterized by a restrictive siting policy and by one interpretation of what constitutes Best Available Control Technology (BACT). Siting is prohibited in areas where deterioration of air quality cannot be tolerated (for example, national parks and other Federal lands) and in nonattainment areas. Flue gas desulfurization (FGD) is required for all new coal units online after 1981. Assumed policy instruments include:

- Current State implementation plans.
- Current New Source Performance Standards.
- Siting prohibited in Class I and nonattainment areas. Since siting is not allowed in any county that contains any part of a Class I area, a significant land area is proscribed for development.
- For new sources online after 1981, BACT is required for $S0_2$. This is interpreted to mean mandatory FGD with 90-percent removal efficiency.

The policy of nonsignificant deterioration is designed to prevent the deterioration of air quality in those regions now cleaner than required by the National Ambient Air Quality Standards. The recent Clean Air Act amendments have the same goal. Area descriptions relating to NSD requirements considered in this analysis are as follows:

- Mandatory Class I if area exceeds 5,000 acres
  - — national and international parks
  - — national wilderness areas and wildlife refuges
- Class I with provision for redesignation as Class I I
  - — national monuments, recreational areas, wild and scenic rivers
- Class I I with provision for redesignation to Class I
  - — national preserves, forests, reservations, and other Federal lands

All mandatory or discretionary Class I areas are considered Class I in the Utility Simulation Model. The model's smallest resolution is at the county level; hence, any county containing any Class I area is designated a Class I county. In this scenario, the siting of fossil-fuel powerplants in Class I counties is prohibited, even though a small plant might be permitted by the increment of deterioration allowed.

In selecting a site for a new plant a utility makes a difficult decision, taking into account the distance to load center, costs of fuel and electricity transmission, availability of water and labor, and siting restrictions for environmental reasons, There are conflicting criteria for siting. Remote siting may be required to remove the source from a polluted area with a high population density, while regulations to prevent the significant deterioration of air quality exert pressure for siting away from clean areas toward areas having greater population density.

Remote siting has been an important alternative for coal. Typically, transportation accounts for a very significant fraction of the cost of coal delivered to the utility. Location near the mine, with long transmission lines, has proved cost effective in some cases. Projections of future costs of transport indicate an increased tendency toward remote siting. On the other hand, nonsignificant deterioration proposals would constrain both the number of available sites and the maximum size of a fossil-fueled plant. Taking all considerations into account leads to two different siting constraints:

- Siting of new (post-1985) fossil-fueled plants conforms to NSD regulations. Transmission costs, transportation costs, availability of water, and suitability of terrain are taken into account only in Class II areas. No siting is allowed in Class I counties, because the allowed air quality increments are too small to support an economically sized generation facility. A Class I county is a county having anywhere within its boundaries a Class I area as specified by the proposed amendments,
- Siting of new (post-1 985) plants is prohibited in areas where primary NAAQS for sulfur oxides, nitrogen oxides, or total suspended particulate are currently exceeded.

Results

The projections generated by the model under the selected scenario approximate an average annual compound growth rate for utility steam coal consumption of 4.2 percent. The total volume is projected to be 942 million tons in the year 2000 compared with actual deliveries to electric utilities of 429 million tons in 1975. Before 1985, the projection is consistently lower than those of several other studies, due to three major causes. One is the exclusion of some noninvestor-owned utilities, which accounted for 27 million tons of coal in 1974. Another is the use in this study of electric power demand growth instead of announced additions to generating capacity as a realistic determinant of future fuel use. The last causes a reduced rate of assumed growth based on recent experience as opposed to historical averages.

Levels of projected coal production by region appear in table 6, and patterns of distribution from producing region to consuming States are detailed in table 7. Figures 5 through 9 are maps indicating those flows of more than 5 million tons per year which traverse distances over 200 miles. Pipeline transportation is unlikely to be economically competitive at lesser distances and volumes.

The results corresponding to the seven additional scenarios indicate that the magnitudes of the flows are quite dependent on assumed demand growth rates, and that the spatial distribution of the coal movements are highly sensitive to environmental regulation and transportation cost assumptions. Penetration of western coal into eastern markets, for example, is highly dependent on transportation costs and on BACT requirements. High transportation costs and BACT tend to reduce the use of western coal east of the Mississippi. Also, the fact that the model chooses only one source of coal for a State, given a set of environmental requirements and embodies no market price-adjustment mechanism, tends to reduce the realism of results at the individual State level. The coal flows presented are therefore only illustrative of a plausible overall national pattern, and embody a high degree of uncertainty.

Table 6. Projected Regional Utility Coal Production

(Millions of tons per year)

Year	Appalachian (Northern, Central, and Southern)	Interior (Eastern and Western)	Western (North, Central, and South)	Total (Including Texas)
1975a	**208**	**134**	**73**	**429**
1980	**111**	**31**	**163**	**399**
1985	**224**	**64**	**223**	**523**
1990	**259**	**101**	**260**	**632**
1995	**297**	**133**	**324**	**772**
2000	**352**	**211**	**364**	**942**

[a] 1975 figures are actual. Differences in the distribution of production between 1975 and 1980 are due primarily to the assumption underlying the model that specified environmental regulations will be complied with by 1980.

Source: Derived from data in Teknekron, Inc.

Table 7. Projected Utility Coal Distribution From Region of Origin to State of End Use
(Millions of tons per year)

State	Year 1980	1985	1990	1995	2000
Alabama (total)	12	12	15	18	21
S. Appalachian	12	12	15	18	21
C. Western	0.20	0.10	0.03	—	—
Arizona (total)	2.7	0.44	0.34	0	0
S. Western	2.7	0.44	0.34	—	—
Arkansas (total)	0	1.6	3.4	7.0	8.4
I. Eastern	—	1.6	1.8	7.0	8.4
C. Western			1.6		
California (total)	0.91	9.2	14	31	39
C. Western	**0.64**	**8.9**	**14**	**31**	**38**
S. Western	**0.27**	**0.27**	—	—	**0.95**
Colorado (total)	**4.4**	**6.3**	**8.8**	**12**	**16**
C. Western	4.4	6.3	8.8	12	16
Connecticut (total)	0	1.1	0	0	0
C. Appalachian	—	1.1	—	—	—
Delaware (total)	1.2	1.0	1.2	1.1	0.96
C. Appalachian	1.2	1.0	1.2	1.1	0.96
C. Western	—	0.03	—	—	—
Florida (total)	8.8	16	21	22	32
S. Appalachian	**8.8**	**16**	**21**	**22**	**32**
Georgia (total)	**1.6**	**19**	**23**	**28**	**39**
I. Eastern	1.6	19	23	28	39
Idaho (total)	1.5	3.0	3,0	2.9	3.0
C. Western	**1.5**	**3.0**	**3.0**	**2.9**	**3.0**
Illinois (total)	**30**	**35**	**38**	**47**	**74**
I. Eastern	10	**16**	**22**	**31**	**58**
C. Western	**20**	**19**	**16**	**16**	**16**
Indiana (total)	**30**	**30**	**43**	**47**	**59**
I. Eastern	—	**5.3**	**18**	**28**	**42**
C. Western	**30**	**25**	**25**	**19**	**17**
Iowa (total)	**5.9**	**8.7**	**9.0**	**7.4**	**10**
I. Eastern	**5.9**	**4.7**	**4.1**	**3.3**	**2.7**
I. Western	—	**3.8**	**4.9**	**4.1**	**7.3**
Kansas (total)	**5.7**	**4.8**	**8.1**	**23**	**19**
I. Eastern	5.7	1.8	—	—	—
I. Western	—	3.0	3.6	—	—
C. Western	—	—	4.5	23	19
Kentucky (total)	23	23	25	29	34
C. Appalachian	**23**	**19**	**5**	**13**	
I. Eastern	—	**3.6**	**9.8**	**16**	**23**
Louisiana (total)	**0**	**8.5**	**9.4**	**14**	**16**
S. Appalachian	—	**1.5**	**8.3**	**11**	**16**
I. Eastern	—	**1.5**	**1.1**	—	—
C. Western	—	**5.5**	—	**3.5**	—

Table 7. Projected Utility Coal Distribution From Region of Origin to State of End Use—Continued

(Millions of tons per year)

	Year				
State	**1980**	**1985**	**1990**	**1995**	**2000**
Maine (total)	0	0	0	0	0
Maryland and D.C. (total)	3.6	6.2	5.6	12	14
N. Appalachian	3.4	5.8	5.1	12	14
C. Appalachian	0.13	0.30	0.40	—	
S. Appalachian	—	—		0.10	0.10
C. Western	0.10	0.10	0.10	0.03	0.03
Massachusetts (total)	0	0	0	0	0
Michigan (total)	25	29	26	26	30
I. Eastern	—	5.8	8.2	7.6	13
N. Western	25	23	18	17	17
C. Western	0.06	—	—	1.8	—
Minnesota (total)	5.4	11	14	16	17
N. Western	5.4	9.7	13	15	16
C. Western	—	1.2	1.1	1.1	1.0
Mississippi (total	3.8	4.9	6.1	10	13
S. Appalachian	3.8	4.9	6.1	10	13
Missouri (total)..	25	27	29	35	41
I. Western.	—	1.6	6,0	17	27
C. Western	25	25	23	18	14
Montana (total)	7.4	7.4	7.3	7.3	7.3
N. Western	**7.4**	**7.4**	**7.3**	**7.3**	**7.3**
Nebraska (total)	**5.2**	**5.2**	**5.2**	**5.2**	**5.2**
C. Western	5.2	5.2	5.2	5.2	5.2
Nevada (total)	6.5	7.4	9.8	7.5	3.9
C. Western	6.5	7.4	9.8	7.5	3.9
New Hampshire (total)	0.10	0.60	0.04	0.50	0.30
N. Appalachian	0.10	0.60	0.04	0.50	0.30
New Jersey (total)	1.5	1.3	1.0	1.0	2.5
N. Appalachian	0.52	0.32	—	—	1.5
C. Appalachian	1.0	1.0	1.0	1.0	1.0
New Mexico (total)	7.3	8.1	9.3	12	10
C. Western	—	—	—	—	**2.4**
S. Western	**7.3**	**8.1**	**9.3**	**12**	**7.9**
New York (total)	**3.8**	**3.5**	**8.8**	**8.8**	**11**
N. Appalachian	**1.9**	**1.8**	**7.2**	**7.6**	**8.3**
C. Appalachian	**1.9**	**1.7**	**1.6**	**1.2**	**2.6**
North Carolina (total)	**18**	**18**	**15**	**15**	**16**
C. Appalachian	18	18	15	15	16
S. Appalachian	0.31	—	0.10	0.01	0.07
North Dakota (total)	0.29	0.77	3.9	6.6	12
N. Western	0.26	0.76	3.9	6.6	12
C. Western	0.03	0.01	0.01	0.01	0.02

Table 7. Projected Utility Coal Distribution From Region of Origin to State of End Use—Continued

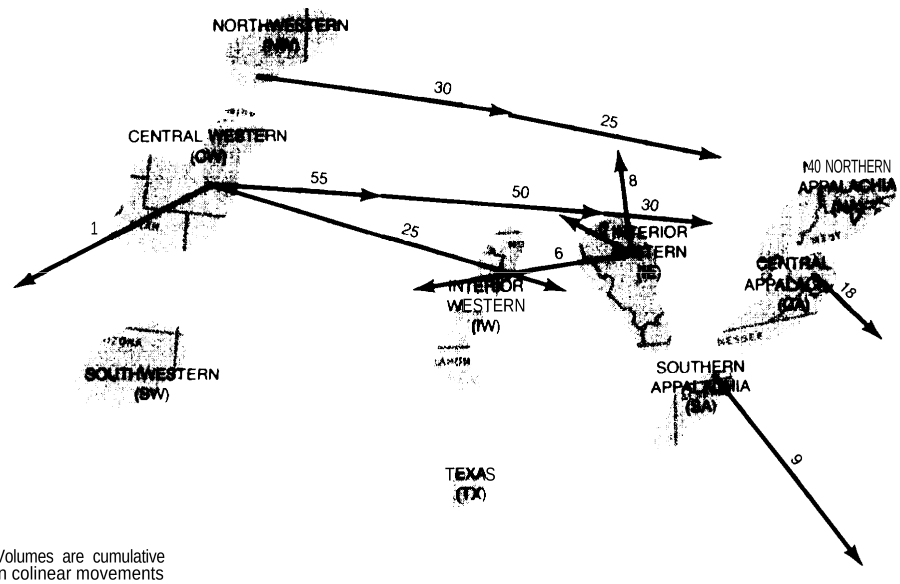
(Millions of tons per year)

State	1980	1985	1990	1995	2000
Ohio (total)	45	48	43	48	48
N. Appalachian	43	47	42	47	47
C. Western	1.6	1.3	1.1	1.1	0.92
Oklahoma (total)	0.02	9.2	14	17	25
I. Western	—	9.2	14	17	25
C. Western	0.02	—	—	—	—
Oregon (total)	1.5	3.1	0.06	5.1	1.0
N. Western	—	—	—	0.9	1.0
C. Western	1.5	3.1	0.06	4.2	—
Pennsylvania (total)	37	36	55	59	67
N. Appalachian	33	32	50	57	67
C. Appalachian	4.0	3.6	4.9	1.9	—
Rhode island (total)	0	0	0	0	0
South Carolina (total)	1.9	2.0	1.7	1.2	1.2
S. Appalachian	1.9	2.0	1.7	1.2	1.2
South Dakota (total)	1.4	2.1	2.2	2.4	2.7
N. Western	1.4		1.4	1.4	—
C. Western	—	0.70	0.80	1.0	2.7
Tennessee (total)	19	8.8	7.0	2.8	0.96
S. Appalachian	19	8.8	7.0	2.8	0.96
Texas (total)	15	48	84	112	141
S. Appalachian	—	1.5	1.1	1.0	—
C. Western	1.3	35	72	93	125
S. Western	—	—	—	0.20	0.20
Texas	14	12	12	18	16
Utah (total)	3.2	4.0	2.0	8.0	18
C. Western	3.2	4.0	2.0	8.0	18
Vermont (total)	o	0	0	0	0
Virginia (total)	6.2	3.4	5.2	5.3	9.2
C. Applalachian	3.4	1.5	4.4	4.5	8.9
S. Applachian	2.8	1.90	0.80	0.80	0.30
Washington (total)	2.9	2.9	2.9	2.9	2.9
N. Western	2.9	2.9	2.9	2.9	2.9
West Virginia (total)	24	23	30	44	52
N. Appalachian	1.2	1.1	0.97	0.54	—
C. Appalachian	23	22	29	43	52
Wisconsin (total)	12	13	9.2	10	6.5
I. Eastern	7.5	9.3	5.9	6.9	3.5
N. Western	4,4	3.9	3.3	3.3	3.0
Wyoming (total)	4.4	10	12	9.8	12
C .Western	4.4	10	12	9.8	12

Source: Data from Teknekron, Inc.

NOTE: These projections are intended to illustrate a plausible overall national pattern and do not represent predictions that the coal volumes will be transported between the listed origins and destinations.

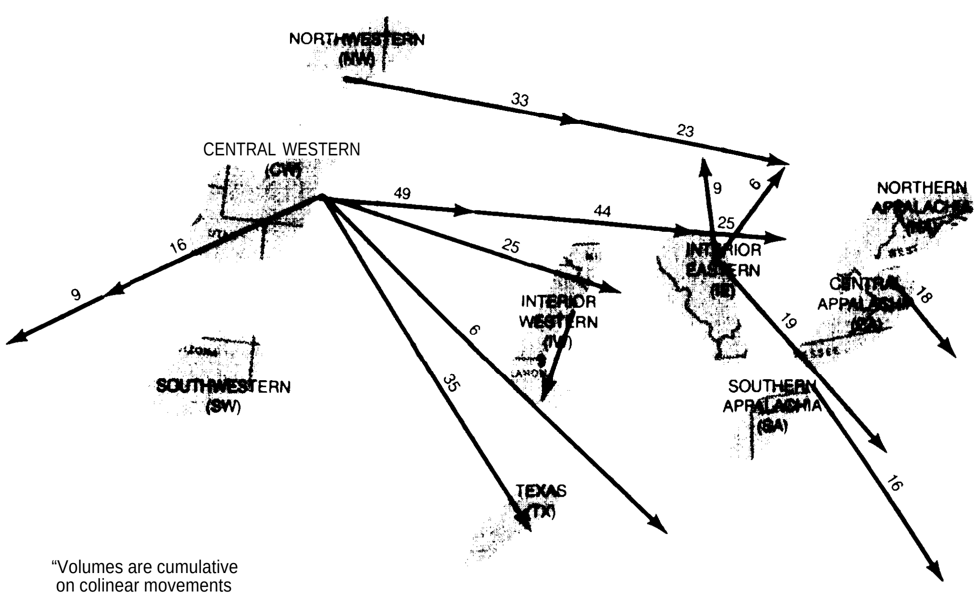
Figure 5–Year 1980 Potential Utility Coal Movements of More Than 5 Million Tons per Year over Distances Greater Than 200 Miles (Millions of Tons per Year)*



● Volumes are cumulative on colinear movements

Source Teknekron Inc

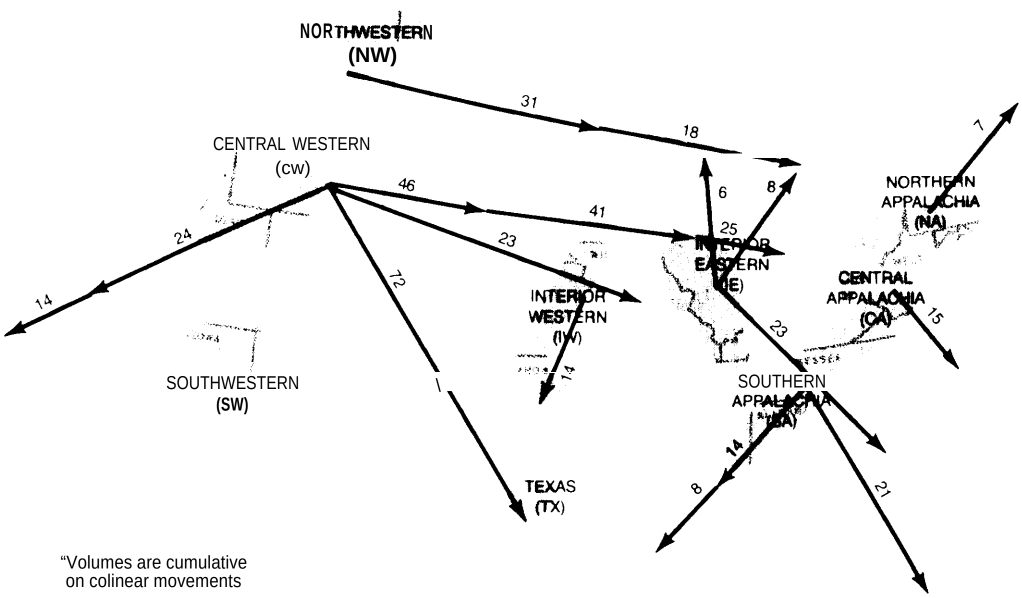
Figure 6–Year 1965 Potential Utility Coal Movements of More Than 5 Million Tons per Year over Distances Greater Than 200 Miles (Millions of Tons per Year)*



*Volumes are cumulative on colinear movements

Source Teknekron Inc

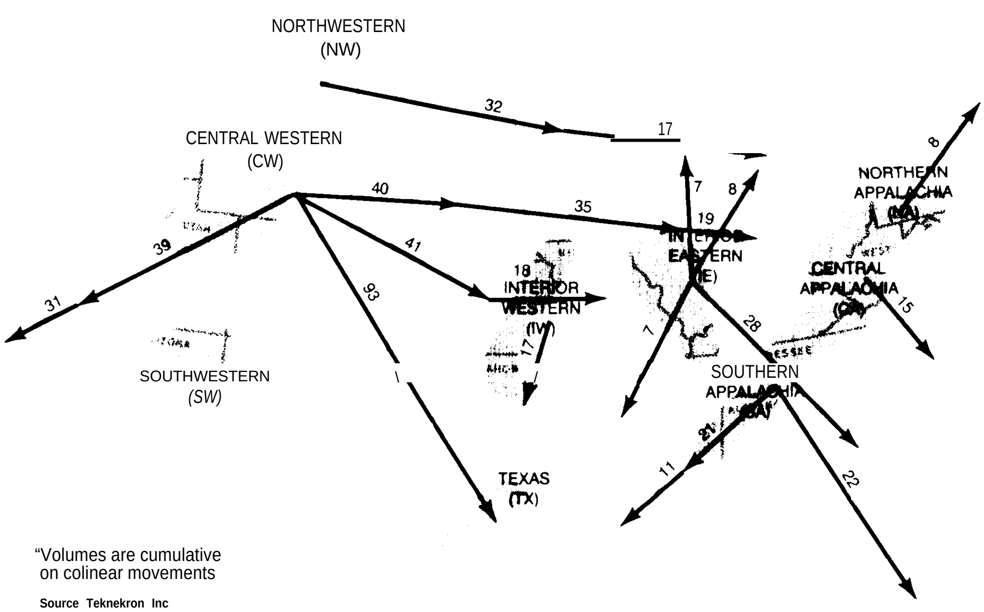
Figure 7–Year 1990 Potential Utility Coal Movements of More Than 5 Million Tons per Year over Distances Greater Than 200 Miles (Millions of Tons per Year)*



"Volumes are cumulative on colinear movements

Source Teknekron Inc

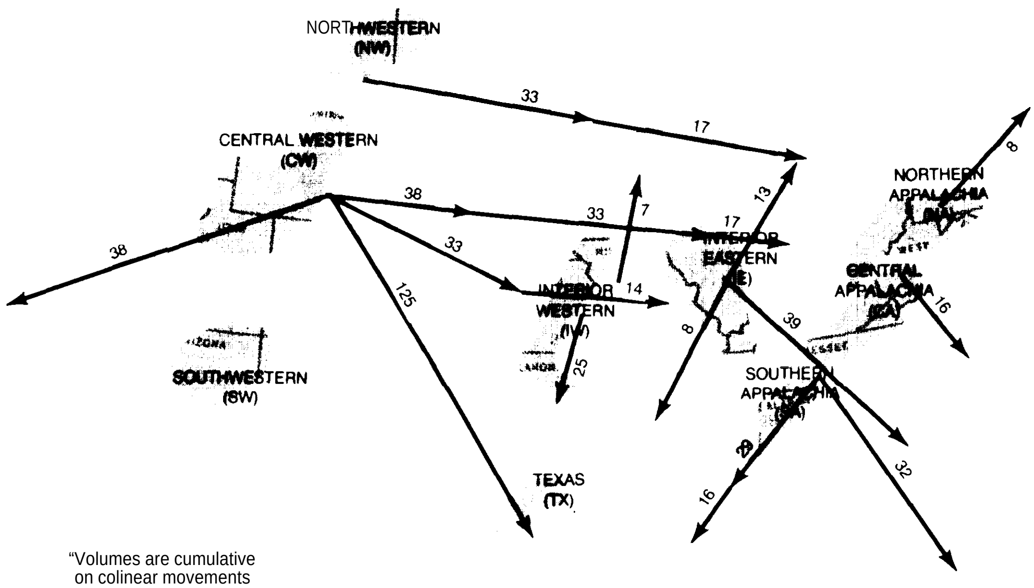
Figure 8– Year 1995 Potential Utilitv Coal Movements of More Than 5 Million Tons per Year over Distances Greater Than 200 Miles (Millions of Tons per Year)*



"Volumes are cumulative on colinear movements

Source Teknekron Inc

Figure 9–Year 2000 Potential Utility Coal Movements of More Than 5 Million Tons per Year over Distances Greater Than 200 Miles (Millions of Tons per Year)*



“Volumes are cumulative on colinear movements

Surce Teknekron Inc

COST COMPARISONS AND TRAFFIC ASSUMPTIONS

Comparison of the economic and environmental features of a world with slurry pipelines to another without them requires the establishment of plausible scenarios describing the nature of the transportation system in each case. The critical characteristics to be specified for each mode are cost and extent of operations. The world without pipelines involves a rail system which, with other present modes, would meet the hypothetical demand for utility coal transportation outlined in the last section. Under the other scenario, one envisions a hybrid rail and pipeline system which would carry projected traffic by the cheaper mode from the shipper’s standpoint.

The second scenario is necessarily highly conjectural, depending not only on the simplified projections of the coal transportation market, but also on crude cost estimates and uncertain predictions of the behavior of transportation firms, their customers, and government regulatory bodies. However, the purpose of this section is to derive a plausible if arbitrary set of market share and cost assumptions that are sufficiently favorable to pipelines to provide a basis for comparison with a “no pipeline” alternative.

costs

Four hypothetical case studies, described in Volume 11, provide the focus for both the cost and environmental analyses of the assessment. Four coal flows from among those identified in the last section were chosen and arbitrarily assigned specific States of origin as follows:

1. Central Western coal from Wyoming to Texas,
2. Northwestern coal from Montana to Minnesota and Wisconsin,
3. Central Western coal from Utah to California.
4. Southern Appalachian coal from Tennessee to Florida

These four origin and destination pairs exhibit differences in a) region of the country, b) condition and circuity of the rail system, c) type of terrain, d) access to water, e) type and **concentration** of mining activity, and f) volumes of coal to be transported.

The costs considered here are incremental ones from the viewpoint of a railroad or pipeline enterprise, and they therefore represent the rates that a firm providing the transportation would have to charge its shippers in order not to lose money on the traffic in question They do not necessarily represent the rates that would be charged in the current regulatory environment, and they include neither profit beyond a minimum cost of capital for direct investment nor any contribution to the fixed costs of a larger railroad or pipeline system. The estimates presented also provide for no change in technology or productivity with time for either mode, and they reflect present, and therefore not necessarily ideal, conditions in the railroad industry. Finally, the costs derived for specific individual movements from engineering considerations as discussed below should not be confused with overall system costs, which include economies of scale and are covered in a later section on economic impacts.

Pipeline Estimating Procedure

To be comparable with rail costs, pipeline estimates here include the entire process of transporting coal from individual mines to powerplants, including collection and distribution by branch feeder lines, Requirements imposed upon a given pipeline by the nature of the application can be expressed in terms of the following factors:

1. Distance the coal must be carried.
2. Volume of coal to be carried,
3. Moisture content of the coal.
4. Difference between elevations of termini.
5. Terrain characteristics.
6. Distance to and elevation of the water Supply.
7. Size and spacing of mines.
8. Size and spacing of powerplants.

engineering design considerations, industrial experience, and data from equipment manufacturers form the basis for identifying and quantifying individual resource requirements as follows:

Initial construction:

1. Slurry preparation and dewatering equipment and facilities.
2. Pump stations, including pumps and lined ponds.
3. Steel pipe, including freight,
4. Right-of-way and pipe laying.
5. Engineering, supervision, inspection, and contingency.

Continuing Operation:

1. Direct Labor.
2. Power.
3. Maintenance, materials, and supplies.
4. Water.
5. Administration.

Cost estimates are derived by applying prices to the above elements, providing for inflation in the continuing operating costs, amortizing the required initial investment, and postulating a tax rate. The details of the methodology and the values used in the analysis are set forth in detail in Volume II, and figures 10 through 14 illustrate how the cost elements that are not site-dependent are related to the volume of coal to be carried, the distance to be covered, and the *required* number of pumping stations. One should note in interpreting the cost relationships, that the pump stations are assumed to operate against a given pressure difference of 1,000 pounds per square inch. Fewer stations are therefore required as the diameter of the pipe increases.

These costs have been adjusted in the case studies to account for acquisition of water and for nonideal construction conditions based on the particular characteristics of a pipeline application. Areas of particular uncertainty include future construction costs and the appropriate price for water.

Rail Estimating Procedure

Although operating experience for railroads is more extensive than for pipelines due to the longer history of the industry and its more established technologies, establishing the marginal, or out-of-pocket costs for a given element of hypothetical traffic is no more .straightforward. The factors determining rail costs for coal unit trains include the following:

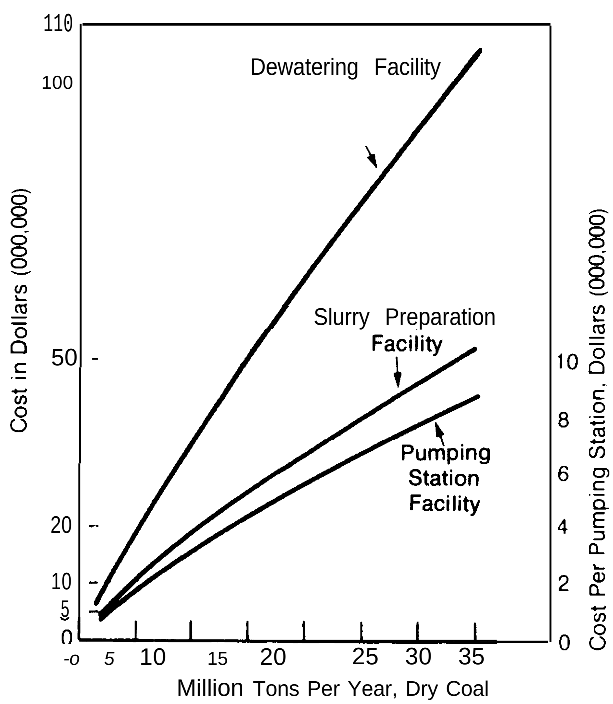
1. Distance the coal must be carried.
2. Volume of the coal to be carried.
3. Unused capacity and condition of tracks along the route.
4. Length and speed of trains.
5. Terrain and circuity of the route.
6. Administration.

The cost elements that do not depend on site-specific conditions appear below:

1. Acquisition of rolling stock —
   $550,000 per locomotive
   $30,000 per 100 net-ton hopper car
   $43,000 per caboose
2. Track improvement —
   $500,000 per mile of new track
   $200,000 per mile of upgraded track
3. Train crews (including dead heading)
   $550 per 100 train miles
4. Diesel fuel –
   $0.35 per gallon
5. Operation and maintenance of rolling stock —
   $0.44 per mile per year per locomotive
   $0.03 per mile per year per hopper car
   $002 per mile per year per caboose
6. Track maintenance per mile per year—
   $5,300 plus $342 per million tons of traffic
7. Administration —
   $0.30 per thousand ton-miles

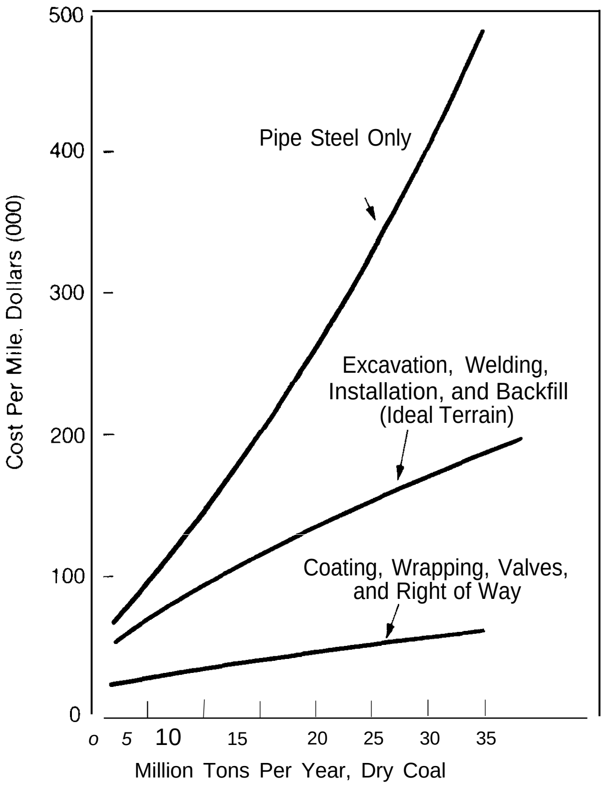
Acquisition and operating costs of loading and unloading facilities depend on site-specific conditions as do the amount of fuel and track upgrading required. The amount of track investment required for a particular traffic element is particularly uncertain, as is the degree to which other traffic should properly be charged for some of the cost of a given improvement. Also, railroad ownership of rolling stock has been assumed. If customers owned the hopper cars, they would pay a reduced transportation rate and would have to finance the acquisition and maintenance of the cars. Utilities often find this arrangement advantageous. Initial investment financing, inflation, and taxes are all treated in the same fashion as for pipelines, and the details of the methodology are also described more fully in Volume II.

Figure 10–Slurry Facility First Costs
(Including an 18 percent provision for engineering, inspection, and contingencies)



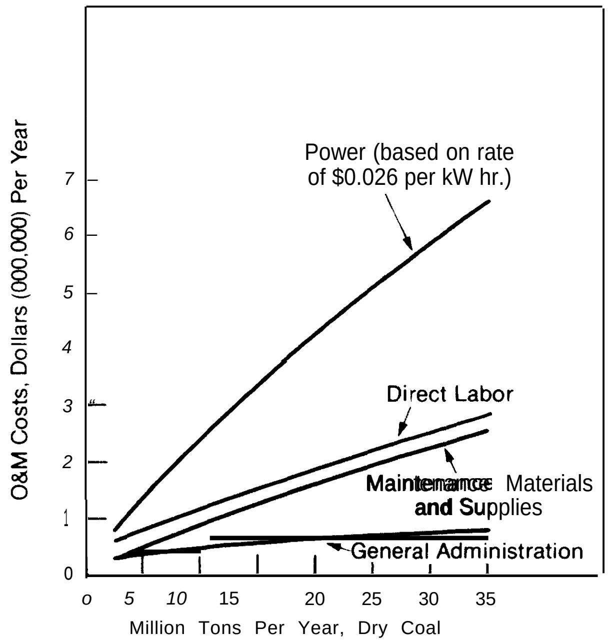
Source General Research Corp

Figure 11– Pipeline First Costs
(Including an 18 percent provision for engineering, inspection, and contingencies)



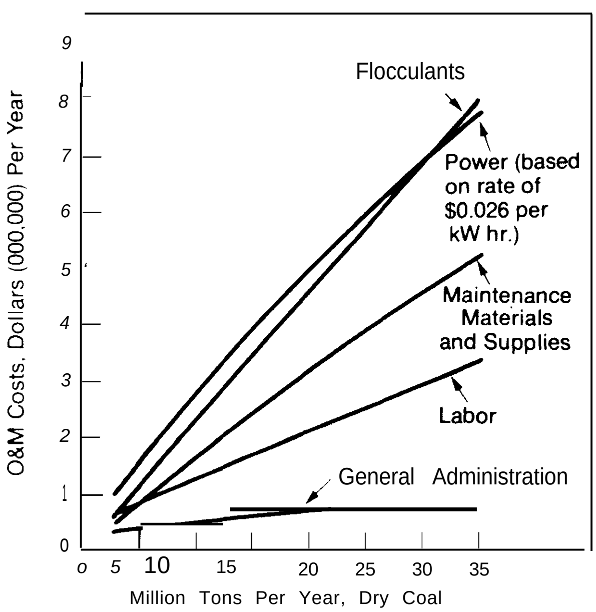
Source General Research Corp

Figure 12–Annual Operation and Maintenance Costs, Slurry Preparation Facility
(Excluding water)



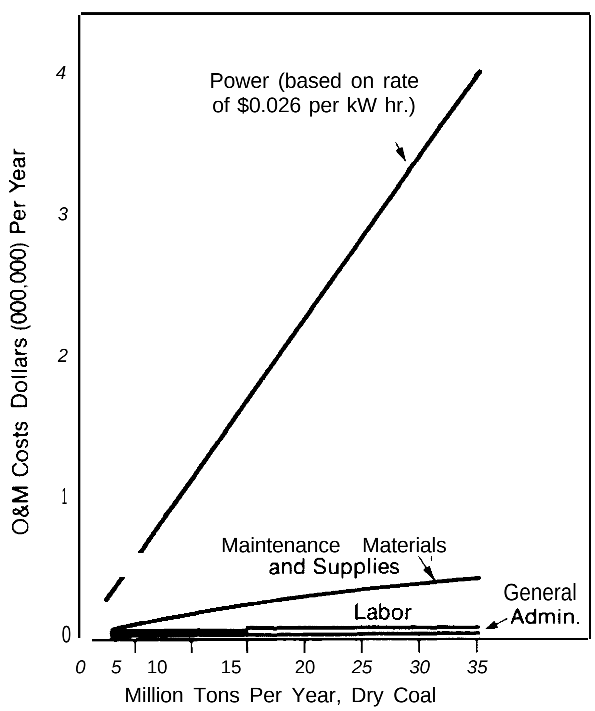
Source General Research Corp.

Figure 13–Annual Operation and Maintenance Costs, Slurry Dewatering Facility



Source General Research Corp

Figure 14–Annual Operation and Maintenance Costs per Pumping Station



Source General Research Corp

Selected Case Results and Discussion

Table 8 illustrates the comparative characteristics and costs of four specific coal flows by rail and pipeline. Pipeline transportation appears more economical in the Wyoming to Texas and Tennessee to Florida cases, and rail is less costly for both Montana to Minnesota and Wisconsin, and for Utah to California.

The Wyoming to Texas case illustrates the advantages of carrying a large volume of coal in a single pipeline over a great distance. The pipeline would be over 1,000 miles long and carry 35 million tons per year over most of its length. To achieve this scale requires that eight powerplants in two regions of Texas be served by the same pipeline, and the fact that only four mines near Gillette, Wyo., could produce the required volume contributes to the economy of operation.

Between Montana and the destinations in Minnesota and Wisconsin, the rail route is direct and in good physical condition. Train lengths of 105 cars and average speeds of 22 miles per hour, including stops for loading and unloading, also play a role in the rail cost advantage in this case, as does the railroad's flexibility to serve economically a relatively larger number of mines and powerplants for a given volume of coal.

The Utah to California case represents the least annual volume, the shortest distance, and the smallest mines served. It also represents the most difficult terrain for both pipeline construction and rail operation, and the advantage of trains is offset partially by their roughly 30-percent greater route circuity and the need to replace 25 percent of the present rail.

The only case east of the Mississippi, from Tennessee to Florida, illustrates that even though several mines and powerplants would have to be served and the rail route is not particularly circuitous, pipelines may be advantageous if rail operating conditions are significantly less than ideal. On this route, which is not necessarily typical of coal-producing areas, 35 percent of the track would have to be replaced or upgraded, and trains would be substantially shorter and slower than i n the other cases.

Other factors not mentioned above which influence the relative costs of unit trains and slurry pipelines include the expected rate of inflation in labor and operating costs of electricity and diesel fuel, and the cost of water delivered at the pipeline source. To oversimplify somewhat, the cost of unit train transportation of coal is roughly one-third amortization of investment in facilities and equipment and two-thirds operating expense, including labor. Pipeline costs, on the other hand represent nearly two-thirds initial investment and just over one-third continuing operation. Therefore, high rates of anticipated inflation favor pipelines over rail, while high real interest rates and labor productivity improvements have the opposite effect. The cost figures derived here are based on a 6-percent annual rate of inflation and a 61A-percent real interest rate, which added together, amount to a nominal discount rate of 1 21/2 percent.

Energy resource costs also influence the relative advantages of each mode. If one considers the fuel required to generate electricity, railroads and pipelines use roughly comparable amounts of energy directly to provide power for equipment. However at $0.35 per gal lon, diesel fuel represents typically about one-eighth of the cost of operating a coal unit train, while electricity at $0.026 per kilowatt hour amounts to approximately one-fifth of the cost of carrying the same coal by an equivalent-sized pipeline. Since the energy portion of the cost is substantial, increases in the cost of diesel fuel relative to that of electricity will improve the competitive position of pipelines, at least until electrification becomes advantageous to the railroads.

High water costs, on the other hand, can substantially weaken the competitive position of pipelines. Carrying 18 million tons of coal from Gillette, Wyo., to Dallas, Tex., for example, would require 8,554 acre-feet of water per year. If this amount were purchased for $20

Table 8. Sample Hypothetical Case Results

Characteristics	Wyoming to Texas	Montana to Minnesota & Wisconsin	Utah to California	Tennessee to Florida
General				
Volume (millions of tons per year)	35	13.5	10	16
Origin Vicinity	Gillette	Colstrip	Price	Tracy City
Destination vicinity	Dallas (18 million tons) Houston (17 million tons)	Becker, M inn. (10 million tons) Portage, Wise. (3.5 million tons)	Barstow	Tampa (8 millions tons) Miami (8 million tons)
Number of mines	4	3	7	8
Number of powerplants	5 (Dallas) 3 (Houston)	3 (Becker) 2 (Portage)	3	3 (Tampa) 4 (Miami)
Pipeline				
Trunkline length	Gillette-Dallas, 936 miles Dallas-Houston, 234 miles	Colstrlp-Becker, 661 miles Becker-Portage, 260 miles	522 miles	Tracy City-Tampa 556 miles Tampa-Miami 247 miles
Average distance from mine to trunkline	12,5 miles	10 miles	12.4 miles	20 miles (Tampa) 22 miles (Miami)
Percentage moisture of coal by weight	21 percent	17 percent	6.6 percent	4.8 percent
Water requirement in acre-feet per year	16,640	7,250	6,961	11,580
Water source	Big Horn River	Big Horn River	Green River	Lake Nickajack
Length of water line	205 miles	80 miles	42 miles	20 miles
Total cost of water delivered per acre-foot	$922	$513	$469	$184
Number of pump stations	Gillette-Dallas 4 Dallas-Houston 3	Colstrip-Becker 8 Becker-Portage 8	7	Tracy City-Tampa 6 Tampa-Miami 4
Outside pipe diameter	Gillette-Dallas 42” Dallas-Houston 29”	Colstrip-Becker 27” Becker-Portage 14”	24”	Tracy City-Tampa 31” Tampa-Miami 22”
Present worth of 30-year life cycle cost (1977 dollars)	$2,502 million	$1,156 million	$996 million	$1,626 million
Annual cost per ton (1977 dollars at a 6.5-percent real cost of money)	$5.50	$6.60	$7.60	$7.80
Simulated rate per ton (1977 dollars with a 12.5-percent nominal return on investment)	To Dallas $5.90 To Houston $6,50	To Becker $6.00 To Portage $10.80	$9.90	To Tampa $7.30 To Miami $9,70

Table 8. Sample Hypothetical Case Results—Continued

Characteristics	Wyoming to Texas	Montana to Minnesota & Wisconsin	Utah to California	Tennessee to Florida
Rail				
Average route length . .	Gillette-Dallas, 1,264 miles Gillette-Houston, 1,584 miles	Colstrip-Becker, 757 miles Colstrip-Portage, 1,055 miles	684 miles	Tracy City-Tampa 776 miles Tracy City-M i am i 938 miles
Number of cars per train . .	105	105	100	60
Average number of locomotives per train	6	Colstrip-Becker, 4.27 Colstrip-Portage, 4.19	6.2	3.9
Average round-trip speed (including time loading and unloading)	22 mph	22 mph	14.2mph	13mph
Average locomotive miles per gallon of fuel	0.4	0.29	0.38	0.33
Percentage of new track required . .	Gillette-Dallas, 5 percent Gillette-Houston, O percent	0 percent	25 percent	5 percent
Percentage of track to be upgraded	Gillette-Dallas 30 percent Gillette-Houston 20 percent	5 percent	10 percent	30 percent
Investment in loading and unloading facilities.	$174 million	$88 million	$64 million	$150 million
Annual operation of loading and unloading facilities. . .	$14 million	$7.0 million	$5.3 million	$9.3 million
Present worth of 30-year life cycle cost (1977 dollars).	$3,939 million	$1,059 million	$893 million	$1,930 million
Annual cost per ton (1977 dollars at a 6.5-percent real cost of money) . . .	$8.60	$6.00	$6.80	$9.20
Simulated rate per ton (1977 dollars with a 12.5-percent nominal return on investment) . . .	To Dallas, $8.70 To Houston, $9.10	To Becker, $5.40 To Portage, $8.40	$7.30	To Tampa, $9.00 To Miami, $10.50

Note: The ranges of uncertainty associated with these specific rail and pipeline cost estimates may be as large as the differences between them. For underlying simplifications and assumptions, see text at the end of this chapter. Also, the coal tonnages are for illustrative purposes only and do not represent predictions that the coal volumes will be transported by pipeline or any other mode between the listed origins and destinations.

Source. Data from General Research Corp.

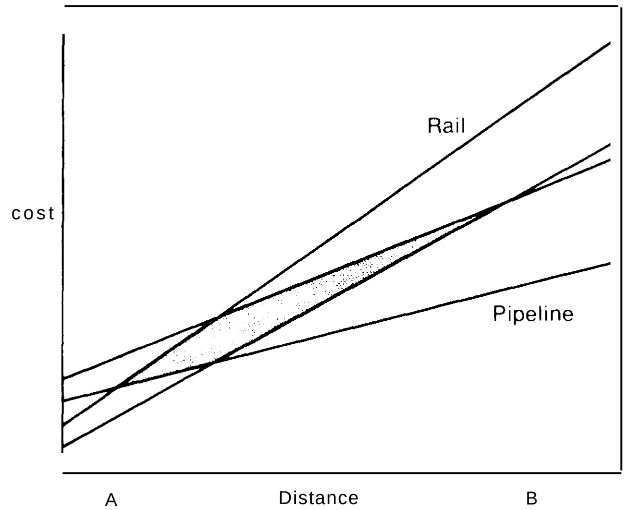
per acre-foot at Big Horn River and transported by pipe to Gillette, the total cost would be $922 per acre-foot, or $0.47 per ton of coal shipped. Of the total amount of water used, about 4,905 acre-feet could be extracted and recycled by return pipeline, raising the total water cost to $1 75 per ton of coal, Increases of this magnitude, whether due to economic competition for limited supplies of western water or to institutional requirements that water be recycled or obtained from distant or costly sources, will diminish the amount of coal traffic for which pipelines can compete effectively

The following list is a recapitulation of the principal factors influencing the relative costs of unit trains and slurry pipelines for coal transportation

1. Annual volume of coal
2 Distance to be traversed
'3 Expec-ted rate of inflation
4 Real interest rate
5 Size and spacing of mines,
6 Presence of general large customers to receive coal
7 Terra in and excavation difficulty
8 Water availability and cost
9 Relative costs of diesel fuel and electricity.
'10 Railroad track circuity and condition
11. Length and speed of trains.

The principal lessons from the foregoing analysis are that a) Slurry pipelines are more economical than unit trains some specific types of individual movements, and b) the comparative costs of the two modes do not lend themselves to easy generalization based on simple criteria The latter observation is illustrated by figure 15, which shows ranges of rail and pipeline costs for a given volume of coal as they vary typically with distance. The precise cost within the range is determined by the several factors other than volume and distance discussed above Note that the cost ranges overlap between distances A and B, and that one can only concude with confidence that rail will be least costly at distances less than A, and that a pipeline will be more economical at distances greater than B.

Figure 15– Form of Typical Rail and Pipeline Cost Ranges for a Given Annual Tonnage



Source Office of Technology Assessment

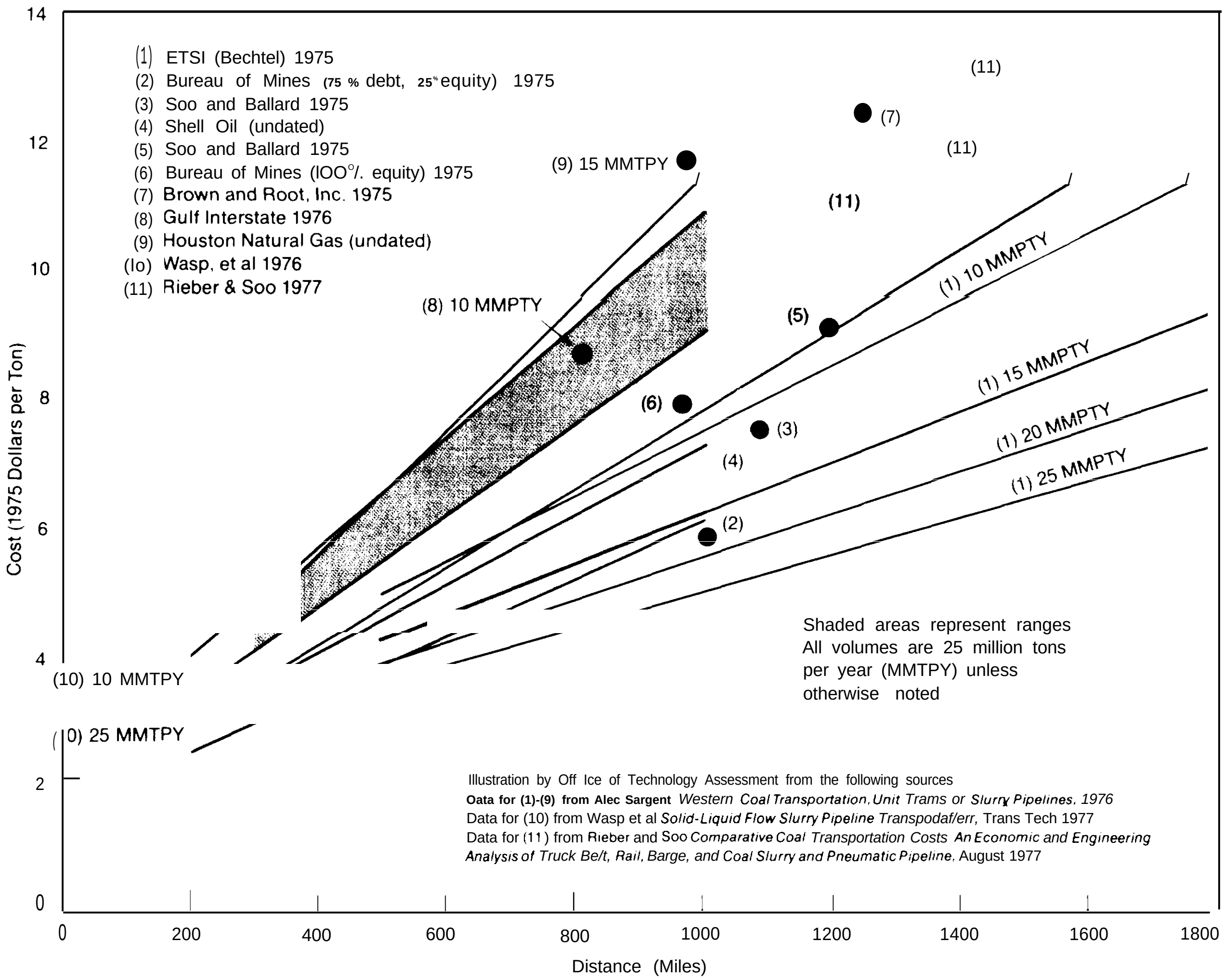
Some generalization is required to compare the case results with previous studies Figure 16 illustrates the results of an assortment of other coal Slurry pipeline cost calculations, and figure 17 shows the results of two other coal unit train studies for comparison. In interpreting the latter, one Should note that regulated tariffs are not always the same as costs, and that individual tariffs vary significantly from the values represented by the ICF regression lines

The results of the case analyses developed here appear in figure 18 Although the differences between any two sets of cost estimates are due in part to dissimilar underlying assumptions and procedures, the results of the studies taken together serve as additlonal evidence of the wide range of unncertainty associated with global generalizations about the relative costs of slurry pipelines and unit trains in specific applications.

Traffic Assumptions

Painting a plausible scenario for the purpose of evaluating the global economic effects, as opposed to the localized costs, of the development of a coal slurry pipeline industry required Ignoring one of the lessons of the cost analysis

Figure 16– Results of Previous Coal Slurry Pipeline Cost Studies

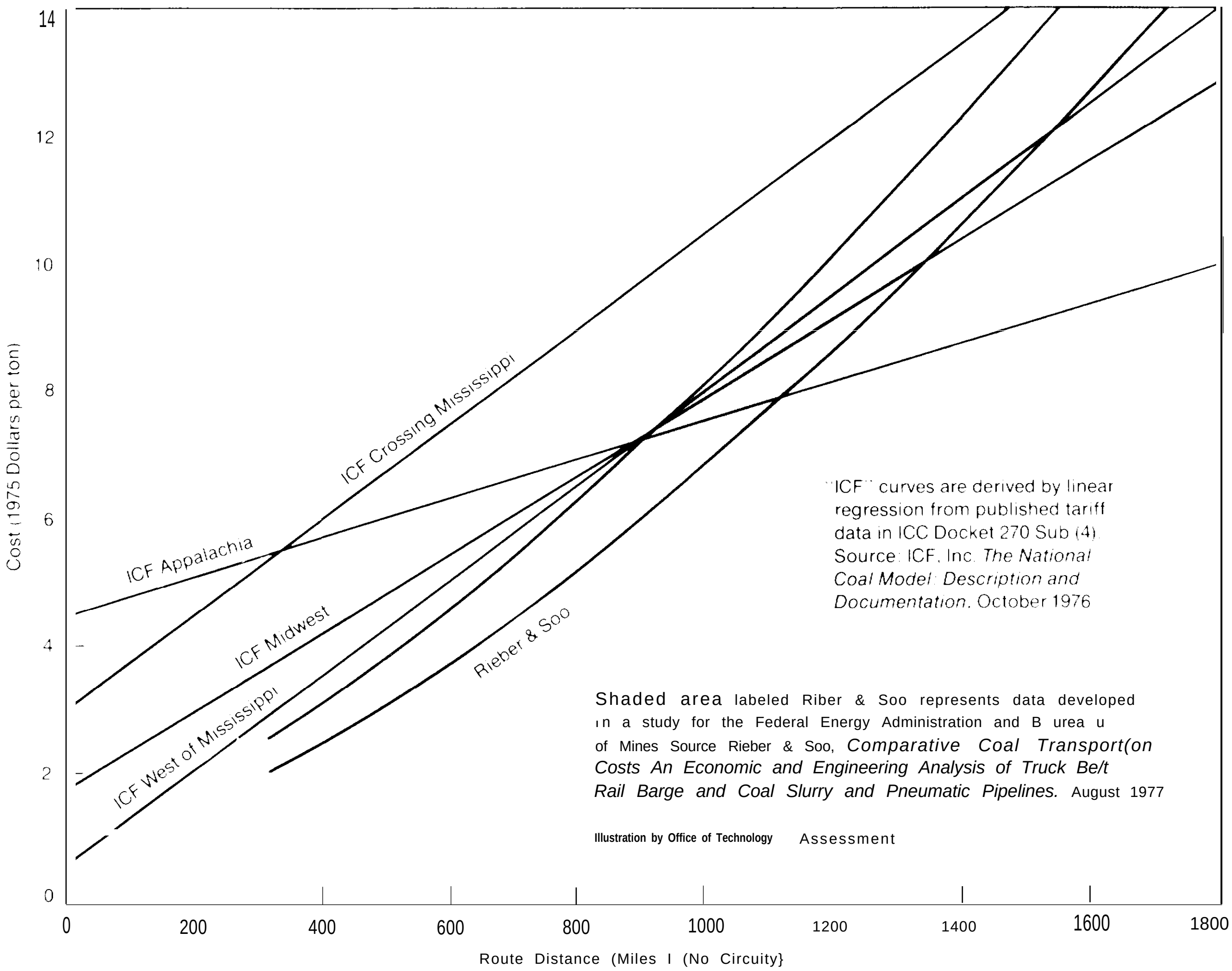


and attempting to deduce, by some general criteria, which of the coal flows identified earlier in table 7 might be carried by pipeline. To accomplish this purpose, with as little violence to the conclusions of the cost analysis as possible, assumed distances and coal volumes were varied artificially and calculations repeated to determine those combinations of values for which rail and pipeline costs are equal under the conditions governing each of the four cases. For simplicity, the computation included only a single destination region for each movement, and the resulting "indifference curves" appear in figure 19.

For each set of conditions, traffic volumes and distances above and to the right of the curve would be carried more economically by pipeline, while rail would be more advantageous otherwise. The conditions most advantageous to rail are therefore represented by the characteristics of the Montana to Becker, Minn., corridor, while those features most favorable to pipelines exist between Tennessee and Tampa, Fla., provided that one does not consider volume and distance.

The flows of coal from producing regions to consuming States in the transportation demand scenario could be compared to the indifference curves and assigned to pipelines whenever the combinations of distance and

Figure 17– Results of Previous Coal Unit Train Cost Studies



sustained volume fell in the region favorable to pipelines under all four sets 'of case condition, and barge transportation was not an obvious competitor. Only Central Western coal destined for Indiana and Texas falls in this category. Five other flows fall in a region of uncertainty between the two extreme indifference curves: Central Western to Missouri, Kansas, and Illinois; Interior Eastern to Georgia; and Southern Appalachian to Florida. Of these, the Florida traffic was assigned to pipeline because of the results of examining that specific case, Missouri and Kansas traffic was assigned to pipeline because of similarity to the Texas case and the possibility of sharing a common pipeline, Illinois was assumed to be served by rail because of the similarity of conditions to the Montana to Minnesota and Wisconsin case, and finally, the Georgia coal was considered unlikely to justify pipeline construction because of the terrain along the route,

A highly speculative but plausible traffic scenario derived in this necessarily somewhat arbitrary manner is illustrated in table 9. All other coal is assumed to travel by another mode, probably rail or barge, These *postulated* volumes are in no way intended as a projection of pipeline market penetration. They only provide a starting point for an analysis of what might happen if the equivalent of approx-

Figure 18– Results of Case Studies Comparing Coal Slurry Pipeline and Unit Train Costs

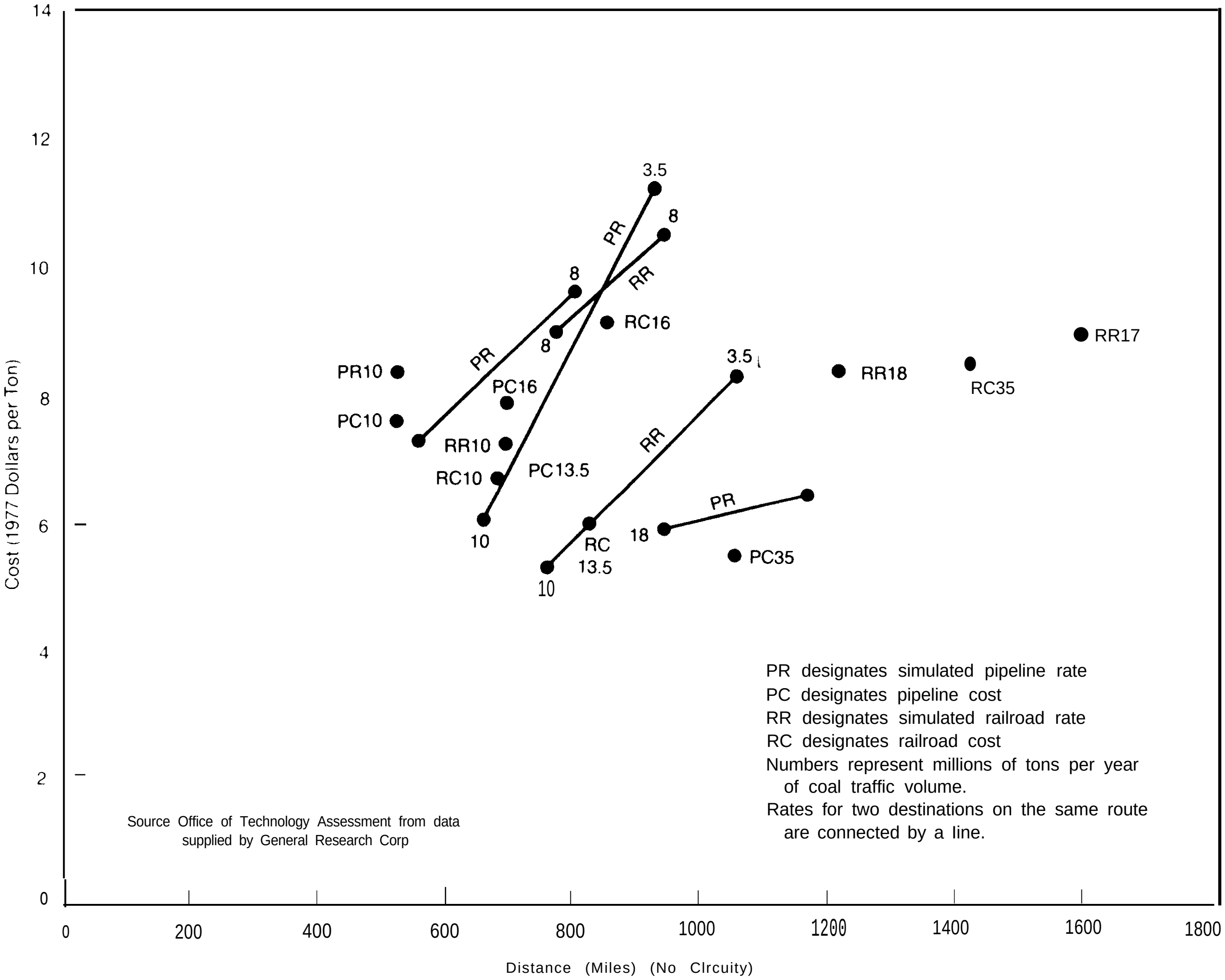
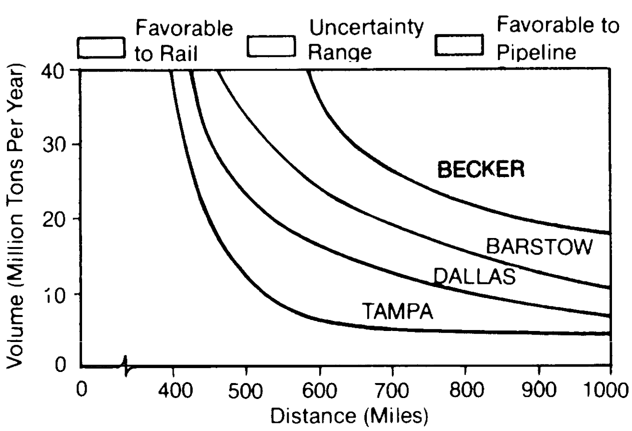


Figure 19– Rail Versus Pipeline Cost Indifference Curves Based Upon Site-Specific Case Study Conditions



Source General Research Corp

Table 9. Pipeline Traffic Scenario

(Millions of tons per year)

Origin / Destination	1985	1990	1995	2000
Central Western				
Indiana.	**17**	**17**	**17**	**17**
Kansas.	**—**	**—**	**19**	**19**
Missouri.	**14**	**14**	**14**	**14**
Texas	**35**	**72**	**93**	**125**
Southern Appalachian				
Florida	16	16	16	32
Total	82	**119**	**159**	**207**

Note: This scenario has been developed for Illustrative purposes and does not represent a prediction that the coal volumes will be transported by pipeline or any other mode between the listed origins and destinations.

imately eight pipelines averaging 25 million tons per year were to be built between now and the year 2000.

Deriving hypothetical transportation costs for all of the listed coal flows required extending the results of the case studies, also on the basis of general and not perfectly applicable relationships. The assumed pipeline costs as derived by regression from case estimates are $272 per ton plus $0.028 per ton-mile for surface-mined coal at the approximate distances and volumes contemplated Corresponding rail costs, also generalized from the cases, are $0.82 per ton plus $0.064 per ton-mile, including a route distance circuity factor of 1.3, operating expenses, and investment in rolling stock and way and structures The methods for extending costs for both modes are elaborated in Volume I I.

A number of important simplifying assumptions underlie the scenario and should be reviewed at this point to place it in perspective. Some weigh in favor of greater apparent pipeline markets and some against.

Assumptions favorable to pipelines —

1. The demand scenario calls for a high rate of growth in power consumption after 1985
2. The demand scenario ‘predicts that all coal of a given category will be purchased by all powerplants in a State from a single source. The result is a pattern of coal flows from artificially concentrated origins
3 The cost analysis assumes that mining and power generation activity is concentrated in circumscribed locations.
4 pipelines are assumed to operate in a stable environment at full capacity. No cutover or startup costs beyond 3-year construction financing has been considered.
5. No possible additional coal tonnage required by powerplants receiving slurry coal due to water content has been accounted for.
6. No substantial increase in the present rate of railroad labor productivity improvement has been allowed for.

Assumptions favorable to railroads –

I The demand scenario calls for a relatively high proportion of nuclear powerplant construction after 1985.
2 The possibility of serving more than one State with a single pipeline has not been considered in the market scenario, except in the case of Kansas and Missouri, and it is not reflected in the demand projections.
3 The possibility of serving industrial customers or coal conversion facilities by slurry pipelines has been ignored.
4 The possibility of distributing dewatered coal slurry by barge is not contemplated in the cost or market analyses.
5. The cost estimates give no credit for the fact that cleaning and grinding coal is more economical in conjunction with slurry pipeline operation.
6. No significant future improvement in pipeline technology has been allowed for.

Additional uncertainties of undeterminable influence involve principally railroad way and structures, investment requirements, future pipeline construction costs, and the appropriate prices to assign to water

V. Economic Impacts

V. Economic Impacts

INTRODUCTION

Objectives

The economic impact analysis section of this report examines the effect that development of coal slurry pipelines could have upon related areas of the economy. The most direct effect would be upon the railroad industry, its employees, suppliers, and customers. Many segments of the railroad industry have encountered financial difficulties in recent decades. The industry has tended to view the current emphasis on coal to be the Nation's primary fuel as an opportunity to regain a measure of financial stability, Coal's physical properties, the large quantities involved, and the long transportation distances without significant waterways for western coal favor railroads against their traditional competitors — barge and truck transportation. However, the primary railroad beneficiaries of the projected increase in coal transportation are certain western railroads that have on the average achieved better financial performance than most of the industry. Railroad industry employees will be directly affected by any development that reduces the industry's volume of business or forces it to modify its methods of operation. The principal supplier industries that would be affected are those that manufacture locomotives, freight cars, and track. Indirect effects would then be felt in the industries supplying the suppliers, principally steel manufacturers.

The railroad customers most likely to switch to pipeline are the large electric utilities that, by themselves or with a few others, can generate sufficient coal demand to achieve pipeline economies of scale. Some other shipments, including those of smaller utilities, farm products, stone and minerals, etc., will tend to encounter higher costs if their shipping charges must cover a larger fraction of the rail road's fixed costs as a result of a reduced rail business volume and downward pressure on some coal rates. Determination of the magnitude of the coal-related fixed cost was one of the principal goals of this study because its al location largely determines where the important economic impacts fall –regionally and by type of consumer— and the size of these impacts.

A second set of economic impacts can be grouped within the category of regional effects. Slurry pipelines consume large quantities of water, and, owing to the geographic location of coal, most of the pipelines originate in somewhat arid regions. Other water users in these regions, primarily agriculture, may be directly affected through any future water scarcity, The environmental implications of pipeline-related water shortages are discussed in chapter VI This chapter examines the economic implications of potential water shortages, Such shortages could affect not only the agricultural sector, but other sectors of regional economies as well, since water availability is an important factor in the location of some industrial activities. A second aspect of regional development to be examined is the payment of State and local taxes. Railroads have been a significant source of revenues in some States, and it is therefore important to appraise the net effect upon regional tax revenues of shifting some coal traffic from railroads to pipelines. A third regional aspect is that the benefits of pipelines may accrue to one area of the country, while the costs are borne in another region. A simple illustration of this possibility is as follows:

1, the projection of future coal movements in chapter IV identified Texas as the recipient of large volumes of coal;

2. if pipelines **are more economic for the Texas coal shipments, the consuming public** in Texas could receive lower rates for their electricity if pipelines are employed;
3. the railroads that lose these coal shipments may need to transfer some of their fixed costs onto other shippers;
4. other major shippers include those shipping grain and beef to the Midwest; thus
5. consumers in the Midwest (and East) may have to pay somewhat higher prices for food products.

It should be noted that this type of regional tradeoff occurs in nearly every regional transfer, e.g., oil and natural gas pipelines going from Texas to other parts of the country, This section attempts to quantify the magnitude of pipeline-related transfers.

The discussion thus far has focused upon the generally adverse impacts pipeline development will have upon the railroads and related industries. Pipelines are obviously a source of economic stimulus, and as such will generate their own set of economic benefits. It was the goal of this study to analyze the net economic impact of pipeline development (benefits minus costs), and to indicate where, and to what extent, each benefit and cost occurs. The principal economic benefit offered by pipelines is that they may more cheaply transport some large volume movements of coal from, for example, origins in the sparsely populated and lightly industrialized West to centers of population and industry in the Midwest, South, and Far West. Our Nation's fuel supply will be increasingly composed of coal, and a significant reduction in the cost of transport would therefore reduce the economic dislocations of a forced switching from oil and gas to coal, In addition, since pipelines are highly capital intensive, the investments associated with them could provide an important near-term economic stimulus to the economy in the form of materials purchases and construction labor employment in some localities.

The following discussion should be read with an understanding of the uncertainty associated with projecting present economic trends into the distant future. Major events could substantially violate the assumptions on which the analysis is based. One example would be a change **in the railroad regulatory environment, resulting from the Rail Revitalization and Regulatory Reform Act or related future legislation. Another example** would be any form of substantial public investment to aid the railroad industry.

Another significant uncertainty involves economies of scale associated with the extent of railroad service. Past experience is not a particularly useful guide for predicting railroad capital and operating cost relationships if the size of the industry is to be radically different from what it has been in recent history, The analysis presented here suggests that marginal costs decline as service expands. If marginal costs increase with expansion of coal unit train operation, the impacts of coal slurry pipeline development would probably be favorable both to the railroad industry and to the shippers of commodities other than coal by rail.

Methodology

The primary focus of the study was the rail road industry because, other than water resources and their allocation, nearly all other economic impacts have their origin within that industry. The central question is: "If railroads lose the revenues associated with a significant number of large-volume coal movements, how will they reallocate their fixed costs among the remaining shippers?" **In order to address this question, it was necessary to project both future revenues to the railroads from all commodities they transport, and the costs of transport as a function of traffic volume. It is not possible to evaluate the implications of railroads losing a large fraction of their coal revenues without knowing the nature of their remaining business volume. Projections of revenues were made** for 10 major railroad shipment categories and for an *all other* category over the 25-year period from 1975 to 2000.

Likewise, cost projections were made for the same period for three operating expenditure categories, for capital investment in rolling stock and way and structures, and for payroll, State, and local taxes. All projections were broken out into the three railroad regions (or districts)–Eastern, Southern, and Western–because the impacts of coal slurry pipelines are centered in the Western and Southern regions, even though the vast majority of rail road coal transportation is current I y located in the Eastern region.

The entire study was carried out in constant 1971 dollars. This is the base year for the input-output model employed to project national railroad revenues by commodity category between 1975 and 2000. Though 1971 dollars are used, a number of adjustments have been made to reflect real changes in the structure of prices since 1971, such as changing real wage rates and energy prices. As a result, though the study is in 1971 dollars, percentage relationships between major variables are those expected to pertain in the future.

A no-pipeline baseline and two pipeline-development scenarios were evaluated in order to assess the economic impacts associated with varying levels of market penetration by the coal slurry pipelines. The baseline, which served as a point of departure, assumes that no additional coal slurry pipelines will be built. The first pipeline scenario, termed the Lost Rail Tonnage scenario, assumes that pipelines will take over the coal-traffic Identified in table 9 of chapter IV. The second scenario, termed the Competitive Rate scenario, postulates that not only r-nay pipelines take over on certain routes, but also that the competitive market pressure of pipelines may force railroads to lower their rates on a set of additional routes. The latter scenario yields qualitatively similar results to the former and is therefore presented in Volume I I

Five cost/price alternatives were evaluated for the baseline **and the two pipeline** scenarios. These five alternatives reflect different assumptions regarding the ratesetting behavior of railroads and the Interstate Commerce Commission (ICC) as well as the relative fuel costs over the forecast periods. Alternative I assumes that the unit charges for railroad service in each region and commodity category will remain at their 1971 levels, and that the cost structure will basically retain its 1971 form, with adjustments for labor real wage and productivity changes. Alternative I I seeks to embody the effect of recent increases in the relative costs of fuel by introducing a one-time approximate doubling of relative fuel costs to simulate the effect of the 1973-74 energy crisis, and by increasing the relative price of fuel 1.5 percent more rapidly than general inflation for the years 1985 to 2000. Alternative III retains the fuel adjustment on the cost side, and assumes that rail revenues per ton-mile will continue to be reduced at their historic rate as a result of railroads passing forward productivity gains for competitive reasons. Alternative IV also retains the fuel cost adjustment, but assumes that revenues will bear a constant relationship to operating expenditures, determined by setting the operating expenditures-to-revenue ratio at 0.8. (A review of historical data indicated that the operating ratio has held reasonably constant near this value over the period 1969 -75.) Alternative V was developed only for the West. It retains the fuel cost adjustment, and changes revenues to satisfy the "Minimum Necessary Net Income" (MNNI) for railroad solvency and investment requirements.

The methodology employed is explained in detail in Volume I I of this report. Briefly, projections for national rail revenues were obtained by aggregating into 10 major categories and an "all other" group the more detailed output and transport by modal share forecasts from an input-output based transportation model. Regional shares of rail revenues from each commodity were projected by using equations obtained by regression analysis of historical data. The coal revenue forecasts were made separately in view of their importance to this

'A 4.8 million ton per year coal slurry pipeline is currently operational in Arizona, and a smaller pipeline is on standby in Ohio study. (For coal, the latest Department of Energy (DOE) forecasts of coal production were allocated to the railroad regions, the railroad shares of coal transport in each region were projected on the basis of historical trends and regional analyses, and the associated revenues were projected taking into account the ongoing shift to the more economic unit train coal shipments.) Operating cost expenditures in each region were projected for three expenditure categories by identifying, through regression analyses, the dependence of costs upon key operating variables, including miles operated, ton-miles, tons-per-car, and freight car miles. Investment requirements were projected by translating the commodity shipment projections into rolling stock and way and structures capital requirements, taking into account the productivity improvements now being made through substantial increases in tons-per-car loadings.

The five cost/price alternatives adapt the railroad revenue and cost projections to reflect different cost and pricing behavior by the railroads. The direct economic impact of coal slurry pipelines upon the railroad industry was established by determining, for each alternative, the differences in the railroad revenue and cost variables between the no-pipeline baseline and the two pipeline scenarios. The impact upon railroad employment was determined by translating the reduction in operating cost expenditures into equivalent hours of employment. The impact upon supplier industries was evaluated by determining the reductions in capital stock requirements associated with loss of the coal traffic. The impact upon payroll, State, and local taxes was determined by calculating the reduction in wages and in the tax base. Potential savings were determined by assessing the residual costs that would have been covered by coal revenues, and now must be allocated to other shippers. The transportation savings resulting from shippers switching to pipelines were determined by calculating the differential in the hypothetical costs established in the last chapter between the two modes and multiplying them by the shipment volumes. Other beneficial aspects of pipeline development were estimated by determining the employment and economic stimulus it could provide.

RAIL COST AND PRICE ALTERNATIVES

In order to assess the economic impact of coal-slurry pipeline development upon railroads, other shippers, other industrial sectors, and the public, it was necessary first to project what the future would be like in the absence of pipelines. Prediction of future railroad economic performance over the 25-year period in this study is an ambitious undertaking in itself. Nevertheless, since it is the difference in economic performance with and without pipelines that must be evaluated, the projection of a No-Pipeline Baseline was an essential analytic component of the present study. By constructing the baseline scenario and two pipeline scenarios within the same internally consistent analytic framework, potential bias associated with necessary analytic assumptions, such as assumed gross national product (GNP) growth rate, should be minimized.

Two other caveats must be borne in mind when reviewing the results of this study. First, as stated previously, the study was conducted using constant 1971 dollars. Thus, the revenue growth projections represent real growth, based upon estimated increases in product output by the railroad sector, e.g., ton-miles of commodities transported. Three alternative case studies were conducted regarding railroad pricing behavior. I n each, real rates were maintained at their 1971 level or reduced. However, reduction of real rates does not mean that railroads will be able to reduce their actual nominal or current dollar rates. The rates charged will be the real rates adjusted for the effect of inflation. The latter will probably be sufficiently large to result in an overall increase in railroad rates, expressed in current dollars. The second caveat is that analysis indicates that railroad economic performance will benefit from increases in coal and other commodity transportation revenues even in the presence of pipelines. Thus, the railroad revenue losses identified in the study as resulting from pipeline development are losses relative to the No-Pipeline Baseline. In other words, the railroads will not be able to achieve as high a level of coal transportation-related revenue gains if coal slurry pipelines are developed, but the railroads will probably nevertheless achieve a substantial revenue increase from overall traffic volume growth, In arriving at these results, this study assumes that real GNP will increase at 2.90 percent per year before 1985 and 2.95 percent from then until 2000, and it projects that rail revenue traffic will expand Slightly more slowly than GNP before 1985 and Slightly faster thereafter

Baseline revenue and cost projections for railroads, presented in the appendix to this volume, form the frame of reference for assessing the impact on the railroads, their shippers, and the consuming public of coal slurry pipeline development Five variations in the form of cost/price alternatives were evaluated in order to test the sensitivity of impact results to the underlying financial assumptions.

Alternative I—Constant Rate and Cost Structure

The study results presented in the appendix constitute Alternative I, This alternative postulates constant cents- per-ton-mile revenues (in 1971 dollars) over the forecast period, and operating costs that embody productivity and real wage changes only for labor. Projections for aggregate Class I railroad revenues under these conditions for the years 1980 to 2000 are presented in table A-2. The corresponding operating expenditure projections are presented in table **A-4. (See appendix.) These revenue and expenditure projections are now** shown together in table 10. Their differences, defined as Net Railway Operating Revenues (NET), are also identified in this table. The Net Railway Operating Revenues should not be considered a proxy for profits. In order to arrive at the Net Income for railroads, as reported to the Interstate Commerce Commission, it is necessary to subtract additional costs, such as taxes, interest payments, dividends, amortization and other fixed charges, net hire of equipment, and net joint-facility rents.

The ratio of operating costs to revenues, termed the operating ratio (OR), is frequently employed as an approximate measure of railroad financial performance. The operating ratios calculated from the data in table 10 are highest in the East, ranging from 0.69 in 1980 down to **0.56** in **2000,** and lowest in the South, ranging from 0.65 in 1980 to 0.53 in 2000. These projected operating ratios are considerably lower than historical values for railroads in this class, which averaged 0.806 over the period 1969-75. That is also true for the regional values, which over the 7-year historical period averaged 0.822 in the East, 0.755 in the South, and 0.783 in the West.

Several factors contribute to the low values projected for the rail road operating ratios. The revenue forecasts assumed that, except for coal, real revenues per ton-mile for each commodity will remain constant at the 1971 values.[2] In fact, historical data indicate that real revenues per ton-mile have been declining for railroads as operational economies are achieved and passed on to the shippers, A second factor affecting the OR results is that relative fuel prices have been held essentially constant over the forecast period, whereas they can be expected to increase faster than general inflation.[3] A third factor affecting the OR results is the selection of a logarithmic

[2] In the case of coa 1, real revenue per ton-mile declines as shipments shift to the more cost effective unit trains

[3] The study is **done** in constant 1971 dollars Thus, holding relative fuel prices "constant enables them to increase at the same rate as general inflation

Table 10. Comparative Railroad Revenue and Operating Costs Projections-Alternative i

(Billions of 1971 dollars)

	1980	1985	1990	1995	2000
East					
Revenues	4.4	4.8	5.0	5.2	5.6
Operating costs	3.2	3.0	3.1	3.2	3.3
Net revenue	1.2	1.8	1.9	2.0	2.3
South					
Revenues	2.8	3.8	4.5	5.8	
Operating costs	1.9	2.1	2.5	3.0	3.6
Net revenue	0.9	1.7	2.0	2.8	3.6
west					
Revenues	7.1	8.8	10.4	12.4	15.0
Operating costs	4.9	5.4	6.3	7.3	8.6
Net revenue	2.2	3.4	4.1	5.1	6.4
U.S.A.[b]					
Revenues	14.4	17.3	19.9	23.4	27.8
Operating costs	10.1	10.5	11.9	13.5	15.5
Net revenue	4.3	6.8	8.0	9.9	12.3

[a]Not total costs. See text for definition. [b]Totals may not add due to rounding.

equation form to project operating expenditures. This functional form reflects achievement of constant economies of scale throughout the forecast period.

Alternative Il—Fuel Cost Adjustment

The revenue projections for Alternative Il remain the same as for Alternative 1. However, the operating expenditures were increased by an upward adjustment of relative fuel costs at a rate exceeding general inflation. The same fuel cost adjustment was made of Alternatives I I to V. This was the only change made to the costing calculation for each of these alternatives. The comparison between railroad revenues and costs for Alternative I I is presented in table 11. Even with the increase in fuel prices, the operating ratios in Alternative 11, that is, 0.68 to 0.72, are significantly lower in 1980 than those prevailing historically. Declining rapidly to 2000, these ratios suggest that the economies of scale enjoyed because of increasing traffic volumes, assumed productivity gains, and constant cents-per-ton-mile revenues outweigh the impact of fuel cost adjustment.

Alternative Ill—Historical Rate Decline

The fuel cost adjustment is retained for this alternative and the revenues in each region are reduced at their historical rates of decline. The latter assumption reflects the apparent tendency of the rate structure to respond to productivity gains. Historically, the annual rates of tariff decline in each region have been: East, 0.02 percent; South, 1.0 percent; and West, 1.55 percent. The revenues projected on this basis, together with the fuel-adjusted costs, are presented in table 12 for Class I railroads. The revenue adjustment, combined with the fuel

Table 11. Comparative Railroad Revenue and Operating Cost[a] Projections—Alternative II

(Billions of 1971 dollars)

	1980	1985	1990	1995	2000
East					
Revenues	4.4	4.8	5.0	5.2	5.6
Operating costs	3.4	3.1	3.2	3.4	3.5
Net revenue	1.0	1.7	1.8	1.8	2.1
South					
Revenues	2.8	3.8	4.5	5,8	7.2
Operating costs	2.0	2.2	2.6	3.2	3.8
Net revenue	0.8	1.6	1.9	2.6	3.4
West					
Revenues	7.1	8.8	10.4	12.4	15.0
Operating costs	5.2	5.6	6.6	7.7	9.0
Net revenue	1.9	3.1	3.8	4.7	6.0
U.S.A.[b]					
Revenues	14.4	17.3	19.9	23.4	27.8
Operating costs	10.5	10.9	12.5	14.3	16.4
Net revenue	3.9	6.4	7.4	9.1	11.4

[a]Not total costs. See text for definition. [b]Totals may not add due to rounding.

Table 12. Comparative Raiload Revenue and Operating Cost[a] Projections—Alternative III

(Billions of 1971 dollars)

	1980	1985	1990	1995	2000
East					
Revenues	4.2	4.5	4.7	4.9	5.3
Operating costs	3.4	3.1	3.2	3.4	3.5
Net revenue	0.8	1.4	1.5	1.5	1.8
South					
Revenues	2.5	3.2	3.7	4.5	5.4
Operating costs	2.0	2.2	2.6	3.2	3.8
Net revenue	0.5	1.0	1.1	1.3	1.6
west					
Revenues	6.1	7.0	7.7	8.6	9.8
Operating costs	5.2	5.6	6.6	7.7	9.0
Net revenue	0.9	1.4	1.1	0.9	0.8
U.S.A.[b]					
Revenues	12.8	14.6	16.1	18.0	20.4
Operating costs	10.5	10.9	12.5	14.3	16.4
Net revenue	2.3	3.7	3.6	3.7	4.0

[a]Not total costs. See text for definition. [b]Totals may not add due to rounding.

cost adjustment, substantially raises the operating ratios to between 0.76 and 0.82 in *1980,* but they again decline below the historic values in the outer years, implying that historic rates of revenue decline are not financially achievable for the remainder of the century.

Alternative IV—Constant Operating Ratio

In Alternative IV, revenues are calculated directly from the cost estimates by assuming that the operating ratio remains constant at 0.8. The operating cost estimates, which embody the fuel cost adjustment, are the same as for Alternatives II and III. These costs, the revenues calculated from them, and their NET are presented in table 13 for the Class I railroads over the period 1980 to 2000.

Alternative IV is conservative and will result in the lowest NET and railroad income projections among the first four alternatives except **in the West. It implies an even faster decline nationally** in cents-per-ton-mile than has prevailed historically. However regional differences emerge. The East and South can decline faster than historical trends, but the West will be unable to maintain its historic rate of decline under this alternative.

Alternative V—Minimum Necessary Net Income

By subtracting payroll, State, and local taxes from the Net Railway Operating Revenues identified in tables 10-13 for Alternatives I through IV, a better approximation was obtained for the income remaining to railroads. The resulting variable, termed Operating Income, is a pre-Federal-tax version of the Net Railway Operating Income reported to the ICC.[4] The

[4]Federal taxes were not explicitly estimated in this report because of their complexities with regard to deferments, credits, etc Federal taxes Imposed upon railroads appear to be approximately 25 percent at the margin, and to average somewhat less

Table 13. **Comparative Railroad Revenue and Operating Cost[a] Projections-Alternative IV**

(Billions of 1971 dollars)

	1980	1985	1990	1995	2000
East					
Revenues.		3.9	4.0		4.4
Operating costs	3.4	3.1	3.2	3.4	3.5
Net revenue.	0.8	0.8	0.8	0.8	0.9
South					
Revenues.	2.5	2.7	3.3	4.0	4.8
Operating costs.	2.0	2.2	2.6	3.2	3.8
Net revenue.	0.5	0.5	0.7	0.8	1.0
West					
Revenues.	6.4	7.0	8.2	9.6	11.3
Operating costs.	5.2	5.6	6.6	7.7	9.0
Net revenue.	1.2	1.4	1.6	1.9	2.3
U.S.A.[b]					
Revenues.	13.1	13.6	15.6	17.8	20.5
Operating costs	10.5	10.9	12.5	14.3	16.4
Net revenue.	2.6	2.7	3.1	3.5	4.1

[a]Not total costs. See text for definition. [b]Totals may not add due to rounding.

actual railroad discretionary income, Net Income, is less than Operating Income by the amount of Federal taxes, interest payments, dividends, amortization charges, other fixed charges, and other miscellaneous income deductions. Nevertheless, Operating Income values provide a useful first indication of the conditions under which railroads will encounter a cash-flow problem, The Operating Income results for Alternatives I through IV are given in table 14 for the southern and western railroad regions, between 1980 and 2000.

The Operating Income results shown in table 14 indicate marked differences between the four cost/price alternatives. The results suggest that the most likely cost/price behavior lies between the specified alternatives, which fall into two groups. Alternatives I and II lead to increasing prosperous railroad economic performance over the forecast period, while Alternatives I I I and IV lead to clearly unacceptable economic results. **In Alternatives I and 11, Operating Incomes** (in constant 1971 dollars) more than triple between 1980 and 2000 for both southern and western railroads. The fuel cost adjustment in Alternative **I I** slightly reduces the rate of Operating **Income** growth, but the maintenance of constant real rates per ton-mile in the face of the projected increases in commodity ton-miles provides an overwhelming upward thrust to revenues,

Viewed from another perspective, the favorable Operating Income results for Alternatives I and I I suggest that railroads will be able competitively to reduce their rates when necessary As discussed previously, rate reductions (in constant dollars) have been the historical pattern. Alternative III was evaluated to see whether these historical trends in rate reductions could be maintained. Clearly they cannot be, at least in the West. The western Operating Incomes decline sharply after 1985 and actually become negative in 2000. These results are based upon a continuation of the historical 1.55 percent annual decline in western rail tariffs. Thus, comparison of Alternatives I I and **I I I** indicates that in the absence of pipeline competition western **rail tariffs** (in constant dollars) could be reduced, but at a lesser rate than achieved historically. Alternative I I I also indicates that in the absence of pipelines the historical 1.0 percent annual decline in southern rail tariffs could be maintained

Alternative IV presents another view of the potential for reduction of railroad tariffs in response to the favorable Operating Income results for Alternatives I and 11. Alternative IV reduces tariffs in such a manner as to maintain the operating ratio at 0.8. The Operating Income results for the South hold constant under these conditions, but the values for western railroads decline continuously throughout the forecast period.

Since none of the first four cost/price alternatives seem to represent a likely behavior mode for railroads, a fifth alternative was evaluated. This alternative employed a bottom-up approach. Instead of determining the Operating Income results of a particular rate-setting approach. as in Alternatives I-IV, Alternative V determined a "Minimum Necessary Net Income" (MNNI) that the railroads must obtain in order to fulfill the minimal requisites of satisfactory financial performance. That is, if railroads are to maintain their functional capability, they must generate sufficient capital to finance necessary rolling stock and way and structures investments.

Computation of the MNNI to satisfy solvency and investment requirements is detailed in table 15. The minimum pretax railroad operating income average for the period 1969-72, converted into *1971* dollars, was employed as the Return-On-Capital Baseline,[5] The 1969-72 period was chosen because it was a time of reasonable, if not robust, health for the railroad industry. Hence, that period furnishes a more realistic goal for railroad operations than the more difficult recent years. Funding for new capital stock must be added to

[5] The Baseline is assumed **to** inc **l ude** funds **for** Federal taxes **at the** approximate **average rate of the 1969-72** period, i e , 20 percent Funds for net lea sing over and above those for changes in capital stock are a lso contained in the Baseline

Table 14. Operating Income Projections for Southern and Western Railroads-Alternatives I to IV

(Millions of 1971 dollars)

	1980	1985	1990	1995	2000
Alternative I					
South					
Net railway operating revenues	$ 917	$1,652	$2,013	$2,746	$3,641
Payroll taxes	(183)	(267)	(256)	(491)	(669)
State and local taxes	(57)	(67)		(88)	(103)
Operating income	676	1,318	1,582	2,167	2,869
West					
Net railway operating revenues	2,209	3,330	4,100	5,044	6,416
Payroll taxes	(477)	(689)	(895)	(1,198)	(1,588)
State and local taxes	(192)	(208)	(225)		
Operating income	1,540	2,433	2,981	3,600	4,555
Alternatively					
South					
Net railway operating revenues		1,568	1,900	2,593	3,437
Payroll taxes	(183)	(267)	(356)	(491)	(669)
State and local taxes	(57)		(75)	(88)	(103)
Operating income	598	1,234	1,469	2,014	2,665
west					
Net railway operating revenues	1,998	3,147	3,814	4,665	5,928
Payroll taxes	(477)	(689)	(895)	(1,198)	(1,588)
State and local taxes	(192)	(208)	(225)	(246)	(273)
Operating income	1,329	2,250	2,694	3,221	4,067
Alternative III					
South					
Net railway operating revenues	522	997	1,047	1,313	1,586
Payroll taxes	(183)	(267)	(356)	(491)	(669)
State and local taxes	(54)	(61)	(66)	(75)	(84)
Operating income	285	669	625	747	833
West					
Net railway operating revenues	995	1,356	1,148	909	739
Payroll taxes	(477)	(689)	(895)	(1,198)	(1,588)
State and local taxes	(181)	(190)	(198)	(207)	(219)
Operating income	337	477	55	-496	-1,068
Alternatively					
South					
Net railway operating revenues	495	547	657	790	952
Payroll taxes	(183)	(267)	(356)	(491)	(669)
State and local taxes	(54)	(57)		(69)	(78)
Operating income	258	223	239	230	205
West					
Net railway operating revenues	1,288	1,401	1,649	1,929	2,260
Payroll taxes	(477)	(689)	(895)	(1,198)	(1,588)
State and local taxes	(184)	(190)	(203)	(217)	(235)
Operating income	627	522	551	514	437

Source: IR&T.

Table 15. Minimum Necessary Net Income for Southern and Western Railroads

(Millions of 1971 dollars)

	1985	1990	1995	2000
South				
Return-on-capital baseline	**355**	**355**	**355**	**355**
Required changes in rate of return owing to:				
Coal-car rolling stock	*4*	8	11	
Noncoal-car rolling stock	8		59	89
Locomotive rolling stock		22	22	*47*
Way and structures	30	**45**	**58**	**73**
Minimum necessary net income	409	462	516	578
West				
Return-on-capital baseline	689	689	689	689
Required changes in rate of return owing to				
Coal-car rolling stock	16	31	49	70
Noncoal-car rolling stock	-50	“19	2	25
Locomotive rolling stock	-22	-12	-2	9
Way and structures	105	155	198	246
Minimum necessary net income	738	844	936	1,039

Source: IR&T.

the minimum required to cover taxes and return on capital investment A 3 5 percent real return was assumed for new investment and existing capital stock Then, the minimum acceptable return given in table 15 was obtained by multiplying .035 times the change in capital stock calculated in the appendix. It must be emphasized that a real return of 3.5 percent is conservatively based on bond-market yields, and represents the absolute minimum required to stay afloat This level of net income may not be sufficient to cover adequate way and structures investments. Comparing the MNNI estimates in table 15 with the Operating Income projections for Alternatives I and IV confirms that the western railroads would be in serious trouble if the historical trends in either cents-per-ton-mile or operating ratio behaviors were to continue.

The necessary railroad revenues implied by the estimated MNNIs are identified in table 16 for western railroads in 1985 and 2000 The operating costs shown were previously given in table 11 and the payroll taxes were given in an earlier section on tax forecasts The State and local taxes were recomputed for table 16, to take into account changes in projected revenues. Comparing these minimum revenue requirements with the revenues projected for Alternatives I through IV again reveals that western railroads cannot maintain their historical rate of revenue decilnes, even in the absence of pipeline competition. In fact, in seems likely that the traditional 80 percent operating ratio may be too high to sustain the railroads in the future.

Table 16. Rail Revenues Necessary To Maintain Minimum Necessary Net Income on Western Railroads

(Millions of 1971 dollars)

	1985	2000
Operating costs	$5,641	$9,040
Payroll taxes	688	1,587
State and local taxes	179	226
Minimum necessary net income	738	1,039
Revenues	$7,246	$11,892

Source: IR&T.

PIPELINE IMPACT ANALYSIS

The results presented in the preceding section were for a baseline situation that assumes no pipeline development. Two pipeline scenarios were postulated in order to provide a context within which to evaluate the potential economic impacts of coal slurry pipeline development. The first scenario, termed the Lost Rail Tonnage scenario and presented here, assumed that railroads would lose five long-haul coal movements to pipelines. The five hypothetical markets of destination where pipelines may take over from railroads were discussed in chapter IV. They are Florida, Indiana, Kansas, Missouri, and Texas. A second scenario, termed the Competitive Rate scenario, assumed that not only would the coal movements of the first scenario be lost by railroads, but also that the threat of pipeline competition would force a reduction in rail rates along a number of additional routes. [6]The latter routes are assumed to be those over which coal flows identified in chapter IV amount to more than 5 million tons annually over distances greater than 500 miles. The results of the second scenario are qualitatively similar to the first and are presented in Volume II.

Lost Rail Tonnage

The hypothetical tonnages employed in this scenario are those identified in table 9 of chapter IV. The quantities are significant. The total tonnage associated with the five coal movements amounts to 11 percent of all tons originated in 1985 (including nonutility coal), and 17 percent of all tons originated by the year 2000. The effect is most striking in the West, where the selected movements represent 18 percent of western railroad shipment projections for 1985, and over 25 percent for 2000. Because the designated coal movements are long-haul shipments, their share of total ton-miles of coal is even larger than of tons originated. Nationally, the five movements represent 30 percent of all railroad coal ton-miles projected for 1985, and 38 percent for 2000, Again, the effect is greatest in the West because this region is characterized by an unusual number of long-haul, large-volume shipments that are susceptible to pipeline movement. The designated movements in the West account for 45 percent of the ton-miles of coal projected for railroads in the year 2000 under the No-Pipeline Baseline.

Operating Cost and Revenue Impacts

Railroad revenue losses associated with the Lost Tonnage coal movements were determined with help of the forecasting formula: [7]

$$\text{Revenues/Ton} = 113{,}7 + 0.382\ (\text{Distance})$$

where Revenues/Ton is in cents per ton, and Distance is in miles. Using this formula, the revenue loss for each route was computed as revenues/ton times total tons, It may be noted that this revenue-loss formula yields results comparable to published rate data. However, there is as yet little actual experience with unit trains for the volumes and distances considered in this study.

The operating costs for the Florida and Texas coal movements were obtained from the case study analysis, as described in chapter IV. The other three movements were judged to be between the cost of the Minnesota and Texas coal movements, for which case studies had been conducted. On this basis, the operating costs for these three shipments were estimated by a tonnage and mileage adjustment of a level of costs between those for Minnesota and Texas. The reduction in railroad operating costs as a result of the shipments lost to

[6]According to the *Dilemma of Freight Transport Regulation,* Ann F Friedlander, Brookings Institution, 1969, p 62, in situations where barge competition has posed a potential threat to railroads, the rate-per-ton charges for various rail moves, including coal, have been substantially reduced In two Instances, the rail rates per ton In the presence of barge competition were only about 60 percent of the rates prevailing in the absence of viable competition Unit train rates, however, contain less room for this sort ot reduction than do those of other types of rail shipment

[7]Derivation ot the formula is decribed in Volume II

Table 17. Lost Tonnage Impacts Upon Railroad Operating Costs

Destination	Coal supply region	Tonnage (millions)	Distance[a] (miles)	Ton-miles (millions)	Rail operating Costs[b] ($/ton)	cost reduction from lost tonnage (millions of 1971 dollars)
			1985			
Florida	So. Appalachian	16	857	13,712	3.98	63.7
Indiana	Central Western	27	1,430	24,310	3.36	57.1
Kansas	Central Western	No transfer in 1985				
Missouri	Central Western	14	1,235	17,290	2.90	52.2
Texas	Central Western	35	1,400	49,014	4.04	141.4
						314.4
			2000			
Florida	So. Appalachian	32	857	27,424	3.49	111.7
Indiana	Central Western	17	1,430	24,310	3.16	53.7
Kansas	Central Western	19	910	17,290	2.01	38.2
Missouri	Central Western	14	1,235	17,290	2.33	41.9
Texas	Central Western	125	1,400	174,795	3.75	465.0
						710.5

[a]Florida and Texas are based upon case study data, the other States calculate the distance at 1.3 times the straight line distance. [b]Not total costs. See text for definition.

Source: IR&T estimates based upon Teknekron and GRC data.

pipelines is given in table 17 for each route in the years 1985 and 2000. The largest effect occurs in the West in 2000, where a 6 5-percent reduction in operating cost is achieved, primarily due to the postulated loss of the Texas coal movement.

Having estimated the railroad revenue and operating cost reductions because of lost coal shipments, the changes in NET were determined The results are shown in table 18. These values indicate that the revenues lost by railroads for the selected routes substantially exceed the operating cost reductions that can be achieved. The results are the same for all the cost) price alternatives since the revenue and cost differentials between the scenario and baseline are exogenously determined for the specific routes involved.

Investment Impacts

Reductions in coal car and locomotive requirements are identified in table 19 for the tonnage losses to pipelines postulated in the Lost Rail Tonnage scenario. The rolling stock requirements for the Florida and Texas shipments were obtained from the case studies described in chapter IV. For the other three moves, it was assumed that coal cars would have a utilization rate of 75,000 miles per car per year and that 5 locomotives would be required for every 100 coal cars. As discussed in the appendix for the No-Pipeline Baseline, hop-

Table 18. Lost Tonnage Impacts Upon Net Railway Operating Revenues[a]

(Millions of 1971 dollars)

	1980	1985	1990	1995	2000
East. . .	0	-5.94	-5.97	-6.14	-6.25
South. .	0	-19.68	-32.76	-33.81	-53.32
West . .	0	-123.85	-352.58	-503.61	-628.30
U.S.A. .	0	-149.47	-391.31	-543.56	-687.87

[a]These values represent the difference between the Net Railway Operating Revenues for the Lost Rail Tonnage scenario and those for the No-Pipeline Baseline. There is no difference between the results for the five cost/price alternatives.

per cars and locomotive suppliers should have no difficulty in furnishing the necessary rolling stock in the absence of pipelines. Since the reduction in equipment requirements identified in table 19 would be only about 5 percent of the Baseline total, pipeline development should have little effect upon the supply situation for railroad rolling stock.

The investment reductions for rolling stock and way and structures associated with the scenario on railroad coal-tonnage losses are shown in table 20. The way and structures investment reductions for the Texas and Florida moves were derived from data presented in table A-6. (See appendix.) The values for the other three moves were obtained by a ton-mile adjustment of long-haul shipments total given in that same table. The Baseline way and structures investment requirements are shown in parentheses for purposes of comparison.

Table 19. Lost Tonnage Impact Upon Railroad Rolling Stock Requirements

(Reduction in vehicle requirements by route)

Category	Destination	1985	1990	1995	2000
Coal hopper cars.	Florida	2,975	3,958	3,958	5,846
	Indiana	3,137	3,137	3,137	3,137
	Kansas	0	0	2,305	2,305
	Missouri	2,964	2,964	2,964	2,964
	Texas	6,383	12,855	16,954	22,768
	Totals	15,549	22,914	29,318	37,038
Locomotives	Florida	196	257	257	379
	Indiana	157.	157	157	157
	Kansas	0	0	115	115
	Missouri	148	148	148	148
	Texas	315	629	839	1.126
	Totals	816	1,191	1,516	1,925

Source: IR&T.

Table 20. Lost Tonnage Impact Upon Railroad Investment Requirements

(Reduction in requirements for the Lost Rail Tonnage scenario relative to No-Pipeline Baseline)

(Millions of 1971 Dollars)

	1980-1985	1985-1990	1990-1995	1995-2000
Coal hopper cars per year (number)	3,110	4,583	5,864	4,230
Annual coal car investment	40.4	59.6	76.2	55.0
Locomotives per year (number).	163	238	304	222
Annual locomotive investment	40.1	58.5	74.8	54.6
Annual way and structures investment	0/38[a]			
(Baseline annual way and structures investment).	(501)	(470)	(453)	(456)
Total annual investment reduction.	80.5/1 18.5	151.1	162.0	128.6

a If pipelines are brought onstream along each route in 1985, the railroads may be unable to achieve any reduction in way and structures investment over the 1980-85 period. The possibility is indicated by the zero value shown in the table. If the pipelines come onstream in 1980, it was estimated that an average annual reduction of $19 million in way and structures investment could be achieved over the 1980-85 period.

[b] Baseline annual way and structures investment is provided for comparison.
Source: IR&T.

The ability of railroads to obtain the necessary financing for coal-related transportation investment has been occasionally questioned. Referring to the Baseline investment requirements discussed in the appendix and the reductions shown in table 20, a number of conclusions can be drawn regarding the critical 1975-85 time period. First, the identified railroad capital requirements are small compared to the demand for capital in the U.S. economy. Second, the investments are required of financially sound western and southern railroads that enjoy fairly easy access to capital markets. Third, the increase in investment for shipments that might go to pipelines is only 4 percent of overall railroad investment. Finally, at least the portion of the investment associated with hopper cars could be shifted to the shippers through leasing arrangements or shipper ownership of cars if the railroad should encounter difficulties in financing investments.

Another investment-related question regards the possibility of " u necessary" capital expenditures. If the bulk of the pipelines were not to come online before 1985, railroads might be forced to make substantial investments in order to provide unit train coal shipments prior to that date. It is unlikely they could recoup these investments. The problem is relatively minor for rolling stock investment, since most of this could be readily shifted to other uses. Track improvements and new track emplacements, however, are less likely to have alternative uses. If the strong assumption is made that rail roads provide full unit train service through 1985, then lose the Lost Rail Tonnage scenario shipments at that time, $270 million of sunk capital in way and structures would be lost. There are three possibilities as to how this problem would be handled in practice:

1. The railroads would simply not make these investments, and hence would provide only slower and more expensive service;
2. The railroads would make these investments but would be forced to charge very high rates to ensure their adequate amortization, or;
3. The railroads would have to absorb very high and unrecoverable capital costs to provide unit train service over the period in question.

The option that would be adopted is, in large part, a matter of regulatory policy.

Employment Impacts

The reductions in railroad employment in response to pipeline development along the five scenario routes are shown in table 21, These reductions correspond to 4.4 percent of the railroad employment that would exist in 2000 in the absence of pipelines. The railroad employment losses (relative to the Baseline) are greatest in the West, representing more than 6 percent of the potential railroad labor force for that region in 1995 and 2000. These railroad employment reductions are only partially offset by the direct employment increases associated with pipeline construction and operation, estimated at between 300 and 500 workers along each route,

The employment requirements identified above are for direct transportation operating employment by the railroads and pipelines. In addition, each transportation mode stimulates employment in equipment supplier and construction industries. These employment requirements vary with regard to the time period considered and the employment measure used. Because pipelines require greater construction expenditures, the total number of job position requirements (operating and other) of the two transport modes were found to shift over time. For the period 1980–90 job position requirements are greater for pipelines than for railroads. After 1990 railroads will generate more jobs than pipelines, but railroad requirements do not exceed the cumulative total for pipeline job requirements until 2000. In the long run, however, both direct and multiplier effects indicated that railroads would provide more jobs than pipelines because the former generate more spending and, in terms of

Table 21. Lost Tonnage Impact Upon Railroad Employment and Compensation by Route[a]

	Destination	1985	1990	1995	2000
Employment	**Florida**	**1,770**	**1,951**	**1,645**	**2,005**
	Indiana	**3,073**	**2,612**	**2,209**	**1,876**
	Kansas	**0**	**0**	**1,568**	**1,334**
	Missouri	**2,810**	**2,390**	**2,018**	**1,716**
	Texas	**4.369**	**7.127**	**8.092**	**9.012**
	Total	12,022	14,080	13,958	15,943
Baseline employment.		**(362,520)**	**(361,950)**	**(362,660)**	**(365,660)**
Compensation (millions of 1971 dollars)	Florida	$29.68	$38.00	$ 37.23	$52.70
	Indiana	51.52	50.87	49.91	49.30
	Kansas	0	0	35.50	35.06
	Missouri	47.11	46,53	45.63	45.09
	Texas	73.23	138.78	183.12	236.76
	Total	$201.54	$274.18	$351.39	$418.91

[a]The employment and compensation numbers given in the table reflect the reduction in each variable for the Lost Rail Tonnage scenario relative to the No-Pipeline Baseline.

[b]The total No-pipeline Baseline employment estimates for each year are provided in parentheses for purposes of comparison.

Source: IR&T.

operating requirements, are more labor intensive.

As with investment needs, transition impacts are also an important consideration regarding employment requirements. The railroads might find themselves with a significant number of surplus employees if pipelines do not come online until 1985. It would be difficult to transfer these employees to other railroad jobs, since aggregate railroad employment was predicted to remain relatively constant in the post-1985 period. Pipeline implementation could therefore lead to layoffs and at least temporary unemployment of a maximum 12,800 railroad employees. The decreases in rail road wage compensation corresponding to the Lost Rail Tonnage employment reductions are also shown in table 21. The effect upon regional economics would be quite small. In fact, in line with the preceding discussion, pipeline labor compensation increases should offset the effect of the railroad compensation decreases up through the year 2000.

Operating Income Impacts

The reduction in railroad employee compensation given in table 21 was translated into a reduction in payroll taxes, in the manner described in the appendix. A similar computation was made for the State and local tax reductions resulting from the lost railroad coal shipments. These changes in railroad tax payments were then employed to evaluate the Operating Income for railroads under the conditions of the Lost Rail Tonnage scenario. The Operating Income results are presented in table 22 for the southern and western railroad regions over the period 1980 to 2000. The values become negative in the western region for Alternative III (historical rate decline) in 1990 through 2000, and decline steadily from an unacceptably low level to negative values for Alternative IV (constant operating ratio). Thus, neither of these rate behaviors could be sustained in the presence of the postulated level of pipeline market competition.

The railroads must at least obtain sufficient revenues to satisfy their MNNI requirements. This corresponds to Alternative V, as discussed for the Baseline. The MNNI revenues for western railroads in the case of the Lost Rail Tonnage scenario are shown in table 23. Comparing these results with those given in table 16

Table 22. Railroad Operating Income 1980-2000—Lost Tonnage Scenario

(Millions of 1971 dollars)

	1980	1985	1990	1995	2000
		Alternative I			
South					
Net railway operating revenues.	$ 917	$1,632	$1,980	$2,713	$3,588
Payroll taxes	(183)	(261)	(347)	(478)	(653)
State and local taxes.	(57)	(66)	(74)	(87)	(101)
Operating income	677	1,305	1,560	2,148	2,834
West					
Net railway operating revenues.	2,209	3,207	3,748	4,540	5,788
Payroll taxes	(477)	(652)	(839)	(1,1 14)	(1 ,479)
State and local taxes.	(192)	(204)	(217)	(234)	(258)
Operating income.	1,540	2,351	2,692	3,192	4,051
		Alternative!			
South					
Net railway operating revenues.	838	1,548	1,867	2,559	3,384
Payroll taxes	(183)	(261)	(347)	(478)	(653)
State and local taxes.	(57)	(66)	(74)	(87)	(101)
Operating income..	598	1,221	1,446	1,994	2,630
West					
Net railway operating revenues	1,998	3,023	3,462	4,162	5,300)
Payroll taxes	(477)	(652)	(839)	(1,114)	(1,479)
State and local taxes.	(192)	(204)	(217)	(234)	(258)
Operating income	1,329	2,167	2,406	2,814	3,563
		Alternative III			
South					
Net railway operating revenues.	522	977	1,015	1,279	1,533
Payroll taxes	(183)	(261)	(347)	(478)	(653)
State and local taxes.	(54)	(60)	(65)	(73)	(82)
Operating income.	285	656	603	728	798
West					
Net railway operating revenues.	995	1,232	795	406	111
Payroll taxes	(477)	(652)	(839)	(1,114)	(1,479)
State and local taxes.	(181)	(185)	(189)	(195)	(204)
Operating income.	337	395	–233	–903	–1,572
		Alternatively			
South					
Net railway operating revenues.	**495**	**528**	**624**	**757**	**899**
Payroll taxes	**(183)**	**(261)**	**(347)**	**(478)**	**(653)**
State and local taxes taxes	**(54)**	**(56)**	**(61)**	**(68)**	**(76)**
Operating income	**258**	**211**	**216**	**211**	**170**
West					
Net railway operating revenues.	1,288	1,277	1,297	1,386	1,632
Payroll taxes	(477)	(652)	(839)	(1,114)	(7,479)
State and local taxes.	(184)	(186)	(194)	(205)	(219)
Operating income.	$ 627	$ 439	$ 264	$ 67	–$ 66

Source: IR&T,

for the Baseline indicates that the expenditure reductions related to tonnage losses permit a maximum reduction in MNNI of **4.1 percent in 1985 and 6.4 percent** in 2000.

Table 23. Rail Revenues To Maintain Minimum Necessary Net Income on Western Railroads— Lost Tonnage Scenario

(Millions of 1971 dollars)

	1985	2000
Operating costs	$5,407	$8,452
Payroll taxes	652	1,479
State and local taxes	175	214
Minimum necessary net income	715	985
Revenues	$6,949	$11,130

Source: IR&T.

System Costs

Two effects must be distinguished in assessing the net economic impact of coal slurry pipeline development. These two effects are: 1) changes that result in net savings or costs to the overall economy, and 2) changes that affect prices or incomes by transferring money from one group to another without a net change in output of the overall economy. **In the case of coal slurry pipelines, the potential net savings to** the economy stem primarily from the labor, capital, and other resources that are released to uses other than coal transportation as a result of the shift from railroad shipments to pipelines. The relative transportation costs for the two alternative systems, with and without pipelines, constituted the basic measure of net savings.

Three additional considerations must be addressed in translating the transportation savings of pipelines into net savings to the economy. First, the total amount of coal transported may increase in response to the reduced transportation charges, and if rail rates charged other shippers increase as a result of the lost coal shipments, transportation of other commodities may correspondingly decrease. These potential shifts in commodity transport could add to, or detract from, the direct pipeline savings. Second, the full amount of the transportation savings are only applicable if resources can be successfully reallocated to other uses in the economy. For example, contained unemployment among railroad workers would imply that the labor resources could not be fully redirected. However, as noted earlier, pipelines offer greater near-term and lesser long-term employment than railroads. Third, the opportunity costs of water in alternative uses may have to be deducted. As discussed further on, these opportunity costs are relatively small if the pipeline water is drawn from what are currently the lowest value uses in the originating basins.

The reader should recall at this point that the pipeline markets and cost advantages on which this analysis is based are hypothetical. The purpose of this section is to illustrate how positive and negative impacts would be distributed if a pipeline industry as described in chapter IV were to develop.

Potential Savings

Utilities stand to benefit from reduced coal transportation charges, the extent of the benefit depending upon the rate differential achieved. Pipeline rates will be critically dependent upon three factors: regulating policy with respect to coal slurry pipelines;[8] competition between pipeline companies; and the relative bargaining power of the pipeline company and electric utility. Since there are several companies capable of building and operating coal slurry pipelines, and electric utilities themselves can invest in pipeline ventures, the ability of pipelines initially to charge rates significantly in excess of costs may be somewhat limited. In addition, the large shipment sizes necessary to achieve favorable pipeline economics mean that the electric utilities involved will tend to be quite large.

[8] Regulatory considerations are discussed in chapter **VI 1 of this report**

Customer size and financial leverage could further serve to restrict the possibilities for excessive pipeline rates. Reduced transportation rates could also increase the demand for coal in some areas, thereby benefiting the mining industry

The rate situation for railroads is more complicated than for pipelines. This study found, as others have, that railroads have historically been able to achieve significant economies of scale. These economies of scale have occasionally led to difficulties in setting railroad rates, This is true because as long as incremental, or marginal, costs' are declining, rates must exceed the incremental costs of each shipment if railroads are to cover effectively their total costs. The proper method of allocating these additional charges to specific rates has been the subject of regulatory debate for decades,

The actual savings to utilities as a result of a shift to pipelines therefore depend not upon differences in costs for the two modes, but upon differences in rates. The railroad rate and incremental railroad cost assumptions used embodied a significant difference between rail rate and incremental rail costs. The maximum savings to utilities would occur if pipeline rates equal led pipeline costs, due either to market or to regulatory forces. The maximum savings would then equal the difference between rail rates and pipeline cost. **In the Lost Rail Tonnage scenario this** would result in savings of $273 million a year in 1985, rising to $710 million a year by 2000. On the other hand, as noted above, pipeline rates may be significantly higher than pipeline costs. The minimum estimate of utility savings would therefore be calculated as the difference between rail rates and incremental rail costs. The estimated savings then would be $49 million a year in 1985, and rising to $416 million a year by 2000. The difference between these two utility savings estimates represent potential monopoly profit to pipelines,

The precedent-based nature of many railroad rates may not permit railroad rate reduction. The Interstate Commerce Commission [ICC) regulation of railroad rates becomes a factor at this point. The ICC attempts to approve rail rates in an internally consistent manner in part so that a customer making a shipment in one region of the country will be charged the same amount as a customer making a comparable shipment in the same region. As a result, the ICC may not approve lower rates where pipeline competition is arising. If the rate reduction were not allowed and the pipelines were able to capture that set of coal shipments, the effect upon the economy as a whole would be a transportation loss since a more expensive transportation mode would be employed along those routes.

Impact Upon Other Shippers

The transportation savings to utilities are directly related to downward adjustments in the rates charged for the coal shipments, whether the adjustment in rates are achieved by transferring shipments to pipelines or as the result of a competitive adjustment in railroad rates. Both adjustments cause a comparable reduction in railroad revenues. To the extent that the revenue losses exceed the corresponding reductions in railroad costs (including tax expenditures, etc.), railroads will suffer a net reduction in coal-transportation-related income. This income reduction can either be absorbed by the railroads, thereby adversely affecting their financial performance, or it can be passed on, in whole or in part, to other shippers. The amounts by which charges to other shippers must be increased in order to attain desired levels of railroad financial performance were determined for two situations. For Alternatives I-IV, revenues were increased by that amount necessary to restore the profits lost (calculated as the difference between railroad rates for coal and the costs of these shipments). **In Alternatives I and II no rate change was required as the profit from coal shipments was not necessary to the financial health of the railroads. For Alternatives III and IV, rate changes would be required in the West to restore an already precarious financial**

'Incremental, or marginal, costs are the change in total cost resulting from an additional unit of output or service

-1 -

status. For Alternative V, the rate increase required to maintain the MNNI was determined. In 1985, the rate increases required to restore pre-pipeline financial positions (for the Lost Rail Tonnage scenario) are from 0.7 to 0.9 percent by 1985 rising from 4 to 4.7 percent by 2000. If western railroads must also lower rates on some coal shipments to meet pipeline competition, the required rate increase for other shippers were estimated to be somewhat higher.

In order to put these potential rate increases into context, it should be noted that they do not represent increases over present rates. Rather they imply that rates would decline less than would occur in the absence of pipeline competition.

Net Savings

The preceding two subsections addressed the manner in which revenue losses and gains may be allocated among railroads, utilities, and other shippers. These allocations fall into the category of revenue transfers. The net savings to the economy are related to the difference in costs (not revenues) between the two shipment modes. Thus, the Lost Rail Tonnage scenario achieves net savings, since the pipelines are assumed to cost less along those routes for which shipment adjustments are made. Competitive pressures on rail rates, on the other hand, merely reallocate revenues without bringing about a net savings to the economy. The potential net savings associated with the pipeline costs and market shares assumed in chapter IV are given in table 24. The values shown are the cumulative savings for the periods 1985-2000, and 1985-2015 assuming that shipment levels remain at their 2000 level from 2000-2015. The aggregate net savings are in excess of $2.5 billion over the 30-year period. These figures are subject to the limitations and simplifying assumptions explained at the end of chapter IV.

Table 24 also shows the sensitivity of the net saving estimates to certain key economic assumptions. A significant fraction of the savings were attributable to assumed large shipments to Texas. **In order to gain insight** into the significance of the other four shipments,

Table 24. Sensitivity of Potential Net Savings From Hypothetical Coal Slurry Pipeline Development

(Discounted present value in billions of 1971 dollars[a])

		Sensitivity y Analysis		
Time **period**	Lost rail tonnage **scenario**[b]	Low Texas[c]	No way and structures **invest mental**	Significant railroad **economies of scale**[e]
1985-2000	1.6	1.2	1.2	0.63
1985-2015f	2.5	1.6	1.9	0.95

a1971 dollars can be converted into 1977 dollars by multiplying by 1.42. Future dollars are discounted to 1977 at 7.15 percent per year.

bThe Lost Rai Tonnage scenario assumes that significant potential net savings can be achieved by substituting pipelines for railroads on selected routes. This sensitivity analysis was designed to evaluate the effect upon potential net savings of various economic assumptions favorable to railroads. As a result, these sensitivity analyses yield lower potential net savings than for the original scenario. This does not mean that the scenario represents the highest possible estimate. Additional pipeline construction would increase those savings as long as they were implemented in response to real cost advantages.

cThe Low Texas case assumes no growth in Texas shipments after 1985.

dThe No Way and Structures Investment case assumes that new track and upgrading expenditures attributable to those unit trains affected by pipeline competition are zero because of benefits elsewhere i n the rai l road system.

eThe Significant Railroad Economies of Scale case assumes a scale factor of .87 for all operating expenditures and **way** and structures investment.

fThe 1985-2000 alternative assumes that shipments Cent inue at the year 2000 levels f rom 2000 to **2015.**

the net savings were calculated assuming no growth beyond 1985 for the Texas pipelines. The net savings remain substantial, being approximately 70 percent of the results with the full Texas shipments.

A more important economic assumption underlying the net savings estimates was the assumption that no changes occur with regard to systemwide costs. Two systemwide changes were examined through sensitivity analyses. First, the possibility was considered that way and structures investments for new track and track upgrading may either attract additional traffic or reduce costs for other shipments. A sensitivity analysis was conducted in order to test the potential importance of this issue. The extreme assumption was posed that all of the way and structures investment attributed to unit trains could, in fact, be assigned to other traffic requirements. On this basis, the way and structures investments for the coal unit train shipments of the Lost Rail Tonnage scenario were set to zero, Even with this extreme assumption, the net savings remain substantial Only one route (Kansas) actually changes sufficiently to return from pipeline to rail.

The analysis of the sensitivity of net savings to way and structures also has another implication which should be noted. In the section on Investment Impacts, a potential problem was raised that railroads might have to make way and structures investments which would then be worthless when pipelines came online. The fact that net savings are still high even in the absence of way and structures investments by railroads also implies that deductions of these transition costs would still leave substantial net savings.

A second way in which the incremental cost analysis may err is by failing to take into account systemwide economies of scale not readily apparent when analyzing a specific route These are in part dependent upon the systemwide total size. Economies of scale have two possible origins: large fixed costs accompanied by relatively constant costs for each additional shipment, or declining incremental costs for each additional shipment. The case of large fixed costs and constant incremental costs presents difficulties in cost allocation and ratesetting, but does not require a correction to the incremental cost-based net savings estimates given in table 24. The case of declining incremental costs does, however, require an adjustment to the incremental cost-based net savings estimates. Unfortunately, prior statistical cost studies, while strongly suggesting the presence of railroad economies of scale, do not permit differentiation between the two cases. For the purposes of a sensitivity test, it was assumed that declining incremental costs hold for all operating cost categories and for way and structures investments. The scale factor of 0.87 was used, i.e., cost increases 0,87 percent for every 1-percent increase in ton-miles. This extreme assumption considerably reduced the size of the net savings, but some net savings remain, as shown in table 24.

The net savings in table 24 were computed assuming that the total transportation system size does not change. That is, neither the total amount of coal transported nor the amount of other goods transported by both rail and pipeline change as a result of the implied changes in rates. **In fact, total goods transported does change with transportation rates. To the extent that utilities use** more coal with lower transportation rates, the resulting benefit to the mining industry from using coal rather than other fuels will increase the net savings attributable to pipelines. To the extent that railroads lose shipments when they attempt to increase rates to maintain necessary income, net savings will decrease. Whether net savings increase or decrease as a result of these two types of offsetting effects depends upon the relative responsiveness to rate changes of the different types of shipments. Current data does not permit a clear judgment as to the direction of this effect, but it would be unlikely to offset the total potential net savings identified in table 24.

Economic Impacts of Water Resource Allocation

The cost analysis described in chapter IV included the costs that pipelines will have to pay for water usage, such as pumping, transportation, and purchase price. These costs are part of the pipeline's operational expenditures. However, they may not reflect the full value of that water in alternative uses. This could happen because, unlike most other resources, water resources are not allocated through markets. Though details vary, water tends to be allocated in the form of water rights. These rights are frequently nontransferable, i.e., one must use the right or lose it, rather than being able to sell it. The problem in establishing water value in alternative uses is further complicated by the substantial subsidies often provided if the water source is a Federal resource project. As a result, the true societal value of water cannot be directly determined from the prices paid, but must be assessed through a comparative evaluation of the water's value in alternative uses. A variety of studies suggest the following ordering of water values in use: municipal water supply tends to have the highest value, industrial use varies by industry but tends to be lower in value than municipal use, and agricultural uses, with the exception of certain high value per-acre crops, such as fruits or vegetables, tend to have the lowest values.

The two principal potential industrial uses in the western coal region are coal gasification and coal mining. In order to appraise the value of water used for coal gasification, the net profits and flexibility of water used for such plants must be estimated. Since the feasibility of these plants in the West is somewhat uncertain, and the engineering details necessary for an analysis of flexibility in water use have not yet been developed, the value of water in this case cannot be quantified at this time. However, a maximum value can be estimated for water if it would otherwise be used for coal mining in the West. The environmental analysis described in chapter VI indicated that up to 331 million tons of coal would be foregone in 2000 if all the case study pipeline-related water were obtained from coal production. On the basis of the 1971 value of Wyoming coal, $4.I4 per ton, the resulting coal production loss would exceed $1.3 billion per year. Of course, only a small fraction of this value represents the opportunity costs associated with water usage. It also includes values for capital, labor, and other inputs that would be redirected into other uses. Nevertheless, the magnitude of the economic loss if coal production were affected by water withdrawals is such that even a small fraction of it would represent a major offset to the savings associated with coal slurry pipelines.

An estimate can also be made for the maximum possible value of water in the largest agricultural application, hay and alfalfa growing. The environmental analysis (see chapter VI) indicated that transporting 125 mill ion tons per year from eastern Wyoming by pipeline would require 69,500 acre-feet of water. If this water were otherwise to be used for hay and alfalfa acreage, 300,000 tons of potential annual hay production would be foregone. At a 1971 value of $26.00 per ton, the annual value of foregone hay production would be $7.8 million. This value includes the value of labor and other inputs. The actual value of the water is probably less than 20 percent of the total. The quantities of production in question are sufficiently small that they should not affect national food prices.

The estimated value of water in coal mining was found to be many times as great as in hay growing. The water would therefore be obtained from the latter usage if it were allocated by economic market conditions. However, water resources are allocated by nonmarket mechanisms in many regions, as discussed in chapter VII. As a result, the economic impact of water diversions by pipelines will be critically dependent upon the water resources policy in each region, and the economic impact will disappear if there is sufficient water to satisfy the needs of all potential users. The availability of water in the pipeline-origin region is discussed in chapter VI.

VI. Environmental and Social Impacts

VI. Environmental and Social Impacts

INTRODUCTION

The following discussion of the environmental and natural resource impacts of transportation of coal, by railroad unit trains or coal slurry pipelines, recognizes the inherent differences between the two modes of transportation The form of the product transported differs, the physical environment under which the products are transported differs and therefore, the environmental impacts differ. Coal slurry pipelines use substantial amounts of water, whereas railroads require essentially no water for the transportation of coal. The major environmental impacts of railroads are the delay, noise, and inconvenience caused by trains traversing populated communities. Both modes of transportation will cause some environmental impacts from construction and facility improvement. Slurry pipelines and increased unit train operations are directly comparable only in the areas of air pollution, safety and health, noise, and energy and materials resource depletion Even these areas present analytical problems: diesel locomotives emit pollutants along a linear path, while the emissions due to power generation for coal slurry pipelines would be concentrated at several point sources. A large percentage of the occupational accidents due to pipelines would occur during construction, but the present study anticipates only a nominal amount of new rail construction. Additionally, many if not al I the impacts are interrelated For example, noise pollution has an effect upon land use, as does the diversion of water to a slurry pipeline from an existing or projected future alternative use

The discussion is limited to the incremental impacts of moving the estimated amounts of coal. That is, analysis of all railroad impacts is not attempted, but rather those impacts attributable to the estimated increased coal transportation. The incremental impacts due to moving comparable amounts of coal by coal slurry pipeline are analyzed, but because of the necessary pipeline construction and the fixed origin, destination, and volume of pipelines, the incremental and total impacts are nearly the same.

The discussion is also limited to the differential impacts of coal slurry pipelines and railroads. It is assumed that the coal will be transported and not, for example, burned at the mine site. Other modes of transmission, while admittedly possible, are not analyzed here.

The people adversely impacted by coal transportation are not necessarily the same people who will benefit from the power generated by the coal. The study is concerned with the nature, extent, and duration of the examined impacts. Railroads and oil and gas pipelines have been on the American scene for many years. Many of their environmental impacts are well known and it is relatively easy to compare them with other aspects of human experience.

Three kinds of impacts were selected for study:

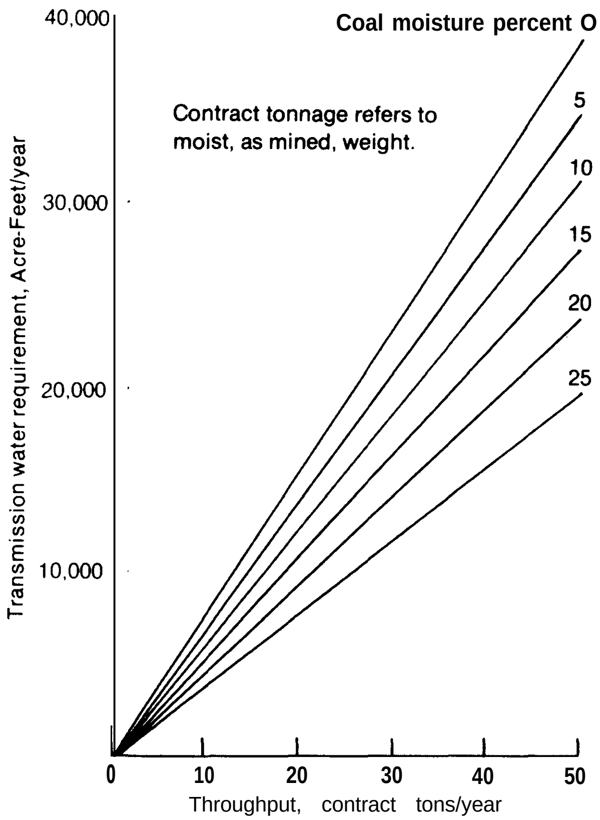
1. Those which have been historically significant, such as air pollution,
2. Those which, from a scientific standpoint, appeared to have the potential for significance; e.g., the interactions between coal and water in the slurry pipeline, and
3. Those which initially appeared to be insignificant but which, due to their frequent appearance in the public debate, required an objective, thorough examination; e.g., the potential for coal dust being blown off of coal hopper cars.

The following section discusses the most important environmental issue associated with coal slurry pipelines — the availability of water. The major environmental impacts associated with increased railroad unit train operation — noise, traffic, delay, and inconvenience — are discussed in the next section. Longer term impacts, chiefly those resulting from pipeline operations, and shorter term impacts, chiefly associated with construction, are reported in later sections. Some of the construction and operation impacts have actually been observed, while other impacts may not have yet been observed but were either deemed likely to occur or subject to enough public debate to be included.

WATER USE BY PIPELINES

As illustrated in figure 20, water requirements for transmission of coal as a slurry are substantial and dependent upon coal-moisture content. The four hypothetical pipelines discussed earlier in this report would require a total of from 35,000 to 47,000 acre-feet per year (AF/yr) of water. These aggregate figures, which are presented by hypothetical pipeline route in table 25, do not reveal much about either the impacts of such water use upon the areas which would supply the water, or the source of the necessary water. To place the consumptive use of water in perspective, the water supply potential of four hypothetical pipeline origins was evaluated. In two source locations, Wyoming and Montana, the Bighorn River would supply water by aqueducts to the slurry pipeline origin. Ground water from the Madison Limestone Formation was also considered as a water source for the pipeline **from Wyoming.** The Tennessee River would supply the pipeline from Tennessee and the Green Rive would be the water source for the pipe ine from Utah.

Figure 20–Transmission Water Requirements as a Function of Coal Throughput Moisture Content



Source Science Applications, Inc

Table 25. Water Requirements for Hypothetical Coal Slurry Pipelines

Route	Million tons of coal per year	Range of annual requirements AF/yr
Wyoming-Texas	**35.0**	**13,000-20,000**
Montana-Minnesota/ Wisconsin	**13.5**	**6,000-8,000**
Tennessee-Florida.	**16.0**	**10,000-12,000**
Utah-California.	**10.0**	**6,000-7,000**

[a] Includes water for transmission and emergency flushing reservoir replenishment. Minimum is for high-moisture coal and no spills. Maximum is for low-moisture coal and a worst case of one spill per year.

Although the four pipieline routes and destinations are hypothetical, the general location of the source of the routes is plausible because of the abundance of coal at the selected locations. Most of the water required for a given pipeline must be available near the pipeline origin. The generalizations from the four specific cases are therefore of widespread importance with respect to water usage and availability.

Two types of potential impacts from the water use were investigated: those upon the immediate, surrounding environment, i.e., streams and aquifers, and those upon alternative water uses, The first category, environmental impacts, are minor for the following reasons:

- Withdrawals of surface water for coal slurry pipeline use would constitute a very small fraction of the physically available flows in supply source streams or rivers. If one ignores other uses of water as a resource, effects upon flow rate, dissolved oxygen concentration, salinity, waste assimilative capacity, and other water quality parameters would probably not be measurable. For example, a group of pipelines moving 125 million tons of coal per year from Wyoming would use a maximum of **3 percent of the Bighorn River's average depleted flow at the Wyoming-**Montana State line. Agricultural uses downstream from the nearby Boysen Reservoir are more likely to deplete flows to a point where water quality seriously declines. Pipelines from Tennessee carrying 31 million tons per year would remove at most O 1 percent of the flow of the Tennessee River. **I n** both cases flows are regulated by reservoirs.
- Although increased pumping of ground water from the Madison Formation in Wyoming could result in declines in potentiometric head at some distance from well fields, there is no evidence that local or regional subsidence or reduced surface streamflow would occur.

The other category of environmentally related impacts from water use by coal slurry pipelines is a reduction in some present or future alternative water uses. In each of the four hypothetical cases studied, the physical supply of water is sufficient to transport the coal even with substantial future expansion of pipeline volumes. However, three legal factors limit the actual water available:

1. Interstate compacts, State legislative restrictions on use, Indian rights, and the possible exercise of Federal reserve rights all place a practical limit upon quantity of water that may be used in a given river basin or State. Ironically, the greater the hydrologic area considered, the more restricted the water supply.
2. The prior appropriation doctrine, based upon the concept of earliest beneficial use of water, dominates the water rights system in the coal-producing areas of the West. In most Western States, including Wyoming and Colorado, the user who is "first in time is first in right. " The holder of a relatively recent right which is subordinate to older claims may be allowed to appropriate or divert little or no water in times of drought.
3. Water rights systems in the West are administered by the States, usually through the State engineer. Obtaining water rights is often a time-consuming, complicated affair, and the would-be appropriator must often "stand in line behind a series of prior applications."[1]

The current drought is dramatizing the scarcity of water in the West at the same time that plans for increased energy development, including mining, electric power generation, coal gasification and liquefaction, and shale oil exploitation, all would require relatively large increases in consumption of the region's

[1] **W** Gertsch, **"Utah** Water Supply, **"** *Study of Alternative Locations of Coal-Fired Electric Generating Plants to Supply Energy From Western Coal to the* Department *of Water Resources*,. University **of California at** Los **Angeles, Institute of** Geophysics **and Planetary** Physics **and** Office of Environmental Science and Engineering, pp 6-45 to 6-53, March 1977

water.[2,3] **In each of the potential coal slurry pipeline origin areas except Tennessee, demand projected for the 1985-2000 period exceeds the legally available supply. In the case of the Bighorn River** in Montana, for example, the combination of present uses, signed contracts for U.S. Bureau of Reclamation water, and applications for future appropriations exceeds the State's compact share of the river's flow by over 450,000 AF/yr. Demands in the entire Montana portion of the Yellowstone River Basin (to which the Bighorn is tributary) will reach the legally available supply by the year 2000.[4] Similarly, according to some projections, the area around Gillette would have (without a slurry pipeline) a deficit of over 100,000 AF/yr by 2000, unless water were imported.[5]

The significance of these deficits is that a coal slurry pipeline could use surface water only at the expense of growth in the existing and new uses. Ground water could in some cases reduce the deficit, but not the competition. For example, water from parts of the Madison Formation is chemically suitable for most municipal, industrial, and agricultural uses, in addition to coal transportation. Furthermore, assuming it were physically possible and economical to withdraw enough water to overcome the projected deficit, withdrawals would **exceed the present estimate of recharge, so that the consequences of groundwater mining would have to be considered.**

It is impossible to predict which specific future water uses would be precluded by coal slurry pipelines. The major types of competing uses would be energy-related industry and agriculture. Rather than speculate upon the myriad of possible futures, "water-use equivalents" of a given slurry pipeline demand were estimated. Table 26 lists the total water-use equivalents for the four pipelines examined in the case studies. For example, the pipeline from Tennessee would consume about the same amount of water as one to three coal gasification plants using the Lurgi process. Similarly, the Montana pipeline would take enough water to revegetate about 3,000 acres of surface-mined land in the Colstrip area in 1985. If all the water for the four pipelines carrying 74.5 mill **ion tons** of coal per year were redirected, it could be used to mine 160 to 220 million tons of coal, reclaim 16,000 to 21,000 acres of surface-mined land, serve up to 10 coal gasification plants or up to 5 coal

[2] R Nehring, B Zycher, and J Wharton, *Coal Development in the Northern Great Plains A Preliminary Report,* **R-1 981** -N SF/RC, prepared by Rand Corp , for National Science Foundation, August 1976

[3] *Report on Water for Energy in the Northern Great Plains Area With Emphasis on the Yellowstone River Basin,* U S Department of the Interior, Water for Energy Management Team, January 1975

[4] Ibid

[5] *The Wyoming Framework Water Plan,* State of Wyoming, State Engineer's Office, Laramie, Wyo , May 1973

Table 26. Water-Use[a] Equivalents for Hypothetical Pipelines

Alternative use	Wyoming-Texas	Montana-Minnesota/Wisconsin	Tennessee-Florida	Utah-California
Coal mining (10^6 tons/yr).	60-90	30-40	50-60	30-40
Mine reclamation (10^3 acres).	6-9	3	5	3
Coal gasification' (plants)				
—Lurgi	1-4	0-2	1-3	0-2
—CO_2 Acceptor	1-4	1-2	1-3	1-2
Coal Liquefaction (plants).	1-2	0-1	1	0-1
Electric power generation (plants).	1-2	0-1	0-1	0-1
Municipal (10^3 **people)**	65-130	50-60	100-120	20-25

[a] Net consumptive use for all categories except municipal. [b] For 2 years. c 250 million scf/day. [d] 100,000 bbl/day. [e] 1,OOO-MWe plant at 35-percent efficiency, 70-percent load factor, wet cooling tower. [f] Based upon projected withdrawal rates for 1990. Also based on total withdrawal and not net consumptive use.

liquefaction facilties, or provide cooling for 2 to 4 powerplants. To process 1 ton of coal, an electric powerplant requires roughly seven times as much water as a slurry pipeline does, and about twice as much water is needed to gasify the same amount of coal, Mining, on the other hand requires approximately half as much water per ton of coal as slurry transportation.

The nature, magnitude, and probability of impacts upon agricultural alternative uses depend entirely upon local conditions. In Tennessee, where only 65 acres are irrigated in the coal source area, the impacts upon agriculture would be minimal, Farming is reportedly marginal in parts of Carbon and Emery counties in Utah, so that some farmers may be willing to sell their water rights and thus eliminate some agricultural uses. Alfalfa, hay, and corn are the main irrigated crops in the Wyoming, Montana, and Utah source areas. Sugar beets are fairly important in Montana, as is irrigated pasture in Utah. Vegetable and fruit crops are not irrigated to as significant an extent as grains. Because of the large present use of irrigation water (about 200,000 AF/yr) and the projected demand for Bighorn River water, agriculture in the Bighorn River Basin is, of all the cases studied here, most **likely to face a conflict with other uses, including coal slurry pipelines,**

The remainder of this section discusses in more detail water availability and the impact **upon future water uses for each of the pipelines.**

Water for the Wyoming Pipeline

The hypothetical 35 million-ton-per-year pipeline from Wyoming would require 12,640 to 19,300 AF/yr of water in Wyoming. Additional water for emergency replenishment could be obtained along the pipeline route in the States of Nebraska, Colorado, Kansas, and Texas, and local sources would be sufficient. Flows in surface streams in the **Powder** River Basin area are low and irregular and therefore are not a reliable water source for coal slurry pipelines. Additionally, the water demands of the pipeline would exceed the available water by 1985 if the Little Missouri, Belle Fourche, and Cheyenne Rivers were relied upon. The Bighorn River Basin in northcentral Wyoming is a reasonable source of water supply for a coal slurry pipeline originating near Gillette. It is estimated that 1.8 million AF/yr are now available to Wyoming from the Bighorn River Basin for new beneficial uses. '

The Madison Formation was analyzed as a potential water source because of the projected future" competition for surface water and the controversy associated with ground water sources in Wyoming. The Madison aquifer consists principally of carbonate rocks of Mississippian age (about 310- to 345-million years old) underlying northeastern Wyoming, southeastern Montana, northwestern Nebraska, and western North and South Dakota. Figure 21 shows the outcrops and subsurface extent of these rocks. The Madison is composed chiefly of limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). Because these carbonate rocks are relatively soluble in water, the development of karst, or solution-cavity features, is common. [7]

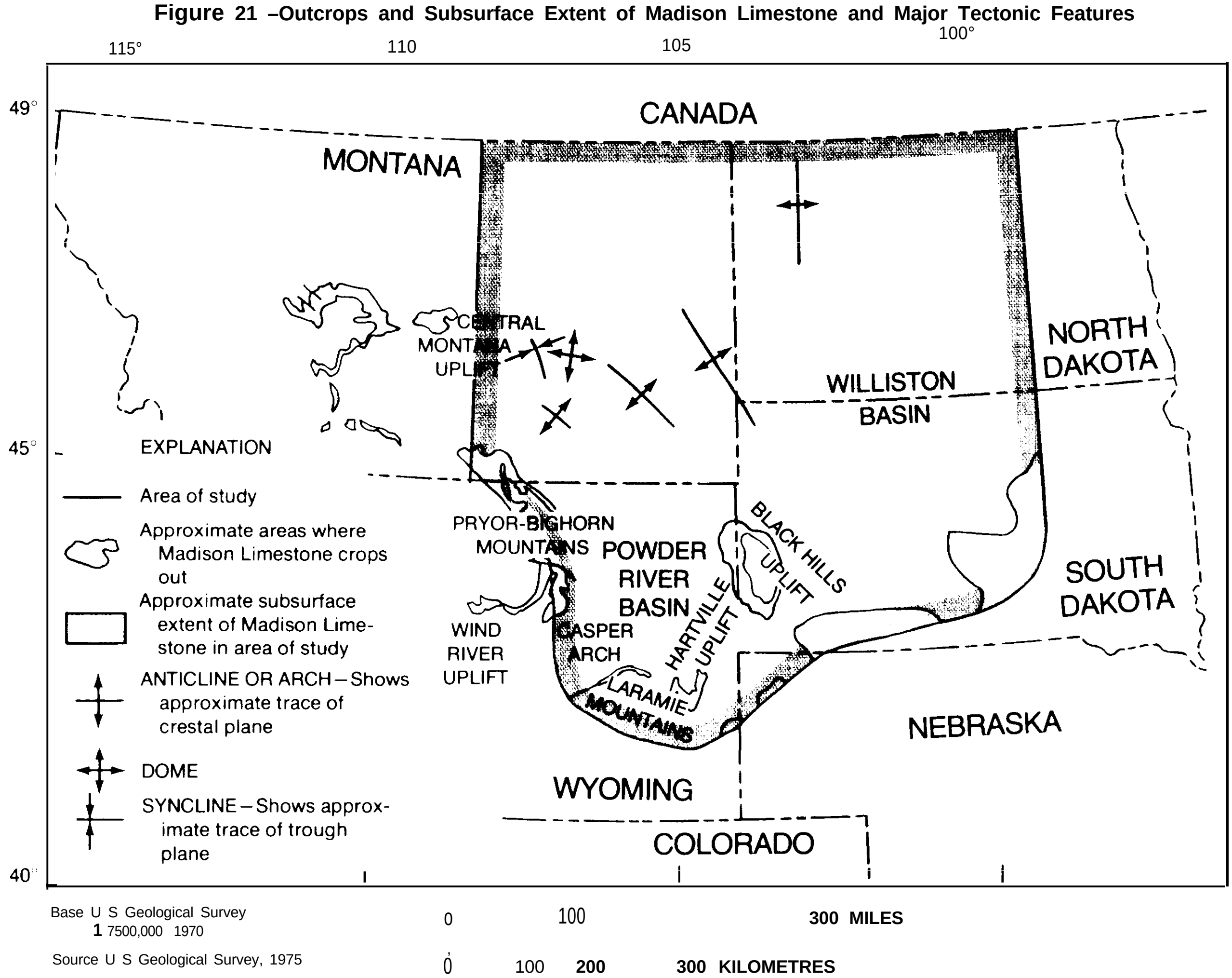
The water-bearing and transmitting capability of the Madison is highly variable because of its primary structure, the karst features, and the filling of the latter. As the Wyoming State Engineer notes, "No rock differs more radically with respect to water yield than limestone. Limestone can rank among the most productive aquifers, or can be as unproductive as shale."[8] The Madison's primary porosity, i.e., that due to open spaces between carbonate grains, appears to be low and to vary spatially. Dolomite beds seem to be more

[6] Ibid

[7] L F Konikow, *Preliminary Digital Model* **of** *Ground Water Flows in the Mad/son Group, Powder River Basin and Adjacent Areas, Wyoming, Montana, South Dakota, North Dakota, and Nebraska,* **U S** Geological Survey Water Resource Investigations 63-75, January 1976

[8] *Investigation of Recharge to Ground Water Reservoirs of Northeastern W yoming (The Powder* **River** *Basin),* State of Wyoming, State E ngineer's Off Ice, June **1976**

Figure 21 –Outcrops and Subsurface Extent of Madison Limestone and Major Tectonic Features



Base U S Geological Survey
1 7500,000 1970

Source U S Geological Survey, 1975

porous than limestone beds in this aquifer. [9] **water is stored mainly in and transmitted through secondary openings such as fractures, joints, and solution cavities.** The occurrence of these secondary openings is quite variable and difficult to predict, which may explain the wide range in yields of water wells drilled into the Madison. [10]

Certain structural features greatly influence the hydrologic characteristics of the Madison. Several areas of folding and faulting have been identified, **while others** have been inferred. Folding and faulting probably have fractured **the rocks and increased their permeability.**[11] Faults often also act either as barriers to lateral movement of ground water or as conduits, although the role of faults in the Madison has not been conclusively determined. The U.S. Geological Survey is testing a hypothesis that the Madison is actually several discontinuous hydrologically isolated aquifers rather than a single continuous one. [12]

Figure 22 shows the configuration of the top

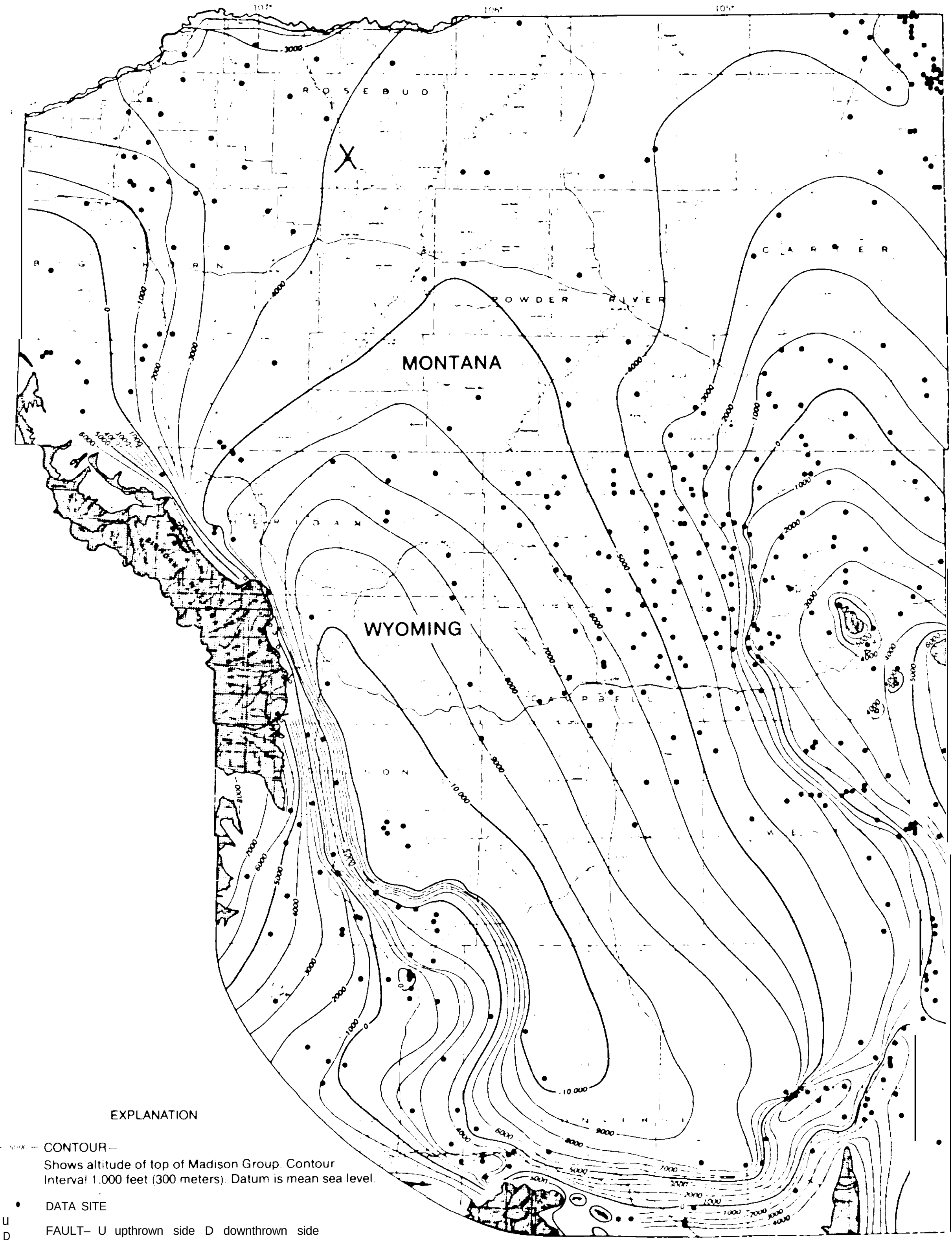
[9] **Leonard Konikow, U S Geological Survey,** Lakewood,Colo, personal communication, **Sept 14, 1977**

[10] L F Konikow, *Preliminary Digital Model of Ground Water Flows in the Mad/son Group, Powder River Basin and Adjacent Areas, Wyoming, Montana, South Dakota, North Dakota, and Nebraska,* U S Geological Survey Water Resource Investigations 63-75, January 1976

[11] *'Plan of Study on the Hydrology of the Mad/son Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming,* U S Geological **Survey, Open File Report 75-631, Denver,** Colo , **December 1975**

[12] E lliot Cushing, **U S Geological Survey,** Lakewood, Colo , **personal** communication, Aug **22, 1977**

Figure 22-Configuration of the Top of the Madison Group



EXPLANATION

— 3000 — CONTOUR—
Shows altitude of top of Madison Group. Contour interval 1,000 feet (300 meters). Datum is mean sea level.

• DATA SITE

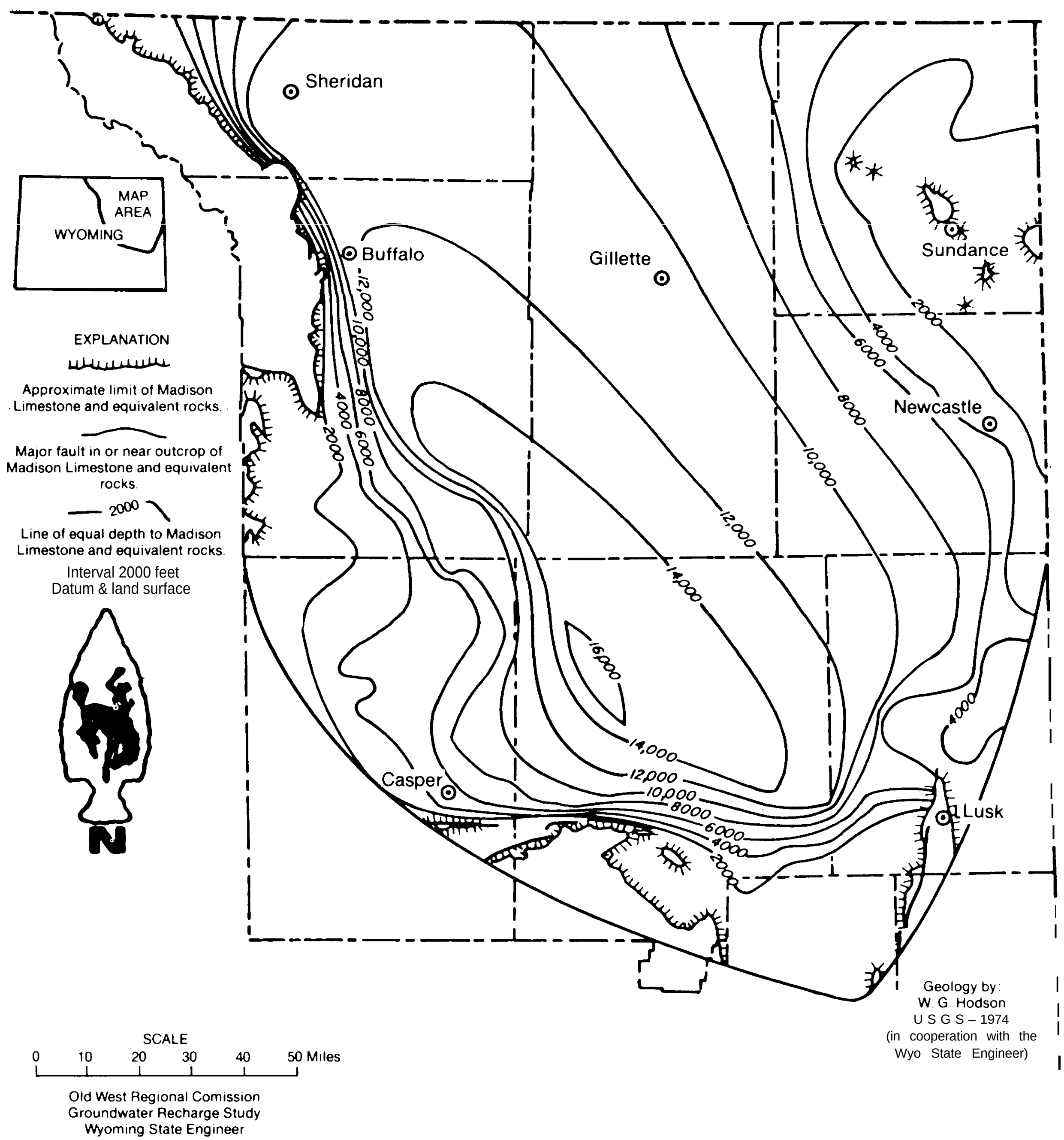
U / D FAULT– U upthrown side D downthrown side

AREA WHERE MADISON GROUP IS ABSENT

Source U S Geological Survey 1976

Contours by F A Swenson W R Miller W G Hodson and F N Visher 1975 of the Madison Group in northeastern Wyoming and southeastern Montana; contour lines show the elevation above mean sea level. Depths to the Madison from the land surface are shown in figure 23. At its deepest portion, which appears to be in Converse County, Wyo., it is about 10,000 feet below sea level and 16,000 feet below the land surface. In the

Figure 23–Depth From Land Surface to the Madison Limestone and Equivalent Rocks in the Powder River Basin and Adjacent Areas



Source State of Wyoming, State Engineer's Off Ice, 1976

Table 27. Selected Data From Madison Formation Wells and Springs, Powder River Basin, Wyo.

No[a]	Location T	Location R	Use[b]	Well depth (feet)	Test date(s)	Discharge (9pm)	Drawdown (feet)	Penetrated thickness (feet[c])	Specific capacity (gpm/ft)
1	33N	75W	OFW	8,591	1963	510	800	235/250	0.64
2	33N	75W		9,337	1951	ND[d]	ND	ND	ND
3	33N	76W	OFW	8,770	1962	75-320	16-92	240/250	3.5-4.7
4	33N	76W	In	6,954	1964	195	ND	ND	ND
5	33N	77W	In	7,615	1966	65	ND	ND	ND
6	36N	62W	T	3,116	1974	104,180	217-386	250/250	0.47,0.48
7	39N	61W	T	2,889	1962	30	36	81/300	0.83
8	40N	61N	OFW	7,467	1971-2	297-359	274-298	350/350	1.0-1.2
9	40N	61N	OFW	5,049	1971-2	491-726	100-133	350/350	4.4-7.1
10	40N	61N	OFW	4,889	1971-2	4,121-5,599	152-202	214/350	25-31
11	40N	61N	OFW	4,975	1971-2	1,700-7,200	35-418	281/310	17-49
12	40N	61N	OFW	4,968	1971-2	482-650	11-25	291/310	26-44
13	41 N	84W	s	424	1963	15	60	200/200	0.25
14	42N	81W		4,246	ND	1,080	ND	ND	ND
15	43N	80W	OFW	9,300	1973	170,315	139,219	340/340	1.2,1.4
16	44N	63W	u	6,881	1967	250	175	400/400	1.4
17	45N	61W	M	2,638	ND	600-1,500	173-462	26/400	3.2-3.6
18	45N	61W	M	2,872	1966	460	200	400/400	1.4
19	45N	61W	c	2,738	1965	176	18	43/400	15
20	45N	61W	s	2,728	ND	1,200	ND	ND	ND
21	45N	61W	In	3,073	ND	117	ND	ND	ND
22	45N	61W		3,028	1960	650	ND	ND	ND
23	45N	61W	OFW	3,596	1960	290	ND	ND	ND
24	46N	60W	S,I	1,178	ND	35	ND	ND	ND
25	46N	62W	S	2,677	ND	30	ND	ND	ND
26	46N	63W	In	2,592	ND	580	ND	ND	ND
27	46N	64W	A	7,542	1956(?)	280	80	428/450	3.5
28	46N	64W	u	5,125	1965,1972	70,308	65,293	450/450	1.1
29	46N	64W	OFW	4,522	ND	30	ND	ND	ND
30	46N	65W	OFW	8,109	1960	425	295	369/450	1.4
31	46N	65W	OFW	7,737	1972	225	76	400/450	3.0
32	46N	66W	OFW	8,780	1972	360	211	390/450	1.7
33	47N	60W	P	380	ND	8	ND	ND	ND
34	48N	65W	M	3,161	1972	210	110	261/500	1.9
35	48N	65W	M	3,191	1972	155	101	464/500	1.5
36	49N	83W	ND	Spring	1973	200	NA[d]	NA	NA
37	52N	61W	ND	Spring	1969	300	NA	NA	NA
38	52N	63W	M	1,123	1972	200	74	23/550	2.7
39	53N	65W	P	1,341	1962	15-55	1-19	42/600	2.9-1.5

[a] Nos. 1-5: Glenrock, 6-12: Northeast NiobraraCounty, 13: Big Horn Mountains, 14-15: Kaycee, 16-24: Newcastle, 5-32: Osage, 33: Black Hills, 34-35: Upton, 36:Johnson County, 37-39: Crook County.
[b] OFW = oil field waterflood, S = stock watering, U = unused, M = municipal, C = commercial, A = abandoned, P = public,T = Test, In = industrial, I = irrigation.
[c] Thickness penetrated by wel l/estimated total thickness of formation.
[d] ND = no data, NA = not applicable.
Source: U.S. Geological Survey, 1976.

southeastern Powder River Basin, the Madison is about 3,000 to 4,000 feet below the land surface.[13] In this area the aquifer is roughly 100- to 500-feet thick (table 27).

The Madison Limestone and related aquifers vary widely in physical and geological charac-

[13] P W Huntoon and T Womack, "Technical Feasibility of the Proposed Energy Transportation Systems Incorporated Well Field, Niobrara County, Wyo ," *Contributions to Geology*, University of Wyoming, Vol 14, No 1, pp 11-25, 1975

teristics, and, as a consequence, so does their ability to store and transmit water. This complexity precludes simple basinwide generalizations from individual well tests, and also make it difficult to establish conclusively that a given observed effect is due to any specific cause.

The potentiometric surface of an aquifer at a given location is the level to which nonflowing water would rise in a well at that location. It is significant because the difference between the levels of the land and the potentiometric surface is the height to which water must be pumped to reach the land surface. If the potentiometric surface is above the land surface, a well will be free flowing and the rate of flow proportional to the difference in the levels. Pumping is necessary when the potentiometric surface is below the land surface and the amount of pumping power required is dependent upon the magnitude of the difference in levels. Figure 24 shows the most recent estimate of the configuration of the potentiometric surface of the Madison in northeast Wyoming and southwest Montana. These data are important in predicting aquifer activity because the ground water will tend to flow from areas of higher to areas of lower potentiometric surface.

Recharge is the process of water addition to the aquifer. The configuration of the potentiometric surface of the Madison aquifer indicates that the major areas of recharge would be the Bighorn and Laramie Mountains on the west and southwest and the Black Hills on the east. Where exposed, the Madison often contains numerous fractures, joints, and cavities which may capture percolating water and thereby localize the recharge effects. The actual recharge to the Madison in Wyoming has been estimated at about 75,000 AF/yr.[14]

In order to estimate future impacts of increased withdrawal of water from the Madison aquifer, those areas which are presently withdrawing water from the aquifer have been analyzed. In several eastern Wyoming locations (Midwest, Newcastle, and Osage) and a western South Dakota location (Edgemont), decreases in the potentiometric surface due to pumping have been observed.[15 16]

Several models are available for interpreting test-well data and predicting the effects, over time and over a given area, of pumping water from the Madison. The predictions of these models can and have been used to support differing points of view on the effects of withdrawals for slurry pipelines. However, all the models are substantially limited by the lack of data on the Madison Formation and by debatable simplifying assumptions. Figures 25 and 26 show the predicted results of the various models for potentiometric levels at the four locations for which data is available. (The specific predictions in the figures are for the withdrawal of 15,000 AF/yr from the Madison by a well field in Niobrara County.) The important conclusion is that the models probably represent the range of possibilities and the *actual* impact of increased pumping is somewhere within this range.

It is clear that increased pumping in a concentrated area on or near the periphery of the Powder River Basin is likely to have a measurable effect upon the potentiometric surface at distances up to 10 or 20 miles. The decrease will cause some wells to flow at lower pressures while greater pumping will be needed to maintain flows in other wells.

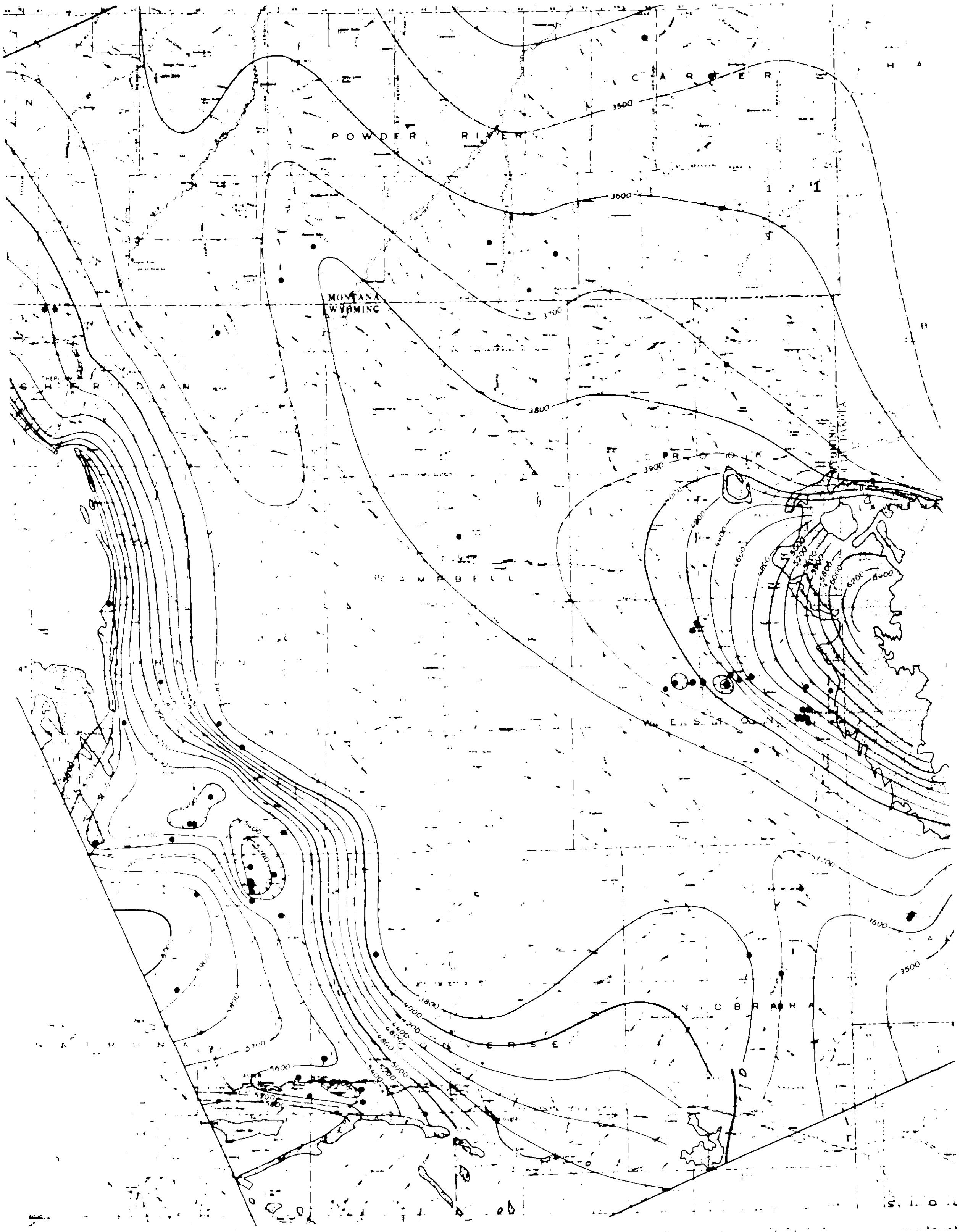
Water quality in the Madison varies from place to place. Some wells yield water which exceeds U.S. Public Health Service drinking water standards, and for example, Edgemont, S. Dak. uses the aquifer as a municipal water supply. In eastern Wyoming and southwestern Nebraska water from some other wells,

14 *Investigation of Recharge to Ground Water Reservoirs of Northeastern Wyoming [The Powder River Basin),* State of Wyoming, State E ngineer's Off Ice, **June 1976**

15 *P/an of Study on the Hydrology of the Madison Limestone and Associated Rocks in Parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming,* U S Geological Survey, Open File Report 75-631, Denver, Colo , December 1975

16 F A Swenson, W R Miller, et al , Maps *Showing Configuration and Thickness and Potentiometric Surface and Water Quality in the Madison Group, Powder River Basin, Wyoming and Montana,* **U S Geological Survey, Miscellaneous Invest** igations **Series, Map 1-847-C (1 1,000,000), Reston, Va , 1976**

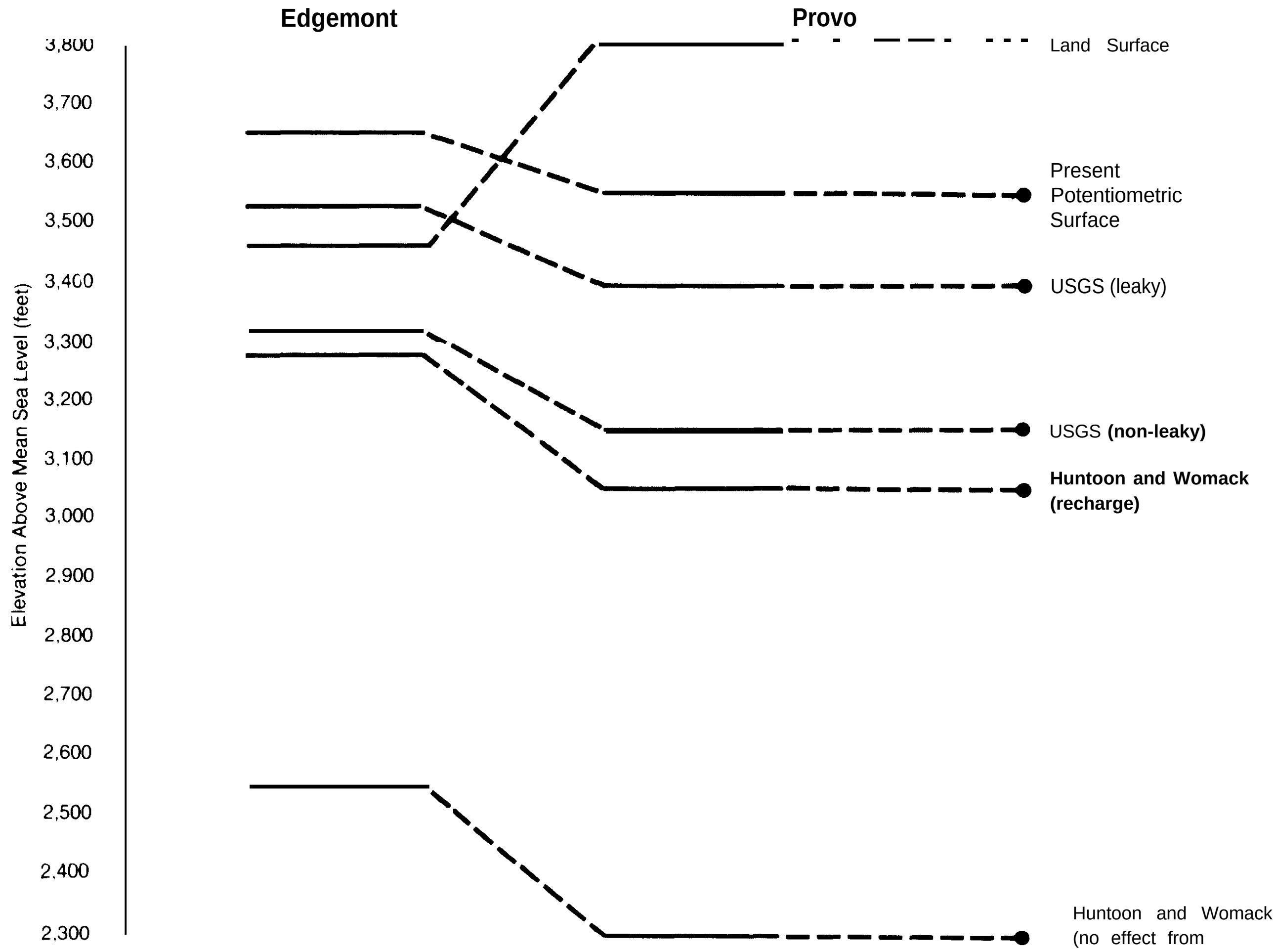
Figure 24– Potentiometric Surface of the Madison in Eastern Wyoming, Southeastern Montana, and Western South Dakota



Source Konikow L F U S Geological Survey Water Resource Investigations 63-75 (January 1976)

Contour shown in feet above mean sea level.

Figure 25—Potential Drawdown of Potentiometric Surface Near Edgemont and Provo, S. Dak., Due to 15.000 Acre-Feet per Year Withdrawal From the Madison Formation "in Niobrara County, Wyo., According to Different Models



Source Science Applications Inc.

although not always suitable for drinking, can be used for stock watering and irrigation.

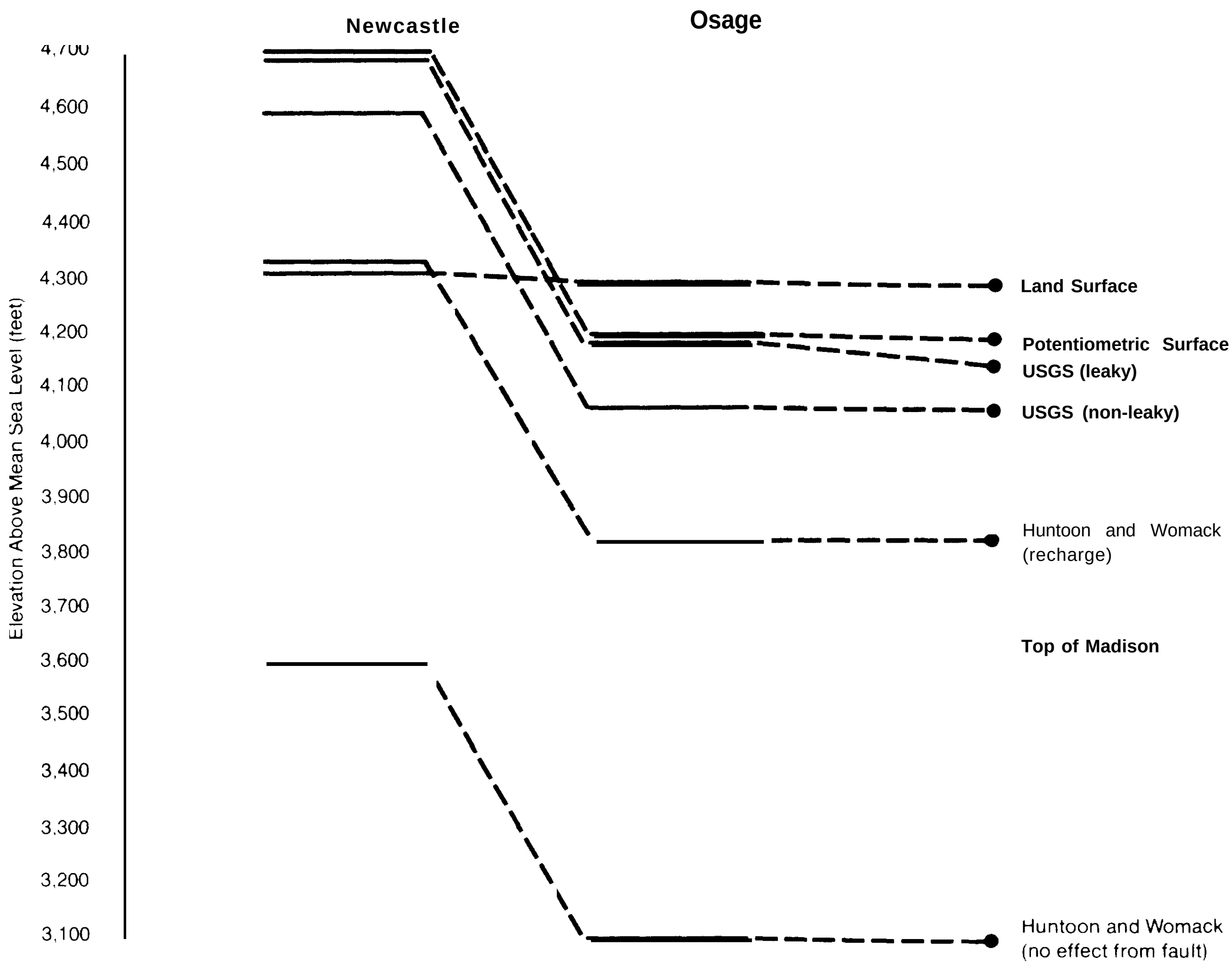
Present Wyoming uses of Madison aquifer water amount to about 25,400 AF/yr, approximately 80 percent of which is for industrial uses such as secondary oil recovery, oil refining, and electric powerplant cooling (see tables 28 and 29). About 3,600 to 3,800 AF/yr are used in Montana for secondary oil recovery and coal mining operations. [7]Annual discharges are about 1,800 AF/yr each for municipal supply at Rapid City and Edgemont, S. Dak.[18] The total present withdrawal-from the Madison is about 32,000 AF/yr.

Positing present levels for existing uses of the water in the Bighorn River Basin and the Madison Formation, there is sufficient unallocated water to supply the maximum levels of the hypothesized coal slurry pipeline.

[17] Ibid

[18] L F Konikow, *Preliminary Digital Model of Ground Water Flows in the Madison* **Group,** *Powder River Basin and Adjacent Areas, Wyoming, Montana, South Dakota, North Dakota, and Nebraska,* U S Geological **Survey Water Resource** Investigations **62-75, January 1976**

Figure 26—Potential Drawdown of Potentiometric Surface Near Newcastle and Osage, Wyo., Due to 15,000 Acre. Feet per Year Withdrawal From the Madison Formation in Niobrara County, Wyo, According to Different Models



Source Science Applications Inc

The uncertainty arises when *future* coal slurry pipeline water use is contrasted with future alternative water uses. Future alternative energy uses include present municipal and agricultural uses plus projected increased municipal, agricultural, industrial, and energy-related uses.

If all projected future alternative uses materialize, a water deficit would require importation of surface water before 2000, probably through aqueducts or increased ground water supply as through pumping the Madison aquifer. If water is imported by aqueducts from the Bighorn River Basin to the Powder River Basin: the surplus from the Bighorn would be sufficient to permit all projected growth to 2000. By 2000, however, Bighorn River surplus would be inadequate. An increase in ground water withdrawals could offset, to an unknown extent, the projected deficits.

It is impossible to identify the specific beneficial uses which would compete with coal slurry pipelines in the face of future deficits.

Table 28. Estimated Water Obtained From Madison Wells

	1973 withdrawal acre-feet	Maximum (year) acre-feet	Minimum (year) acre-feet
Wyoming			
Converse County.	540	1,651(1970)	410(1962
Crook County. . . .	187	187(1973)	5(1963)
Johnson County. .	2,116	4,345(1968)	2,100(1961)
Natrona County . .	15,542	20,103(1971)	100(1954)
Niobrara County. .	o	7(1964)	4(1966)
Sheridan County .	152	300(1933)	125(1967)
Weston County . .	6,904	6,904(1973)	1,290(1942)
Total Wyoming (1973).	25,441		
Montana[a]	***3,620***		
South Dakota[a]. . .	***3,620***		
Total (1973). . . .	32,681		

[a]Konikow, *L. F., Preliminary Digital Model of Ground Water Flows in the Madison Group, Powder River Basin and Adjacent Areas, Wyoming, Montana, South Dakota, North Dakota, and Nebraska,* **U.S.** Geological Survey Water Resource Investigations 63-75, January 1976,

Source: State of Wyoming, State Engineer's Office, *Investigation of Recharge to Ground Water Reservoirs of Northeastern Wyoming (The Powder River Basin)* (June 1976), unless otherwise noted.

Table 29. Uses of Madison Ground Water in Wyoming, 1973

Use	Acre-feet withdrawn
Municipal	**3,258**
Domestic, commercial, stock, fish, and irrigation	**1,558**
Industrial	**20,595**
Total	**25,441**

Source: State of Wyoming, State Engineer's Office, 1976.

Water for the Montana Pipeline

The coal source for the pipeline from Montana would be Colstrip, Mont. Flows **in the** surface streams in the immediate area are too unreliable to supply water for coal slurry pipelines, which will require 6,300 to 7,600 AF/yr. The U.S. Bureau of Reclamation has suggested the use of an aqueduct to divert water from the Bighorn River. ” Such a diversion could provide about 209,000 AF/yr (see figure 27). However, Montana law may preclude use of such water for coal slurry pipelines, however, inasmuch as such use to transport coal out of State has been deemed by statute not to be a beneficial use.

By the terms of the Yellowstone River Compact, Montana's share of the Bighorn River's flow averages about 400,000 AF/yr. Although present uses of this water account for only about half this amount, projected future demands exceed supply by the year 2000. Table 30 shows that present unexercised industrial options (rights to purchase water, usually from existing or proposed storage facilities, for a given time) and applications exceed Montana's share of the Bighorn River. Pipelines will have to compete with alternative water uses for water.

Table 30. Water Supply and Demand, Bighorn River Basin, Mont.

Use category	Water quantity AF/yr
Present agriculture	200,700
Industrial options[a].	228,000
Additional applications.	422,000
Total projected demand[b].	850,700
Montana's share of Bighorn	400,000
Projected deficit.	450,700

[a]Not exercised as of January 1975.
[b]Does not include municipal use or reservoir evaporation.

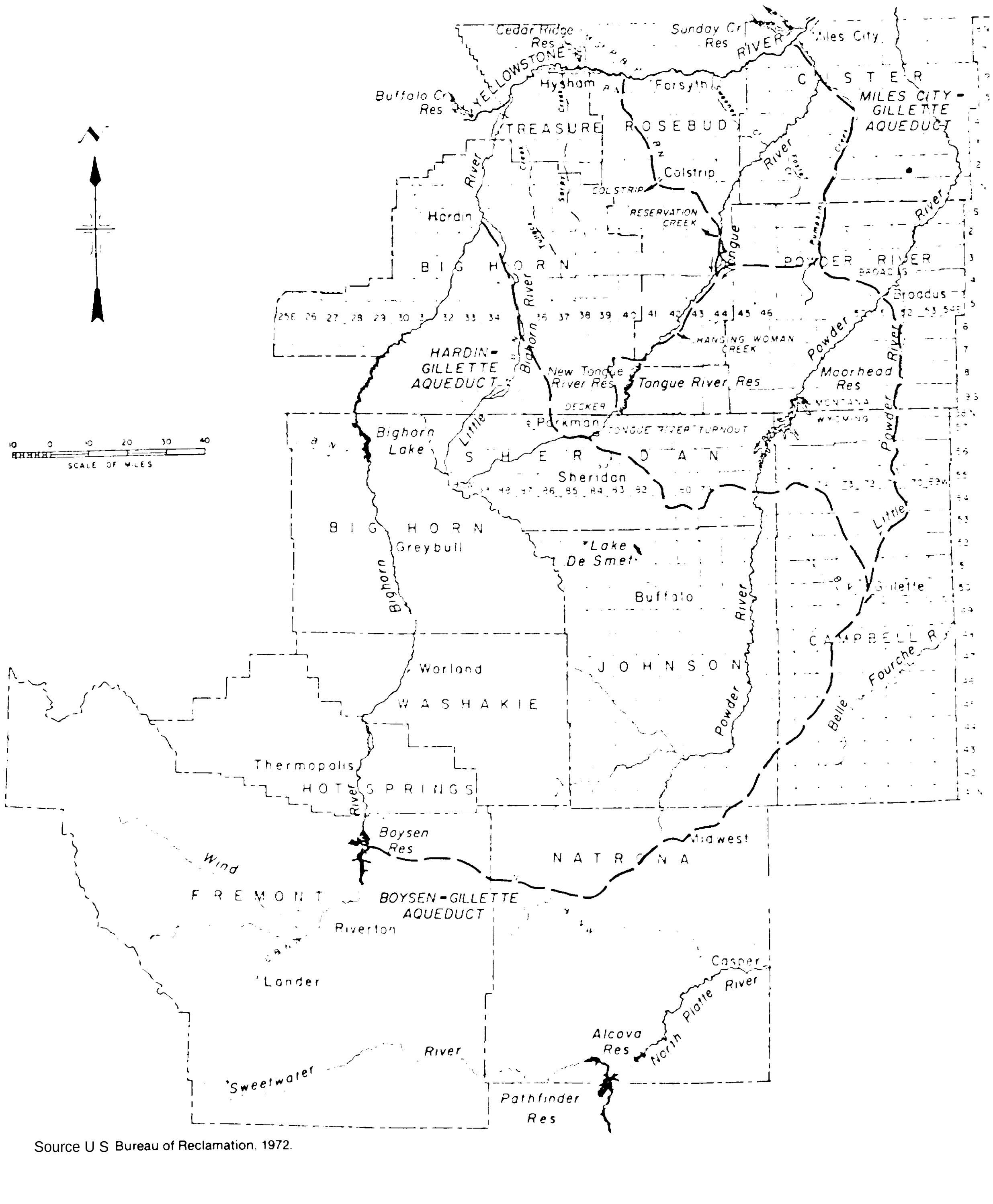
Source: U.S. Department of the Interior, Water for Energy Management Team (January 1975).

Water for the Tennessee Pipeline

The hypothetical coal slurry pipeline has its source near Tracy City, Term. The pipeline would require 10,300 to 12,100 AF/yr. The location of this pipeline source is on a divide straddling three drainage systems. To supply a coal slurry pipeline, water must either be brought

[19] *Appraisal Report on Montana-Wyoming Aqueducts,* U.S. Bureau of Reclamation, Denver, Colo , April 1972

Figure 27– Proposed Aqueducts, Bighorn River to Colstrip



Source U S Bureau of Reclamation, 1972.

uphill to the coal or the coal must be conveyed to a reliable water source. Ample water is available in the Tennessee River and could be withdrawn downstream from Nickajack Lake, a nearby reservoir, and pumped about 1,300 feet up to Tracy City. Ground water supply is not a feasible alternative in southeast Tennessee.

Given the large flows in the Tennessee River (average 2.56 x 10^7 AF/yr) withdrawal of up to 12,000 AF/yr by several coal slurry pipelines would not be expected to have any significant impact upon stream water quality. The primary current consumptive uses of water in the Tracy City area are municipal and do not present apparent conflict with future alternative water uses, including pipelines.

Water for the Utah Pipeline

The hypothetical coal slurry pipeline from Utah would transport coal from any of the seams in the Book Cliffs or Wasatch Plateau in east-central Utah. Water requirements for the hypothetical route would be 6,390 to 7,150 AF/yr. In addition to the water necessary for the slurry, water may be required for revegetation of the pipeline right-of-way. Water for revegetation, however, must be supplied at locations along the route, not just at the pipeline source,

Coal in this area is mined in rugged terrain characterized by high escarpments and narrow ravines. If the slurry preparation plant were at a mine site, water would have to be pumped through elevation gains of up to 1,000 feet. The alternative would be to deliver coal by train, truck, or conveyor to the base of the cliffs. The Green River at Green River City has an average discharge of 4.614 million AF/yr, and the minimum flow between 1894 and 1970 was 184.6 thousand AF/yr.[20] The Price River at Woodside, Utah (22 miles upstream from the confluence with the Green) has an average discharge of **74,620** AF/yr.[21] Physical supply of water for use in a slurry pipeline is ample. The Green River, because of its greater flow, is the most likely water source for this route. The Navajo sandstone aquifer underlies this area, but local data on yields are very limited, and it is not considered here as an alternative source.

The chief limitation upon water use for coal slurry pipelines in Utah appears to be institutional. The Green River joins the Colorado River about 50 air miles south of the town of Green River, and the Price is a tributary of the Green River. Any use of surface water (and certain ground water sources) in eastern Utah must be considered in the context of Utah's participation in the Colorado River Compact, whereunder the Lower Colorado River Basin must receive 75 million acrefeet of Colorado River water over any 10-year period; the Upper Basin's annual share is thus the total flow minus 7.5 million acre-feet. By further agreement among the Upper Basin States, Utah is entitled to 23 percent of whatever the Upper Basin has left after deliveries to the Lower Basin .[22] The State's annual allotment is about 1.2 to 1.4 million AF/yr.

Additionally, in Utah, all water belongs to the public and may be appropriated for beneficial use.[23] For an application to be approved there must be unappropriated water, the diversion plan must be physically and financially feasible, and the appropriation must not be speculative. Whether water use for a coal slurry pipeline meets these requirements must be determined by the State engineer, under guidelines from the Utah Board of Water Resources.

It is questionable whether the transfer of

[20] *Surface Water Supply of the United* States, 1 **966-1970, Part 9,** *Colorado River Basin,* Vol 2, *Colorado River Basin from Green River to Compact Point,* **U S** Geological **Survey, Water-Supply Paper 2125, 1971**

[21] Ibid

[22] G D Weatherford, **"Legal** Institutional **Assessment of the Water Allocation** Priorities in **the Colorado** River **Basin, "** *Utah Coal for Southern California* Energy *Consumption,* P C Grew, M Simmons, and B Sokolow **(Eds),** University **of California at Los** Angeles, Department of Environmental Science and Engineering, Report 76-19, pp 3-1 to 3-23, 1976

[23] R Putich, J Wegner, et al , "Utah Water Law, " *Study* of *Alternative Locations of Coal-Fired Electric Generating Plants to Supply Energy From Western* **Coal** *to the Department of Water Resources,* University **of California at Los Angeles, Institute of Geophysics and Planetary Physics and Off Ice of Environmental Science and** Engineering, **pp 6-109 to 6-120, March 1977**

Utah water to another State is legal.[24] 25 Such a transfer may be possible if the receiving State reciprocates. Transport of water from Utah to California would constitute transfer from the Upper Colorado River Basin to the Lower Basin and must be compatible with the Colorado River Compact. In the final analysis, the hypothetical coal slurry pipeline would compete with other future alternative water uses, many of them energy related, for a limited water supply.

Alternative Water Supply Sources

Given the relative scarcity of water in some potential coal slurry pipeline origins, it has been suggested that pipelines use water less suitable for other beneficial uses. [26 27] Saline water is defined as water having a TDS (total dissolved solids) concentration exceeding 1,000 miligrams per liter (mg/1).A number of saline western ground water sources, including parts of the Madison Limestone, have been identified 28 For example, water with a TDS concentration exceeding about 1,300 (mg/l is not useful for crop irrigation, Although water with high concentrations of TDS or other constituents may require treatment by the user, it can liberate fresh water at the pipeline source for other uses, In addition, diversion of highly saline waters from tributary streams could help meet downstream salinity reduction goals. It has also been suggested that primary sewage treatment effluent be used as the coal slurry carrier medium. 29 30 Irrigation return flows are another possible water source. Finally, recovered slurry water could be recycled in the coal slurry pipeline.

End uses of the recovered slurry water may affect the feasiblity of using saline water or water with high TDS. Use as evaporative cooling tower makeup or direct discharge to streams would require treatment of the recovered slurry water, although conventional lime and soda ash softening followed by ion exchange resin treatment may suffice. [31]

Primary sewage treatment effluent also has high TDS, as well as considerable organic material, bacteria, and other contaminants. Secondary treatment effluent, which is considerably more amenable to reuse, was used in 1973 in nine powerplant cooling systems, 32 and has been proposed for at least one more, and has been suggested for use in pipelines. An important question is whether local communities in coal-producing areas can generate enough sewage effluent to supply a coal slurry pipeline. For example, all the community domestic wastewater treatment facilities in the two counties near the origin of the hypothetical Utah slurry pipeline, produce a combined total of 3.4 million gallons per day of effluent, or about 3,850 AF/yr.[34] If this could all be collected, it would still be insufficient except as a supplementary supply. Advantages of using sewage effluent are that a reliable minimum daily flow is obtainable in areas of water shortage, and such use decreases the need for construct ion of sewage treatment facilities.

[24] W Gertsch, U S Energy Research and Development Administration Idaho Operations Office, Idaho Falls, Idaho, personal communication, July 19, 1977

[25] David Everett, U S Bureau of Land Management, Cedar City District Office, Cedar City, Utah, personal communication, July 11, 1977

[26] J K Rice, J M Evans, and M Warner, *Environmental Considerations of the Use of Saline Water in* Cod *I Slurry Pipelines*

[27] James Lambert, U S Bureau of Land Management, Cheyenne, Wyo, personal communication, Aug 21, 1977

[28] *National Energy Transportation*, Vol 1, *Current Systems and Movements*, Congressional Research Service, May 1977

[29] A C Buck, "Negligible Environmental Impact of Coal Slurry Pipelines" *Proceedings of the 2nd International Technical Conference on Slurry Transportation* Las Vegas N ev, pp 81-87, Mar 24, 1977

[30] J W Moore, Statement before U S House of Representatives Committee on Interior and Insular Affairs, Subcommittee on Indian Affairs and Public Lands—Mines and Mining Cheyenne, Wyo, June 9, 1977

[31] G K Malik, Associate Plant Engineer, Mohave Generating Station, Nev, personal communication, July 12, 1977

[32] E Goldman and P J Kelleher, 'Water Reuse in Fossil Fueled Power Stations," *Complete Water Reuse Industry's Opportunity*, L K Cecil (Ed), American Institute of Chemical Engineers, pp 240-249, 1973

[33] C L Weddle and A C Rogers, *Water Reclamation Process Evaluation for the Arizona Nuclear Power Project* presented at the American Institute of Chemical Engineers Water Reuse Conference, Chicago, Ill, May 4-8, 1975

[34] L J Meyers, R D Millar, and R E Turley "Water Challenges in Carbon and Emery Counties, *Impact of Energy Development on Utah Water Resources, Proceedings of the 3rd Annual Conference of the Utah Section of the American Water Resources Association*, pp 97-1 31, Feb 20, 1975

A final alternative water source is recycling and reuse of the recovered coal slurry pipeline wastewater. The major disadvantage of this alternative is the added cost of a return pipeline. The advantage is that water requirements would be substantially decreased. The extent of water savings is dependent upon the moisture content of the coal, as well as the efficiency of the dewatering process, and typically about two-thirds of the water could be recycled.

If saline water were to be used in a coal slurry pipeline, the main problem for the system itself would be increased corrosivity in the presence of high-dissolved solids concentrations. Increased use of corrosion inhibitors may be required. Suspension of finely divided coal in water with high sodium concentrations may cause, through an ion exchange, an increase in sodium bound to the coal surface, resulting in fouling problems when the coal is burned.[35] A mitigating measure could be to wash the coal with low-TDS or acidified water.

Coal-Water Interactions and Corrosion

Possible chemical interactions between coal and the carrier medium are important because of possible adverse environmental impacts from: 1) a slurry spill or pipeline rupture; 2) slurry dewatering process and water reuse or waste water disposal; and 3) alteration of combustion characteristics of the end-product coal. Nonetheless, very little is known about coal-water interactions.

Coal, a combustible solid formed from decomposed vegetation, has a wide variety of physical and chemical properties. The chief elements in coal are carbon, hydrogen, and oxygen, with smaller amounts of nitrogen, sulfur, and a large number of trace elements. Oxygen content ranges from about 1.5 percent by weight in anthracite to about 30 percent in lignite, The higher the oxygen content the more chemically reactive the coal.

Coal in slurry form has a large surface area in contact with the water. For example, if each coal particle is assumed to be spherical and completely surrounded by water, then given the particle size distribution of the existing Black Mesa pipeline[36] the contact area, or possible reactive surface, for one contract ton of coal is about 220,000 square meters, or about 55 acres. Thus, because of the variety of reactive compounds in coal, the large reactive surface, and the long residence time (about 13 days for a 1,1 70-mile pipeline), coal-water interactions could be substantial.

Although considerable evidence is available concerning what materials will be leached from coal by water in the presence of air, almost none exists for the anaerobic conditions that will be encountered in a pipeline. The reactions involved in the well-known acid-mine drainage phenomenon, for example, require oxygen. Oxygen will be present in a slurry pipeline system only where the slurry is prepared and first introduced into the pipe.

In summary, as long as the slurry water is oxygenated for at least the initial part of the journey, it is likely that some constituents will be transferred from the solid to the liquid phase. The extent of leaching will depend upon the initial pH, the presence of potentially leachable species in the feed water, and the tendency of dissolved ions to precipitate at slurry temperature and pH. Coal composition is also critical. Before firm conclusions on chemical reactions in a real slurry may be drawn, information on leaching under anaerobic conditions is necessary.

Corrosion and corrosion inhibitors may affect slurry wastewater quality. In general, corrosivity (the corrosion rate) increases with increasing temperature, dissolved ionic strength, and decreasing pH. These factors can be directly affected by coal surface interactions.

Chemical additives are known to be effective in minimizing corrosion. If corrosion inhibitors are not used, an appreciable amount

[35] J K Rice, **J M** Evans, and M Warner, *Environmental Considerations of the Use of Saline Water in Coal Slurry Pipelines*

16 M L Dina, *Operating Experience at the 1580-M W Coal Slurry Fired* Generating *Station*, presented at the International Conference on Slurry Transportation at Battelle Memorial Institute, Columbus, Ohio, Feb 3, 1976

of iron will enter the slurry, but apparently only a small amount of iron will remain in solution. One corrosion inhibitor, hexavalent chromium, could pose environmental problems in the event of a spill. Wildlife drinking the spilled slurry wastewater with the corrosion inhibitor could be poisoned. 37

Slurry Water Reuse and Impacts

At the receiving end of a coal slurry pipeline, the slurry may be dewatered by several means (either alone or in combination): centrifugation, chemical flocculation, [38] vacuum filtration, [39] or heating. Slurry dewatering yields are variable, but calculations based on figures reported by one plant[40] indicate that 64 percent of the slurry carrier medium is available for reuse.

[37] G.K. Malik, Associate Plant Engineer, Mohave Generating Station, Nev., personal communication, July 12, 1977.

[38] M.L. Dina, *Operating Experience at the 1580-MW Coal Slurry Fired Generating Station*, presented at the International Conference on Slurry Transportation at Battelle Memorial Institute, Columbus, Ohio, Feb. 3, 1976.

[39] *Proposal for a Coal Slurry Transportation System by Houston Natural Gas Corporation and Rio Grande Industries, Inc.* Houston Natural Gas Corporation, undated.

[40] M.L. Dina, *Operating Experience at the 1580-MW Coal Slurry Fired Generating Station*, presented at the International conference on Slurry Transportation at Battelle Memorial Institute, Columbus, Ohio, Feb. 3, 1976.

The ultimate use of the recovered water depends upon its chemical quality at the point where it leaves the slurry system and the technical and economic feasibility of treating it to permit alternative reuses. The three major potential reuses are: makeup water for a powerplant cooling system, discharge to surface waters, and agricultural irrigation.

Table 31 lists the effluent requirements which recycled coal slurry water must meet in order to be discharged into a water of the United States from a steam powerplant, the most likely end point of slurry pipeline. The effect of contaminants in recovered slurry water upon compliance with water quality standards is difficult to assess, because in most cases the recovered slurry water will be given more treatment or mixed with other water streams within the plant. Prior to discharge, the powerplant or other coal slurry pipeline terminus would be required to obtain a discharge permit under the National Pollution Discharge Elimination System of the Federal Water Pollution Control Act of 1972, administered by the Environmental Protection Agency (EPA). Also, some of the 65 priority pollutants identified under the settlement agreement in National Resources Defense Council vs Train include trace materials present in coal.

Table 31. EPA Discharge Standards for New Sources, Steam Electric Power Generating Point Source Category

Effluence characteristic	Source	**Maximum for** any one day	**Maximum average for 30 consecutive** days
pH	All except once-through cooling	6.0-9.0	
Total suspended solids	Low-volume wastes[a]	100 mg/l	30 mg/l
	Bottom ash transport	100 mg/l	30 mg/l
	Boiler blowdown	100 mg/l	30 mg/l
	Fly ash transport	Zero discharge	
Total copper	Boiler blowdown	1.0 mg/l	1.0mg/l
Total iron	Boiler blowdown	1.0 mg/l	1.0 mg/l
Corrosion inhibitors	Cooling tower blowdown	No detectable amount	

[a] Wastewaters from wet scrubbers, ion exchange water treatment, blowdown from recirculating house service water system, etc.
[b] Mass discharge limit is 0.05 x flow x values in table.
c Include, but are not limited to, zinc, chromium, and phosphorus.
Source: 39 **C.F.R. 36186,40 C.F.R. 7095,23987, and 42 C.F.R. 15690.**

The second alternative end use—direct discharge to surface streams–might be considered if the water from the slurry were not used after dewatering at the destination powerplant, or if the plant used once-through cooling. A discharge permit would be required in this case as well. No standards currently exist for slurry discharge so "engineering judgment" as to best available technology would apply.

as to best available technology would apply.

The only significant problem with the third alternative slurry end use — agricultural irrigation — is the high levels of TDS (400 to 1,100 mg/1) in slurry water. Dilution with better quality local water could reduce the TDS levels sufficiently to permit agricultural uses.

COMMUNITY DISRUPTION BY RAILROADS

The major environmental impact of increased unit train operation will be the impact upon the daily lives of the people of the communities through which the unit trains will pass. Many towns, especially in the West, have been built around and because of the railroads. Railroad rights-of-way often divide major portions of towns. The impact of increased unit train operations will be to increase the volume of traffic on certain routes, and perhaps this increase will reach a point where it disrupts the transportation, land use, and social patterns of the residents. The impacts are not environmental in the strict, traditional sense. They are instead social impacts — affecting the lifestyles of people.

Virtually all the train-related environmental impacts discussed elsewhere in this chapter have a social and psychological component. Social components of the impacts cannot be readily quantified largely because of the variability of human response. Nonetheless, the possibility and variability of human reactions must be noted. For example, 26,000 additional people living between Gillette, Wyo., and Houston, Tex., would be exposed to noise levels exceeding EPA recommended standards as a result of 17 million tons per year of increased coal traffic along the hypothetical route. If train noise makes an impacted area less desirable, then the people affected will either move or adjust their lives to the noise. Increased train traffic could alter commuting patterns. People may have to leave home earlier every day to compensate for possible delays caused by trains on their trip to work. The main point here is that thousands of people will each be affected in a relatively small way.

One immediate measurable aspect of the disruption is rail-highway grade crossing accidents. **In the period 1965-74, an annual U.S. average of 21,000 rail-related accidents occurred, of which 5,000, or 24 percent, occurred at rail-highway grade crossings. In attempting to determine whether such accidents** will increase with an increased volume of unit train operations, simple assumptions are inapplicable. Accident rates are a function of type of crossing protection, numbers of tracks, numbers of trains and vehicles per day, urban or rural setting, and time of day. It is clear from analysis of 3,870 grade crossings in **21 States that increased unit train operation** would result in increased accidents. The increase is not in direct proportion to the increase in train volume. A 74.5 million tons per year increase in coal traffic could result in 8 deaths and 30 injuries above present levels if the case assumptions are correct (see table 32). For example, in one hypothetical case, a 90-percent increase in train traffic will yield a 21-**percent increase** in deaths and injuries. These accident rates would be reduced by the installation of any traffic protection improvements.

The frustration or inconvenience to the local community and accidents indirectly related to increased train volume are not readily quan-

Table 32. Predicted Annual Injuries and Deaths Based on Present and Hypothetical Train Traffic Levels

Route	Present rail traffic		Rail traffic with hypothetical added tonnage		Incremental impact of added tonnage		No. of crossings	Coal tonnage (10^6tons/Yr)
	Deaths	Injuries	Deaths	Injuries	Deaths	Injuries		
Gillette-Dal lab.	6.0	23.1	8.1	31.1	2.1	8.0	659	18
Gillette-Houston	10.9	42.8	13.2	51.9	2.3	9.1	1,393	17
Colstrip-Becker/Portage	8.6	33.1	9.4	36.6	0.8	3.5	695	13.5
Tracy City-Waycross	6.0	23.6	6.5	25.2	0.5	1.6	480	16
Waycross-Tampa	1.3	5.1	1.6	6.4	0.3	1.3	190	8
Waycross-Ft. Lauderdale	4.1	15.9	5.4	20.9	1.3	5.0	281	8
Price-Barstow	1.5	5.7	1.8	7.1	0.5	2.3	172	10
Total	38.0	149.0	46.0	179.0	8.0	31.0	3,870	74.5

Source: Science Applications, Inc.

Table 33. Annual Added Vehicle Operation Costs **(1974 Dollars) and Travel Time Due To Increased Coal Train Traffic**

Movement	Vehicle operation costs ($)		Traveler time costs ($)		Total ($)			Time stopped (hrs.)		
	T_1	T_2	T_1	T_2	T_1	T_2	T_2-T_1	T_1	T_2	T_2-T_1
Gillette to Dallas	3,160	3,532	2,184	4,489	5,344	8,021	2,677	347	1,366	1,019
Gillette to Houston	3,639	4,023	3,024	5,288	6,663	9,311	2,648	647	1,693	1,046
Colstrip to Becker.	1,879	2,028	2,112	3,013	3,991	5,041	1,050	602	983	381
Colstrip to Portage.	Cannot distinguish between T_1 and T_2.									
Tracy City to Waycross. . . .	2,707	2,832	3,108	3,589	5,815	6,458	643	898	1,225	327
Waycross to Tampa	526	542	423	467	949	1,009	60	86	104	18
Waycross to Ft. Lauderdale	4,169	4,297	5,078	5,440	9,247	9,737	490	1,456	1,820	364
Price to Barstow	650,	691	583	800	1,233	1,491	258	137	225	88
Totals							7,826			3,243

T_1 — Present rail traffic In trains per day. T_2 — Rail traffic with hypothetical added tonnage in trains per day.
Source: Science Applications, Inc.

tifiable. Stopping and waiting for trains to pass through railroad crossings results in additional vehicle operation and travel-time costs. Assuming present train and highway traffic plus the added coal trains considered in the four case studies, the estimated added costs were calculated. As shown in table 33, the coal unit trains would impose estimated added annual delays of 3,243 vehicle hours if no new grade crossings are built. The precise amount of time and cost borne by any one person or community cannot be accurately calculated, but spread across miles of track individual delays and costs should be relatively minor.

Mitigation of increased railroad-highway accidents and traffic delays requires costly grade separations. Cost aside, grade separations are an important alternative for vehicular traffic at railroad crossings, although other types of disruption may not be easily mitigated.

Increased train traffic in communities that are divided by railroad tracks without grade separations could yield unquantifiable problems. For example, emergency fire, medical, or police vehicles may occasionally be temporarily delayed in reaching emergency situations. Grade separations should therefore be considered where this type of problem is significant.

Increased rail traffic could cause problems in rural areas where the land is primarily used in ranching and farming. Either "sheep-tight" fences, designed to reduce hazards to free-ranging animals, or frequent train traffic will prevent ranchers from crossing railroad tracks with their herds. Increased unit train traffic, additional fencing, or new rail construction could make this problem worse. On the other hand, cattle passes are built in new rail lines, and old lines often parallel highways, which block the passage of cattle independently of rail activity.

Another impact of increased train traffic with social and psychological implications for the affected community is noise. The main noise sources in unit train operations are the locomotives' diesel-electric motors, the interaction between wheels and rails, and the vibrations of hopper cars.[41] Maximum train sound levels range between 80 and 100 decibels (dBA) at a distance of 50 feet,[42] but the perception of sound is very subjective and subject to reduction by land forms, thick vegetation, and densely packed housing or buildings. The day-night average sound level (L_{dn}), which is a noise exposure measure weighted more heavily for nighttime than for daytime, increases with increasing numbers of rail line haul operations. Table 34 identifies the human effects of various EPA recommended noise levels outdoors in residential areas and on farms. The Environmental Protection Agency has judged the level of 55 dBA to be the maximum allowable L_{dn} which protects public health and welfare, with an adequate margin of safety.

Guidelines for community noise exposure, based on the L_{dn}, were available, so the population potentially exposed to noise levels exceeding the standard was estimated as shown in table 35. **In short,** the noise impact for each hypothetical railroad route depended upon two factors: 1) the predicted increase in the number of railroad line-haul operations due to heavier coal traffic, and 2) the population densities along the proposed routes. Although the increased number of people likely to be subjected to levels above 55 dBA can only be roughly estimated, it is clear that the number will increase.

The impact upon the lives of the affected people of the increased exposure is impossible to assess because noise impacts depend heav-

4.J M Fath, D S Blomquist, et al , Measurement *of Railroad Noise* – **Line** *Operation and Retarders,* National Bureau of Standards **(NT I S** COM-75-10088), **1974**

42 Ibid

Table 34. Summary of Noise Levels Identified by EPA as Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety

Effect protected against	Recommended noise level		Area
Hearing loss	$L_{eq(24)}$[a]	70 dBA	All areas
Outdoor activity interference and annoyance	L_{dn}	55 dBA	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eg(24)}$	55 dBA	Outdoor areas where people spend limited amounts of time, such as schoolyards, playgrounds, etc.
Indoor activity interference and **annoyance**	L_{dn}	45 dBA	Indoor residential areas
	$L_{eg(24)}$	**45 dBA**	**Other indoor areas with human activities such as schools, etc.**

[a]L_{eq} is the constant A-weighted sound level which conveys an equivalent amount of sound energy as does an A-weighted time-varying sound over a given time period. $L_{eq(24)}$ is the L_{eq} of a 24-hour period.

Source: Adapted from U.S. Environmental Protection Agency, NTIS:PB 239429(1974).

Table 35. Population Exposed to Noise Levels Exceeding EPA Community Noise Guidelines Along Case Study Routes

	Total trains per day						
Route	10	25	50	90	T_1[a]	T_2[a]	Percent increase
Gillette-Dallas[b]	67,800	111,000	164,900	220,600	58,000	88,000	52
Gillette-Houston[c]	70,300	115,000	170,800	228,600	78,000	104,000	33
Colstrip-Becker[d]	30,900	50,500	75,000	100,300	45,000	53,000	18
Becker-Portage[e]	21,300	34,900	51,800	69,400	32,500	34,000	5
Tracy City-Waycross[f]	29,700	48,600	72,200	96,600	50,000	63,000	26
Waycross-Tampa[g]	11,100	18,200	27,100	36,200	10,500	14,500	38
Waycross-Ft. Lauderdale[h]	28,300	46,300	68,700	92,000	44,000	51,000	16
Price- Barstool	16,800	27,400	40,700	54,500	19,000	22,500	18

[a]T_1 is the current number of trains per day as it appears in grade-crossing inventory data. $T_2 = T_1$ plus the projected increase in coal trains per day. [b]Average T_1 and T_2 are 7.2 and 16.6, respectively. [c]Average T_1 and T_2 are 11.4 and 20.8, respectively. [d]Average T_1 and T_2 are 19.6 and 26.6, respectively. [e]Average T_1 and T_2 are 21.6 and 23.4, respectively. [f]Average T_1 and T_2 are 20.7 and 35.3, respectively. [g]Average T_1 and T_2 are 9.1 and 16.4, respectively. [h]Average T_1 and T_2 are 22.4 and 29.7, respectively. [i]Average T_1 and T_2 are 12.6 and 15.9, respectively.

Source: Science Applications, Inc.

ily upon subjective factors which vary from individual to individual. Among the factors which will influence individual perception of impact are:

- Length and speed of the train;
- Time of day noise occurs (this is taken into account in estimating the L_{dn} value);
- Whether windows are opened or closed;
- Background noise level when trains are not present;
- Presence of particularly disturbing or pleasing sound frequencies, i.e., some people may enjoy the sound of a train horn in the night, while others may dislike it;
- History of prior exposure to train noise; and
- History of noise exposure in general.

For example, n terms of total number of people impacted by train noise, the effect would be greatest in urban areas. Background noise and noise tolerance may well be highest in these areas however, thereby minimizing the subjective response to the increased train noise,

Careful planning now can help to avoid some of the serious negative impacts of increased traffic. Rapidly developing communities should plan urban growth to avoid community division by railroad tracks. Rail traffic should be routed around densely populated areas, and where new tracks are being laid, they should whenever possible bypass extant communities. Areas along railroad rights-of-way can be zoned nonresidential so as to minimize the noise impact of increased rail traffic, Where warranted, grade separations can be built or tracks otherwise relocated.

CONSTRUCTION IMPACTS

With the exception of the previously enumerated water requirements for coal slurry pipelines and the peculiar community impacts of railroad unit train operations, the environmental impacts of construction and operation of coal slurry pipelines and railroads are comparable in many respects. Most of the railroad lines which will be utilized by coal unit trains are already in existence, and impacts from new track construction will therefore not be as extensive as impacts from coal slurry pipeline construction. This section discusses the environmental impacts of pipeline and new railroad construction activities. Some impacts, noise from construction equipment, for example, will occur only during actual construction, whereas other impacts, like destruction of vegetation, will require a few years to rectify. In most locations, construction impacts for coal slurry pipelines and new railroad construction are relatively minor. In arid and biologically sensitive areas, however, construction impacts are magnified. Fortunately, by careful advance planning, most particularly sensitive locations–marshes, ponds, refuge areas, etc., can be avoided by route alterations. When these locations cannot be bypassed, adverse biological impacts can be mitigated by performing construction activities during the biologically least sensitive time of the year. The adverse impacts of construction on rare, threatened, or endangered species must be minimized, if not avoided entirely. [43]

The same type of short- and long-term impacts that are discussed for pipelines will be experienced in railroad construction. However, the mitigating measures available after completion of a pipeline, i.e., revegetation, recontouring and eventual return to original land uses, are not entirely applicable to railroad rights-of-way because of the continued above--ground surface existence of the rail lines,

The most obvious environmental impact of pipeline construct ion is the clearing of vegetation —trees, shrubs, and grasses—from the pipeline route and right-of-way (see figure 28).[44] 45 Construction of the pipeline also requires trenching by blasting and excavation with backhoes, stockpiling of the soil, installation of the pipe, and back-filling. Since 100 foot rights-of-way are required, as much as 12 acres per mile of pipeline could be impacted.

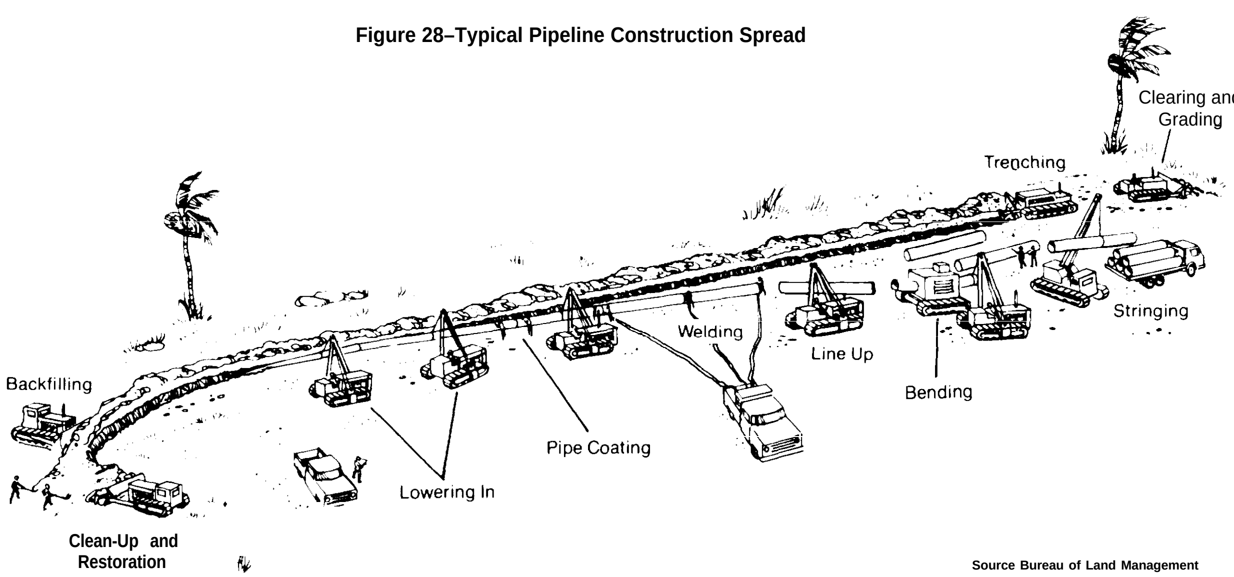
The loss of vegetation will, in turn, temporarily disrupt, on a local scale, primary biological productivity, which provides energy for higher organisms. **Additionally, some animal communities will be affected** by increased human activity (e. g., hunting and vehicular accidents). **In some cases the animals will be destroyed;** in other cases, they will be forced to relocate until the construction activity subsides or the habitat returns to its original or a comparable condition. Forced relocation of wildlife during reproductive or breeding seasons may magnify the adverse impact on wildlife.

[43] *Threatened Wildlife of the United* States, U S Department of the Interior, Fish and Wildlife Service, U S Government Printing **Off Ice, Washington, D C , March 1973**

44 F C Vasek, **H B Johnson, and D H** Eslinger, **"Effects of** Pipeline Construction **on Creosote Bush Scrub Vegetation of the** Mojave **Desert, "** *Madrono,* **Vol 23, No 1,** pp 1-13, 1975

[45] *Final Environmental Impact Statement, Alaska Natural Gas Transportation System, Overview Volume,* **U S Bureau of Land Management**

Figure 28–Typical Pipeline Construction Spread



Source Bureau of Land Management

Construction of pipeline and railroad facilities for coal handling will require permanent use of land for spurs and sidings, bridges, loading and unloading facilities, and maintenance stations. During the construction phase, vegetation will be destroyed and local fauna will be forced to relocate. The effects of floral and faunal disruption from rail construction will be similar to the effects from coal slurry pipeline construction, however, they will generally not be reversible as they are for pipelines. Disruption of biological communities is discussed in this chapter as an impact of railroad operation.

Increased presence of people and machinery during construction increases the fire hazard for both railroad and pipeline construction. Fire would result in further loss of vegetative cover, wildlife habitats, and disruption of biologic communities.

The duration of coal slurry pipeline construction impacts may be governed by the extent of compaction, mixture of soil layers, and alteration of drainage patterns, all of which affect the potential for revegetation. Erosion by both wind and water of lands left without vegetative cover could be substantial, particularly on steep slopes in arid climates.[46] Soil particles may be blown or carried away by surface runoff, resulting in loss of topsoil, unsightly and potentially hazardous alterations of the ground surface, and pollution of rivers and streams.[47] Rapid establishment of a new vegetative cover will help minimize these problems.

Pipeline construct ion will temporarily disrupt soils and destroy vegetation along the right-of-way, creating an undesirable visual effect and exposing bare soil to chemical change and erosion. Experience has shown that most areas affected by pipeline construction can be successfully revegetated. Revegetation is a natural process which occurs after a major disturbance of the vegetative cover, whether by fire, erosion, or human activity. Natural revegetation is a relatively slow process and may require a number of years[48 49] depending on various geographic, geological, and climatic factors. Rapid revegetation to reduce erosion and restore biological productivity by deliberate planting of desirable plant species is necessary in some areas. In Wyoming, crested wheat grass (Agropyron desertorum) has been used to establish a quick grass cover. It does not spread, but it is not invaded by native species and leaves an area usually discordant with the surrounding region. Potential revegetation problems in the West include: prevention of mixing the top soil with the "hardpan" or "caliche" (a layer of impenetrable carbonate soils); inadequacy of water supply for plant growth;[50 51] and difficulty of quickly establishing ground covers which will be easily invaded by the surrounding native species. Revegetation can also minimize the impact of construction activities related to railroad construction. The track and immediate right-of-way may not be revegetated but the wider area affected by heavy construction activity can be.

The aesthetic and productive value of land may be temporarily decreased by pipeline construction. Most of the pipeline right-of-way in the hypothetical routes examined in this report cuts through agricultural land, and disruption of agriculture therefore could be a significant environmental impact. The production of at least one full growing season would be lost for croplands, possibly more for natural grazing lands. For example, as much as 7,600 acres of pastureland and 3,500 acres of harvested cropland would be lost for the single hypothetical

[46] D G A Whitten and J R V Brooks, *The Penguin Dictionary of Geology*, Penguin Books, Baltimore, Md , 1972

[47] *Final Environmental Impact Statement, Alaska Natural Gas Transportation System, Overview Volume*, U S Bureau of Land Management

[48] F C Vasek, H B Johnson, and D H Eslinger, "Effects of Pipeline Construct Ion on Creosote Bush Scrub Vegetation of the Mojave Desert," *Madrono*, Vol 23, No 1, pp 1-11 1975

[49] W T Plass, "Revegetating Surface-Mined Land," *Mining Congress Journal*, Vol 60, No 4, pp 53-59, 1974

[50] A R Verma and J L Thames, "Rehabilitation of Land Disturbed by Surface Mining Coal in Arizona," *Journal of Soil and Water Conservation*, pp 129-131, May-June 1975

[51] F C Vasek, H B Johnson, and D H Eslinger, "Effects of Pipeline Constructlon on Creosote Bush Scrub Vegetation of the Mojave Desert," *Madrono*, Vol 23, No 1, pp 1-13, 1975

Wyoming to Texas pipeline (table 36). Note that the lost acreages represent very small percentages of the county totals. Loss of agricultural productivity will probably be a negligible impact of railroad construction activity because so little new construction will be necessary, and the small amounts of new construction will most likely be as spurs and therefore not transect agricultural lands.

Pipeline construction may disrupt recreational activities and aesthetic values in certain areas. This construction impact can be minimized by careful route planning to avoid recreational areas, and to time construction with seasons of low use. Disruption of streambeds and flows can also be minimized by scheduling construction during low-flow periods, so as to avoid temporary impacts such as sediment loading, reduced visibility, photosynthesis, and resultant altered productivity.

Pipeline grades must be below 16 percent. Notching or sidehill cuttings to achieve these gradients may create sharp topographic features and surface runoff.[52,53] Careful recontouring of the lands to the original contours will minimize long-term adverse impacts on slopes and streams. Railroads require a 1-percent grade, so greater amounts of grading, cutting, and filling may be required for the limited amounts of new track construction. Wherever possible, steep slopes should be stabilized to acceptable angles and physically covered to prevent erosion until vegetation is established.

Dust-particle emissions from land clearing, blasting, excavation, grading, cut and fill operation, and operation of vehicles on unpaved roads is another impact of pipeline construction. Estimates of the precise amount of dust emissions are site-specific in that they depend upon soil moisture, soil particle size and distribution, and local meteorological conditions such as wind and humidity. Dust emissions can be reduced by about 50 percent by wetting down the construction area twice daily.[54]

Dust-particle emissions during railroad construction are of the same character as air emissions from coal slurry pipeline construction. A quantitative comparison is not attempted, however, because of the site specificity of such factors.

Noise emissions are another impact of pipeline and railroad construction. Most pipeline construction will avoid heavily populated areas, noise is a relatively minor impact, and the magnitude of pipeline construction noise is no different from other construction noise.

The impacts of construction of coal slurry pipelines and new railroad trackage are qualitatively similar. It is expected that new track construction will require greater circuitry, grading, and cut and fill activities because of the lesser-required grade for railroads (1 percent) as compared to pipelines (16 percent). However, the total amount of new track construction will be very small compared to pipeline construction, because the railroad network necessary for coal unit train operation is largely extant. Finally, because pipelines will be buried beneath the Earth's surface there is greater opportunity to mitigate adverse construction impacts by recontouring and revegetation of the pipeline right-of-way. Pipeline routes can also now be planned to avoid especially sensitive areas of biological, agricultural, or other important human activity. This rerouting to mitigate environmental impacts must be balanced with the costs of various routes.

The geographical area of construction affects the significance of these impacts. Although extensive pipeline construction is anticipated, the narrowness of the rights-of-way

[52] B W Sindelar, R L Hodder, and M E Majerus, *Surface-Mined land Reclamation Research in Montana*, Montana State University, Montana Agricultural Experiment Station, Research Report 40, April 1973

[53] W C Bramble and R H Ashley, "Natural Revegetation of Spoils Banks in Central Pennsylvania, " Ecology, Vol 36, No 3, pp 417-423, 1955

[54] G A Jutze, K Axetell, jr , and W Parker, *Investigation of Fugitive Dust Sources Emissions and Control*, U S Environmental Protection Agency, Research Triangle Park, N C , EPA-45013 -74-036a, June 1974

Table 36. Agricultural Land Use Along Hypothetical Wyoming-Texas Pipeline Route

State/County	Total acreage: County	Total acreage: Farmland	7% of county land in farms	Acreage: Pastureland	Acreage: Harvested crop land	Acreage: Woodland	Total county: Miles traversed	Total county: Acres disturbed
WYOMING								
Campbell	**3,043,520**	**2,905,296**	**95.5**	**2,650,848**	**66,637**	5,821	46	552
Weston	**1,540,416**	**1,514,920**	**98.3**	**1,269,502**	**16,424**	96,974	17	204
Converse	**2,740,224**	**2,439,713**	**89.0**	**2,332,325**	**41,427**	17,178	3	36
Niobrara	**1,672,960**	**1,593,748**	**95.3**	**1,499,910**	**50,309**	11,946	69	828
Goshen	**1,425,984**	**1,299,978**	**91.2**	**1,014,638**	**166,666**	14,962	21	252
	10,423,104	9,753,655	**93.6**	**6,116,375**	341,463	146,881	156	1,872
NEBRASKA								
Sioux	1,320,192	1,014,620	**76.9**	**918,495**	**56,064**	**29,448**	30	360
Scotts Bluff	464,448	434,023	**93.4**	**225,015**	**165,723**	**3,594**	24	288
Banner	472,320	412,126	**87.3**	**220,069**	**99,571**	**767**	19	228
Merrill	897,408	778,422	**86.7**	**566,863**	**142,092**	**5,640**	3	36
Cheyenne	758,912	767,591	**101 .2a**	**218,688**	**276,944**	**836**	44	528
	3,913,280	**3,406,782**	87.1	**1,231,553**	**740,394**	**40,285**	120	1,440
COLORADO								
Logan	1,166,272	**1,149,769**	98.6	**579,793**	**284,267**	**6,866**	40	480
Phillips	435,200	**467,309**	107.4[a]	**99,194**	**217,896**	**739**	4	48
Yuma	1,522,816	**1,433,473**	94.1	**819,067**	**365,958**	**6,217**	65	780
	3,124,288	**3,050,551**	**97.6**	1,497,454	**868,121**	13,822	109	1.308
KANSAS								
Sherman	675,200	617,347	**91.4**	178,537	263,277	**1,833**	**36**	432
Wallace	583,040	507,271	**87.0**	229,010	150,332	**417**	**35**	420
Logan	686,720	589,876	**85.9**	266,836	161,968	**4,605**	**9**	108
Wichita	463,360	420,293	**90.7**	87,719	205,131	**233**	**36**	432
Kearny	547,264	495,951	**90.6**	174,168	181,435	**344**	**4**	48
Finney	832,896	669,155	**80.3**	197,759	315,943	**962**	**39**	468
Haskell	371,200	365,903	**98.6**	48,892	237,692	**206**	**17**	204
Gray	557,952	519,931	**93.2**	97,831	279,155	**1,220**	**6**	72
Meade	626,368	674,923	**107.8**[a]	332,409	213,988	**3,619**	**38**	456
	5,344,000	4,860,650	**91.0**	1,613,161	2,008,921	**13,439**	220	2,640
OKLAHOMA								
Beaver	**1,145,344**	1,096,044	**95.7**	652,135	334,576	**8,905**	38	456
Ellis	**794,880**	705,121	**88.7**	503,162	146,756	**13,387**	54	648
Roger Mills	**729,600**	686,026	**94.0**	495,104	106,372	**6,388**	27	324
Beckham	**580,480**	498,778	**85.9**	304,389	153,787	**6,221**	4	48
Washita	**645,696**	623,462	**96.6**	243,708	335,668	**7,133**	28	336
Kiowa	**657,216**	635,696	**96,7**	277,243	311,083	**3,605**	43	516
Tillman	**576,832**	525,189	**91.0**	170,952	312,392	**3,579**	29	348
Comanche	**693,760**	399,659	**57.6**	264,683	94,666	**9,545**	3	36
Cotton	**416,320**	365,037	**76.7**	179,688	163,172	**3,348**	4	48
	6,240,128	**5,535,023**	88.7	3,091,064	1,958,472	62,111	230	2,760
TEXAS								
Wichita	390,912	**305,699**	78.2	184,627	96,151	**6,679**	19	228
Clay	705,344	**633,564**	89.8	524,734	72,875	**9,326**	34	408
Jack	604,928	**485,116**	80.2	417,9343	12,208	**33,659**	36	432
Parker	577,664	**429,407**	74.3	337,041	33,825	**28,139**	37	444
Hood	272,640	**221,006**	81.1	180,252	20,142	**8,254**	5	60
Johnson	473,472	**314,219**	66.4	174,185	86,124	**6,171**	25	300
Hill	646,400	**449,540**	69.5	195,644	200,984	**8,106**	32	384
McLennan	640,000	**521,270**	81.4	285,137	161,548	**17,048**	28	336
Falls	488,960	**521,270**	81.1	238,310	116,653	**18,831**		312
Limestone	595,520	**431,771**	72.4	328,869	47,176	**31,216**	(b)	(b)
Robertson	561,216	**380,628**	67.8	281,047	47,176	**52,967**	28	336
Brozos	374,720	**261,086**	69.7	190,820	32,098	**36,640**	19	228
Grimes	512.704	**339.505**	66.2	269,090	23,460	**29.305**	39	468
Mont-gomery	697,408	171,985	24.8	130,727	5,717	44,716	7	84
	7,541,888	5,341,483	70.8	3,738,421	**956,583**	331,057	335	4,020

[a]The acreages of farms which are in more than one county are credited to one county sometimes making the farmland averages fOr that county greater than the total acreage for that county.

[b]The Pipeline route runs along the approximate boundary between these two counties.

Source: Science Applications, Inc.

limits the regional environmental significance. The impacts discussed here are geographically very narrow, but in certain very sensitive ecosystems, such as deserts, wetlands, and habitats of rare or endangered species, these impacts assume greater significance than they would elsewhere.

OPERATIONAL IMPACTS

This section discusses the impacts of operation, as opposed to construction, of coal slurry pipelines and coal unit trains. The major impacts for each mode of transportation, water requirement for pipelines, and community disruption including railroad highway accidents and delays and noise by unit trains, have been discussed earlier.

Air

Pipeline operations will have an indirect and relatively minor impact upon air quality if the electricity required to run pumps, slurry preparation equipment, and dewatering facilities is generated by combustion of fossil fuels. If it is assumed that the electricity would be provided by coal-fired powerplants operating at 35 percent efficiency and meeting EPA new source performance standards for nitrogen oxides (NO_x), sulfur dioxide (SO_x), and particulate emissions, then emissions of these pollutants for all of the four pipeline cases would be 12,000, 21,000, and 1,700 tons per year of NO., $S0_x$, and particulate, respectively.

The environmental impact of the total number of emissions is difficult to assess. In most cases, power will be required at various points along the pipeline route, thus, the impact of the air emissions would therefore be widely distributed. In reality, these emissions would increase local levels by less than a few percent and probably not have a significant impact on local ambient air quality.

Diesel-electric locomotives emit carbon monoxide (CO), hydrocarbons (HCs), nitrogen oxides (chiefly nitric oxide (NO)), particulate, and other pollutants during line-haul operations. The amount of each pollutant emitted depends upon several factors, including fuel composition and heating value, load, grade and use or lack of abatement equipment. In table 37, emission factors, in terms of pounds of pollutants emitted per 1,000 gallons of diesel fuel consumed, are listed. To put these emissions into perspective, consider the emissions for a unit train coal movement from Wyoming, of about four times the volume of the hypothetical pipeline to Dallas, Tex. Such a movement of 65 million tons of coal would require 228 million gallons of diesel fuel per year.

Table 38 shows the emissions expected therefrom and compares the train emissions to the emissions from highway vehicle traffic.

Another useful way of examining air-pollution impacts would be to determine the impact on ambient air quality. Table 39 shows the locomotive emissions and resultant ambient concentrations for the very unlikely worst case situation in Wyoming. Wyoming State ambient air quality standards are shown for comparison. Ambient concentration of CO, SO_x and particulate would be at least two orders of magnitude below Wyoming standards. Hydrocarbon emissions approach the standard. Nitrogen oxide emissions appear to exceed the standards, although, the standards are for nitrogen dioxide while emissions are predominantly nitric oxide. Thus, even the worst case analysis of locomotive emissions would not, in and of itself, violate ambient air quality standards.

The environmental impact of these pollutants is difficult to assess. They clearly represent a source of increased air emissions,

Table 37. Diesel Locomotive Emission Factors

Emissions, lb/1 ,000 gal. fuel consumed

Pollutant	Engine type: 2-Stroke supercharged road	2-Stroke turbocharged road	4-Stroke road	Composite average used	
Carbon monoxide.	66	160	180	174C	160[d]
Hydrocarbons.	148	28	99	78c	28[d]
Nitrogen oxides (NO_x as NO_2)...	350	330	470	430[c]	330[d]
Particulates [a].		25[b]		25	
Sulfur oxides		57[b]		57	
Aldehydes (as HCHO)		5.5[b]		5.5	
Organic acids		7[b]		7	

[a]Based upon highway diesel emissions; no actual Locomotive particulate emission test data available.
[b]Based upon national distribution of engine types.
[c]For all case studies except Utah-California.
[d]For Utah-California case study.
Source: U.S. Environmental Protection Agency, *Compilation o/Air Pollutant Emission Factors,* 2nd Ed. (Feb. 1976).

Table 38. Estimation of Vehicle Equivalent of Diesel Locomotive Air-Pollutant Emissions for 65 Million Tons of Coal per Year Between Wyoming and Texas

Pollutant	Locomotive emissions lb/h r-mile	1977 Highway vehicle equivalents: Automobiles vehicles/hour	All vehicle types vehicles/hour
Carbon monoxide.	3.7	39-92	29
Hydrocarbons.	1.7	190-530	100
Nitrogen oxides	9.1	700-1,100	910
Sulfur oxides.	1.2	N D[c]	2,500[d]
Particulate.	0.53	N D[c]	**450**[d]

aAssumes consumption of 228 million gallons/year of diesel fuel, 1,227-mile one-way haulage distance.
[b]Highway vehicle equivalents were defined as the number of highway vehicles which would emit the same amount of the specified pollutant as would the train movement of specified dimensions.
CNO data for comparison.
[d]National average emissions are 4.9 x 10-4 lb/mile SO_x and 1.2 x 10-3 lb/mile of particulates.
Source: Science Applications, Inc.

yet they are neither from an easily controlled stationary source nor a continuous mobile source, like, for example, continuous passage of automobiles. Rather, train passage is a relatively isolated event, with opportunity for pollutant dispersal during intervals between train passages. The impact of air emissions from unit train operations cannot be compared to air emissions associated with coal slurry pipeline operation in any meaningful manner. Pipeline- related emissions are from powerplants which produce the energy *for* pipeline uses, whereas railroad unit train emissions are dispersed over the length of the rail route.

Table 39. Worst Case Ambient Air-Pollutant Concentrations for Unit Trains Transporting 65 Million Tons of Coal per Year From Wyoming to Texas[a]

Pollutant	Locomotive emissions lb/h r-mile	Worst case concentrate ion μg/m³	Wyoming standard μg/m³	Time period
Carbon monoxide	2.92	210	10,000	8-hr maximum, not to be exceeded more than once/year
Hydro- carbons	1.31	95	160	3-hr maximum, not to be exceeded more than once/year
Nitrogen oxides	7.20	520	1 00[b]	Annual arithmetic mean
Sulfur oxides	0.95	2.9	260	24-hr maximum, not to be exceeded more than once/year
Particulate	0.42	1.3	150	24-hr maximum, not to be exceeded more than once/year

[a]Assumes shipment of 65 x 10^6 tons/year over 1,227 miles, with diesel fuel consumption of 227,871,000 gallons/year.
[b]Standard is for NO_2, whereas emissions are mostly NO.
Source: Science Applications, Inc.

Dust Emissions

It has been suggested that unit coal train operations, including loading and unloading of hopper cars, occasionally result in the emission of coal fines and other fugitive dust particles to the atmosphere. Fugitive dust emissions may occur (1) during loading of hopper cars, (2) during unloading, (3) as blowoff from hopper cars in transit, or (4) through entrainment of dust accumulated alongside the tracks.

Modern train loading facilities consist of 10,000-ton-capacity temporary storage silos equipped with chutes for depositing the coal directly into the hopper cars, with water jets to spray the falling coal to suppress coal dust. For all practical purposes, dust emissions are confined to an area extending a few feet from the silo exit and entrance, and do not pose a community air-pollution problem. (Workers control the loading from within sealed enclosures and are thus not exposed to the coal dust.) Coal losses appear to be negligible compared to the volume loaded.

The main types of unloading are bottom dumping and rotary dumping.[55] Rotary dumping facilities are entirely enclosed and would present about the same minimal degree of pollution hazard as would the loading silos. Emissions from any type of loading facility would remain within the boundaries of the receiving facility, except for occasional entrainment by gusts of wind.

Although blowoff from coal trains has been raised as an environmental issue, supporting scientific data are lacking. Predictions of increased emissions due to expanded coal transportation appear to be extrapolations of historical experience in the East, where relatively dry coal was more likely to leak from poorly sealed hopper cars.[56] Western coal, having a relatively high moisture content, tends not to be dusty. An increasing number of hop-

55 R, G. S., "Decide Between Rotary and Bottom-Dump Coal Unloading," *Power,* Vol. 119, No. 8, p 47,1975,

56 FE Arm brusterand B. J Candela, *Research A nalysis of Factors Affecting Transportation of Coal by Rail and Slurry Pipelines,* Final Report, Vol. 1, prepared by Hudson Institute, Inc , N Y , for Burlington Northern Inc , April 1976

per cars, notably those unloaded by rotary dumping, have permanently sealed bottoms. It is believed that most fine particles are either lost during the first few miles of haulage or settle to the bottom of the hoppers very early.[57]

The Western Weighing and Inspection Bureau, which performs weighing services for western railroads, reports that it has received no claims of coal lost in transit.[58] Any difference between the weights of the coal cars at origin and destination, which would reflect the amount of coal lost, are not detectable.[59] Local officials in Wyoming, Colorado, and Illinois, all of which have appreciable coal train traffic, report that they have received no complaints of fugitive coal dust emissions.[60 61 62 63]

Finally, it has been observed that a moving train may stir up dust accumulated alongside the right-of-way. The extent and effects of this entrainment depend upon local conditions, such as recency of precipitation and wind speed and direction. In a strong wind, the impacts of the train could probably not be distinguished from those of general airborne particulate pollution.

In summary, western experience and limited scientific evidence indicate that fugitive dust emissions from unit train operations are likely to have negligible impact on air quality.

[57] Thomas Healey, Environmental Division, Peabody Coal Company, St Louis, Mo , personal communication, Sept 16, 1977

[58] D Thomason Western Weighing and Inspection Bureau, Denver, Colo , personal communication, Sept 19, 1977

[59] Gary Root, General Manager of Transportation and Distribution, Amax Coal Company, personal communication, Sept 19,1977

[60] Bernard Dailey, Wyoming Department of Environmental Quality, Air Quality Division, personal communication, Sept 9, 1977

[61] William Reese, Colorado Department of Public Health, Air Pollution Control Division, personal communication, Sept 15, 1977

[62] Anthony Telford, Illinois Environmental Protection Agency, Division of Air Pollution Control, Analysis Section, personal communication, Sept 15, 1977

[63] Edward Crooke, Director of Environmental Studies, Argonne National Laboratory, Argonne, Ill , personal communication, Sept 15,1977

Disruption of Biological Communities

Railroad lines generally constitute a visible linear strip of artificial texture, color, and landform across the landscape. The cleared break in the vegetational community divides the natural territory and provides room for the establishment of a new transitional community along the edge of the permanently cleared roadbed shoulder. This transitional community is characteristically an area of open low-herbaceous vegetation maintained in an immature stage of succession by maintenance of the railroad right-of-way and occasional fires. Transition zones often exhibit high plant diversity and greater biological productivity.[64] Habitats associated with railroad lines often support different flora and fauna than the surrounding region.[65 66 67] Increased rail operations will perpetuate this man-created ecotone.

While division of natural territories may enhance development of transitional communities, its effects are not all beneficial. Creation of a visible discordant strip may affect wildlife behavior patterns, as some species are hesitant to enter a region which has been disturbed. In addition, wildlife movements may further be affected by the additional noise and activity of passing trains, and the establishment of fences to protect livestock from accidental collision.

The question of the effect of railroad fencing and operation upon wildlife migration is controversial. Arguments supporting and opposing the contention that railroads constitute barriers are each handicapped by a lack of

[64] R L Smith, *Ecology and Field Biology*, 2nd Edition, Harper and Row Publishers, San Francisco, Calif , 1974

[65] J G. Kelcey, "Industrial Development and Wildlife Conservation," *Environmental Conservation*, Vol 2, No 2, pp 99-108, 1975

[66] B Lejmbach, "The Flora of Railway Tracks of Eastern Pomerania Coast," *Fragm Florist Gebot*, Vol 21, No. 1, pp 53-66, 1975, cited in *Biological Abstracts, No 47275*, November 1976.

[67] V V Sentemov, "Adventitious Species of Corispermum L in the Flora of the Udmurtian ASSR," Bot *ZH*, Vol 54, No 6, p. 934, 1969, cited in *Biological* Abstracts, No 59045, June 1971.

hard data." Theoretically, a fence designed to be sheep- and antelope-tight will present a physical barrier and alter established animal predation patterns, isolate communities, and thereby prevent cross-breeding, and disrupt seasonal migration. The effect of such a barrier is of particular concern if migration to traditional breeding or nesting areas is inhibited and reproduction is reduced. " It is believed by some that antelope movement (especially the longer range migration of antelope during severe storms) may be restricted. On the other hand, in many instances the railroad right-of-way parallels a major highway which might, in itself, act as a barrier anyway.

If it is assumed that livestock protection fences will present a barrier to wildlife migration, provision for crossing should be required. However, wildlife behavior response is difficult to predict. Even if crossings of adequate size and distribution are provided, wildlife may not use them, especially if the animals are frightened by trains, storms, or predators.

Wildfires also disrupt biological communities. Railroads are reportedly a significant cause of vegetation wildfires. For example, tables 40 and *41* show wildfire occurrences in Nebraska and Wyoming. Although the precise number may under-report the number of fires'" and may in some cases (about 15 percent[71]) misidentify the source, it is clear that railroads do cause a number of fires. The railroad fires burn substantial acreage, as shown in table 42.

Fires can be started by sparks from locomotive exhaust and steel brakeshoes or by operating and maintenance crews. To reduce the fire hazard, nonsparking brakeshoes are generally used for coal unit trains, fireguards are created along the right-of-way by mechanical or chemical clearing, and other spark-arresting equipment and fuel additives are employed. Turbochargers, with which most unit-train locomotives are expected to be equipped in the future, also act as spark arresters. 72

Careless use of flares by maintenance-of-way crews has been identified as a cause of. fires, but its significance is uncertain. According to a. Wyoming State fire official, railroads seem receptive to suggested fire prevention programs directed toward railroad personnel.[73] Other measures to reduce fire hazards include ontrack fire patrols by the railroad companies" and nonsparking composition brakeshoes on new hopper cars. 75

With improved fire prevention techniques, increased use of the trackage (which may result in greater reporting, awareness, and prevention of fires), and the increased exposure of wildlands to sparks, the incremental change in wildfires due to unit train operation is difficult to determine.

The major operational impact of coal slurry pipelines with disruptive effects on biological communities is accidental spills of slurry. There are three principal ways by which a slurry spill could occur along the transmisison route: 1) pipeline rupture due to excessive pressure; 2) breakage resulting when the pipeline is accidentally struck by digging equipment; and 3) washout of the pipeline during a flood. Under the relatively high pressures of coal slurry in portions of the pipe, small leaks will normally develop quickly into major

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[68] **James** Lambert, U S Bureau of Land Management, Cheyenne, Wyo , personal communication, Aug. 23,1977

[69] *Final* [environmental *Impact Statement, A laska Natural Gas Transportation System, Overview* **Volume, U S.** Bureau of Land Management.

70 U S Department of the Interior, *Final Environment/ Statement, Proposed Development of Coal Resources in the Eastern Powder River Coal Basin of* **Wyoming, Vol. I I 1, U.S. Department of Agriculture, Interstate Commerce Commission, 1974.**

[71] **Michael Gagin, Wyoming State Forestry Division, Cheyenne, Wyo , personal communication, Aug. 26,1977**

[72] **U S Department of the Interior,** *Final* **Environment/** *Statement, Proposed Development of Coal Resource in the* **Eastern** *Powder River Coal* **Basin** *of* **Wyoming, Vol 111, U S Department of Agriculture, Interstate Commerce Commission, 1974.**

73 Michael Gagin, Wyoming State Forestry Division, Cheyenne, Wyo , personal communication, Aug. 26,1977

74 Allan R. Boyce, Burlington Northern, St. Paul, Minn , personal communication, Sept. 6, 1977,

[75] **Al Ian R Boyce, Burlington Northern, St Paul, Minn., personal communication, Aug 15, 1977.**

Table 40. Wildfire Occurrence in Nebraska, 1971-76

Cause	Year 1971	1972	1973	1974	1975	1976	6-yr avg.
Railroad.	274	373	387	723	535	763	509
Debris burning	413	593	208	426	420	798	476
Equipment use	211	113	123	244	185	278	192
Lightning	102	73	99	311	107	173	144
Smoking	51	79	51	150	108	170	102
Electric fences..	33	41	16	37	28	23	30
Children	24	29	6	34	27	50	28
Incendiary	13	5	4	43	33	34	22
Campfires	4	2	1	11	3	9	6
Miscellaneous	127	209	121	322	313	389	247
TOTAL	1,252	1,517	1,016	2,301	1,759	2,687	1,755

Source: Westover D.E., *Nebraska Wildfires,* State of Nebraska, Department of Forestry (1977)

Table 41. Wildfire Occurrence in Campbell and Converse Counties, Wyo., 1971-73

Cause	Number of fires 1971	1972	1973	1971-1973	Acres burned 1971	1972	1973	1971-1973
Railroads.	43	28	32	34	1,163	2,762	242	1,389
Lightning.	21	40	30	30	21,981	8,170	3,025	11,052
Other	13	34	21	23	2,066	1,020	184	1,090
TOTAL. .	77	102	83	87	25,190	11,952	3,451	13,531

Source: U.S. Department of the Interior, *Final E/S, Proposed Deveopment of Coal Resources in the Eastern Powder River Coal Basin of Wyoming (1974).*

Table 42. Acreage Burned by Wildfires in Nebraska, 1971-76

Cause	Year 1971	1972	1973	1974	1975	1976	6-year average
Debris burning.	13,647	12,975	1,467	3,655	30,272	4,315	11,055
Railroad	4,652	13,183	2,080	7,197	6,752	2,424	6,048
Lightning	7,224	2,249	8,467	7,309	4,402	5,095	5,791
Equipment use	1,740	4,489	4,465	5,307	8,822	4,850	4,945
Miscellaneous.	5,151	3,788	980	6,105	1,800	3,567	3,565
Smoking.	555	2,021a	608	3,147	399	1,222	1,325
Children	71	69	3,662	177	27	56	677
Incendiary	18	27	0	2,410	262	50	461
Electric fence	--		5	298	799	99	300
Campfire.	30	11	10	86	30	16	31
TOTAL	33,088	158,812	21,744	35,691	53,565	21,694	34,198

[a]This figure does not include the Mullen Fire of March 1972, which burned 120,000 acres.

Source: Westover, D. E., *Nebraska Wildfires,* State of Nebraska, Department of Forestry (1977).

ruptures.[76] The quantity of slurry released to the environment will depend upon the flow rate, pressure, burial depth, overburden density, time for detection and pipeline shutdown, and proximity of holding ponds. Pipelines have been constructed with reserve holding ponds along the way. Using this approach, the slurry flow would be arrested in event of spill and the offending section of pipeline evacuated into the pond.

Only one coal slurry pipeline spill has been recorded, ” and the environmental impacts, primarily land and water impacts, are therefore only speculative. Presumably, the coal particles will be filtered from the water by the top few feet of soil. The effect of the coal in the soil upon plant growth is unknown. The impact of a spill into streams depends upon the relative flows of the stream and the spill. Coal sludge could temporarily harm aerobic benthic organisms, hamper fish feeding, smother eggs and larvae, and adversely affect spawning. Temperature changes and coal sludge could result in fish kills as well. These impacts, however, are not likely to be severe.

7. **Edward j Wasp, Vice President, Energy Transportation Systems, Inc , San Francisco, Calif , personal communication, July 8,1977.**

77 John Montfort, Black Mesa Pipeline Company, Flagstaff, Ariz , personal communication, Sept 21,1977

Energy/Materials Requirements

An environmental impact of pipeline construction and operation and railroad expansion and operation is the consumption of energy and materials made from natural resources. Steel and energy requirements for the four hypothetical pipeline routes are shown in table 43, and steel for hopper cars, locomotives, and rails (for new construction and replacement) and energy to produce the steel and for transportation of coal are shown in table 44. The direct steel requirements for pipelines and railroads to transport 74.5 million tons of coal over a 35-year period are 1.3 million tons for pipelines and 3.5 million tons for railroads. Although pipelines require less steel, recycling is less costly for railroads. Similarly, the energy directly required to produce the steel and for coal transportation is greater for pipelines than for rail, averaging for the cases 610 Btu per net ton-mile for pipelines and 390 Btu per net ton-mile for railroads. Greater rail circuity diminishes this relative advantage somewhat. Averages are frequently misleading, however, and energy requirements can differ quite widely in a given case. The results presented here include pipelines which for economic reasons would probably not be constructed. In addition, railroad locomotives use diesel fuel derived from petroleum, while pipe-

Table 43. Steel and Energy Requirements for the Case Study Pipelines

(35-year life cycle)

	Wyoming to Texas	Montana to Wisconsin	Utah to California	Tennessee to Florida	Grand totals
Coal transport (10° tons/year).	**35**	**13.5**	**10**	**16**	**74.5**
Steel requirement (10^3 tons).	**733**	**216**	**133**	**245**	**1,327**
Energy for making steel (10^{12} Btu).	**17**	**5**	**3**	**6**	**31**
Energy for construction (10^{12} Btu).	**3**	**2**	1	**2**	**8**
Energy for operation (10^{12} Btu/year)	**14**	**7**	**6**	**10**	**37**
Total energy (10^{12} Btu/year)	**15**	**7**	**6**	**10**	**38**
Total energy per 10° tons of coal transported (10^{12} Btu).	**0.4**	**0.5**	**0.6**	**0.6**	**0.5**
Operation energy per net ton-mile (Btu)[a].	410	710	1,150	920	610
Percentage of energy content of the coal required to transport it 1.000 miles	2.3	3.9	6.4	3.8	3.2

[a]Rounded to nearest 10 Btu.
Source: Data from Science Applications, Inc.

Table 44. Steel and Energy Requirements of the Railroad Case Studies

(35-year life cycle)

	Wyoming to Texas	Montana to Wisconsin	Utah to California	Tennessee to Florida	Grand totals
Coal transport (10' tons/year).	35	13.5	10	16	74.5
Steel for hopper cars(10^3 tons)	461	110	102	218	891
Steel for locomotives (103 tons).	110	22	30	58	220
Steel for rails (10^3 tons).	1,446	319	201	398	2,364
Total steel requirement (10^3 tons)	2,017	451	333	674	3,475
Energy for making steel (10^{12} Btu).	12	3	2	4	21
Energy for transportation (10^{12} Btu/year) .	17	4	2	8	32
Total energy (10^{12} Btu/year)	17	4	3	8	32
Total energy per 10^6 tons of coal transported (10^{12} Btu)	0.5	0.3	0.3	0.5	0.4
Transportation energy per net ton-mile (Btu)[a].	340	360	440	580	390
Percentage of the energy content of the coal required to transport it 1,000 miles	1.9	2.0	2.4	2.4	2.0

aRounded to nearest 10 Btu. Mileages arelargerthan forpipelines duetogreater circuity.

Source: Data from Science Applications, inc.

line pumps operate on electricity often derived from other fuels.

Occupational Health and Safety

Occupational injuries and disability days for pipeline construction and operation and railroad operation are shown in tables 45 and 46, respectively. Historical data on accidents on coal slurry pipelines are limited, and pipeline accident rates were estimated from oil pipeline data. The last column of table 45 shows the number of injuries and disability days for construction for 3,146 miles of pipeline (the total length of the four hypothetical routes) and transport of 74.5 million tons of coal annually. On the average, one disability day would result from each 45 million ton-miles of coal transported, about half of which are due to construction, if one assumes that the pipeline will be in operation for 35 years. Data were not available for estimating deaths due to pipeline construction or operations.

Deaths, injuries, and disability days for railroad employees were estimated from accident rates on general freight train operations excluding labor categories not applicable to unit trains. As shown in table 46, in carrying the same 74.5 mill ion tons of coal per year as pipelines, railroads would, according to the estimate, experience 1.9 deaths, 304 lost work-day injuries, and 14,000 disability days annually. One disability day occurs per 6 million ton-miles of coal transported and one death per 43 bill ion ton-miles.

Employees will be exposed to noise from several operations in coal slurry pipeline systems, including water pumping, coal slurry preparation, slurry pumping, and dewatering. [78] Coal slurry preparation involves crushing and grinding operations which generate considerable noise. Pipeline employees are reportedly exposed to noise levels in the range of 90 to 95 dBA by these processes[79] but the plants are sufficiently few and remote to avoid significant community noise impacts. Deep-well submersible pumps are used to draw water from wells, and because of the depth at which the pumps are located, no noise is

[78] W S Gray and P F Mason, "Slurry Pipelines: What the Coal Man Should Know in the Planning Stage, " *Coal Age,* Vol 80, No 9, pp 5a-62, 1975

7. John Montfort, Black Mesa Pipeline Company, Flagstaff, Ariz , personal communication, June 30, 1977

Table 45. Predicted Occupational Injuries and Lost Workdays From Case Study Pipeline Construction and Operation

	Wyoming to Texas	Montana to Minnesota & Wisconsin	Utah to California	Tennessee to Florida	Total
Construction					
Injuries	281	221	125	193	820
Lost workdays	5,228	4,112	2,326	3,591	15,257
Operation					
Injuries per year	31	8	4	9	
Lost workdays per year	577	149	74	167	967
Million net ton-miles[a]					
Per injury	942	702	653	724	831
Per lost workday	51	38	35	39	45

[a]Including construction assuming a 35-year pipeline life.

Source: Science Applications, Inc.

Table 46. Predicted Occupational injuries, Lost Workdays, and Deaths From Case Study Unit Train Service Expansion

	Wyoming to Texas	Montant to Minnesota &Wisconsin	Utah to California	Tennessee to Florida	Total
injuries					
Number per year	140	48	38	78	304
Lost workdays per year	6,300	2,160	1,710	3,510	13,680
Deaths per year	0.98	0.27	0.12	0.51	1.9
Million net ton-miles[a]					
Per injury	355	235	180	176	268
Per lost workday	7.9	5.2	4.0	3.9	6.0
Million net ton-miles[a]					
Per death	51,000	41,000	35,000	27,000	43,000

[a]Mileage is larger than for pipelines due to greater circuity.

Source: Science Applications, Inc.

reported at ground level. The mainline pumps of pipelines can be quite noisy, like any unshielded 5,000 horsepower pump emitting 82 dBA at 50 feet.[80] However, built-in shielding and enclosure in a pumphouse reduce the sound level significantly .8' Railroad noise was discussed in the section of this chapter on community disruption, and railroad employees are exposed to the same sources at closer proximity.

The above figures should be regarded as estimates because of the type of data available and the assumptions made in extrapolating disability days from these data. Nonetheless, the figures provide a useful indication of total and relative employee health and safety for railroads and coal slurry pipelines. Even including the accidents associated with construction of pipelines, as well as operation, railroads experience significantly more disability days than pipelines.

[80] *Draft Environmental Impact Statement, Crude Oil Transportation System: Valdez, Alaska to Midland, Tex.*, U.S. Bureau of Land Management, November 1976

[81] Nick Tuttle Williams Brothers Process $2 rvices, Tulsa, Okla , personal communication, June 28,1977.

VII. Legal and Regulatory Analysis

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INTRODUCTION

This chapter discusses the four major areas of law which affect coal slurry pipeline development. The sections on environmental and water law are relevant independently of Federal coal slurry pipeline legislation, in that if pipelines are built, even without Federal legislation, the pipelines will require acquisition of water and water rights and compliance with Federal environmental protection statutes. Allocation of water and protection of water rights has traditionally been a matter of State law. It is possible, but unlikely, that pending Federal legislation will greatly alter the legal framework of water allocation, Compliance with the National Environmental Policy Act (N EPA) will be triggered if pipeline construction involves any major Federal action which significantly affects the environment. The Federal Water Pollution Control Act (FWPCA) must be complied with if pollutants or hazardous substances are discharged into the waters of the United States.

The other two sections—transportation regulation and eminent domain law — are directly applicable to pending legislation. The kind of eminent domain– Federal or State– employed in acquisition of pipeline rights-of-way is dependent upon the specific language of the legislation enacted. Similarly, the kind of regulation imposed on coal slurry pipelines is dependent upon whether legislation is passed and what provisions are contained in that legislation. For example, as a condition of receipt of a grant of Federal eminent domain, coal slurry pipelines may be subjected to Interstate Commerce Commission (ICC) regulation as common carriers.

Eight major legal provisions, within the four areas of legal specialty, have recurred in the assessment of coal transportation by coal slurry pipelines and railroad unit trains. our analysis reveals that four of these provisions tend to promote pipeline development, while the other four tend to favor rail transportation. These eight major legal provisions are enumerated below.

Legal Provisions Which Favor Pipelines

1. Stringent common carrier obligations.– By virtue of ICC regulation as a common carrier, railroads are required to provide some unprofitable service on low-volume branch lines, for example, and to provide equal service to small as well as large shippers. Pipelines, even if deemed common carriers, will probably not be subject to such stringent requirements if the regulatory structure for pipelines carrying other commodities is a guide.

2. Rate of return.–Although the situation may change with the implementation of the Railroad Revitalization and Regulatory Reform Act, the allowed rates of return on rail investment have historically been considerably less than those allowed in the present pipeline industry. Railroads therefore will probably find capital improvements to provide improved or less costly service more difficult to bring about than will pipelines, unless parity in ratesetting is required by legislation.

3. **Railroads must negotiate rate in-**creases.–Railroad regulation provides that tariffs can be appealed at any time, and increases must be negotiated annually. There is one minor exception in the Rail-

road Revitalization and Regulatory Reform Act of 1976 which permits a rate to stand for 5 years, if more than $1 million is invested in related facility improvements. Pipelines, on the other hand, typically contain cost escalation clauses within the long-term delivery contracts.

4. No long-term contracts for rail.-Under ICC regulation, railroads are prohibited from entering into long-term shipping contracts. Pipelines are not presently or foreseeably so restrained, Long-term shipping contracts enable the carrier to protect investments in equipment and facility improvements.

Legal Provisions Which Favor Railroads

5. State eminent domain. -Since new railroad trackage will rarely be required, railroads have little need for further powers of eminent domain to gain rights-of-way. Pipelines, however, require rights-of-way through numerous States for long-distance construction. Presently, nine States have granted State power of eminent domain specifically to coal slurry pipelines, Other States have no statutes granting such power. Thus, an obstacle to pipeline construction is acquisition of rights-of-way.

6. **Water rights.-Railroads do not require more than minimal quantities of water** for coal transportation. Pipelines, on the other hand, require great quantities of water, generally in Western States where water is relatively scarce and competition therefore great. Acquisition of water rights is dependent upon the laws and administrative regulations of the particular jurisdiction.

7. Commodities clause.–The commodities clause of the Interstate Commerce Act (I CA) presently forbids railroads from carrying commodities owned or manufactured by the railroad. Railroads can, in some cases, circumvent this provision through holding companies and other arrangements. The commodities clauses in proposed legislation for coal slurry pipelines would be much more stringent, Pipeline operators would be forbidden from any ownership interest in the end line activity (e. g., utility powerplant) or any source activity (e. g., coal mining or coal-land ownership rights). Under this provision utilities and mining companies or their contractors would have more difficulty in building and operating a pipeline.

8. **EIS requirement.– If Federal eminent domain legislation is enacted, or other major Federal action is invoked,** such as granting of rights-of-way across Federal lands, or granting a certificate of public convenience and necessity, NE PA **requires that the Federal agency file an environmental impact statement (E IS) if the action will have a significant effect on the environment. Although an impact statement is prepared** only once, one will generally be required for coal slurry pipeline construction, and it will demand substantial resources of the pipeline operator. Because the tracks are already in existence, and new trains and rate changes are not usually considered major Federal actions with significant effects on the environment, railroads will be much less likely to trigger the E I S **process. And even where an E I S is required it will rarely be as extensive as that required** for a coal slurry pipeline.

Coal slurry pipelines are a technological and legal innovation, and much of the following discussion therefore relies on legal precedent applicable to other types of pipelines. Other types of pipelines differ in some ways, and the present comparison at least highlights areas where distinctions indicate a need for specific legislation or regulation,

TRANSPORTATION REGULATION

Regulation of coal slurry pipelines in interstate commerce turns initially upon whether or not pipelines qualify as common carriers. Under the property clause of the Constitution, the Federal Government has the constitutional power to require pipelines to operate as common carriers as a condition of the grant of Federal eminent domain or the grant of right-of-way across Federal lands.

Two major types of regulation are imposed upon pipelines, Pipelines carrying commodities in interstate commerce are subject to ICC reporting, valuation, and accounting requirements designed to keep ICC abreast of all current financial and physical conditions within the pipeline industry which may trigger the need for regulatory changes. Secondly, pipelines which assume common carrier characteristics are required to serve, on an equal basis, all similarly situated persons requesting pipeline transportation and to charge rates within the ICC reasonableness requirement.

The chief characteristics of common carriers is that they transport, indiscriminately for consideration, all of the freight of the type they purport to carry which is tendered to them. Common carrier regulation has been imposed even on pipeline carriers that held title to al I the property they transported Analysis of case law reveals that the term“ common carrier” as defined in the ICA includes all pipelines, whether they are in fact private, contract, or common carriers. Commodities are in interstate commerce: 1) when they are transferred by purchase to pipelines prior to shipment to another State, or 2) when they are transported across State borders for sale or for use by someone other than the pipeline company; but not when they are transported for the pipelines own use to or from its own facilities. Further, the various carrier regulation provisions of ICA can be imposed on pipelines independently of one another. The reporting-type requirements may be imposed upon every pipeline carrying coal in interstate commerce, whether the carrier is actually private, contract, or common. The Interstate Commerce Commission may impose additional ICA common carrier-for-hire-duties on pipelines within its jurisdiction which acquire ownership to commodities and transport them across State borders, and which operate in such a manner as to create competitive imbalances within the industry which produces, processes, or markets the commodities transported.

The following three possible types of coal slurry pipelines could be regulated as common carriers in substance:

1. a coal slurry pipeline which transports all coal slurry tendered to it;
2. a pipeline that purchases coal from all mines in the area from which it operates; and
3. a pipeline that provides essentially the only efficient means of transportation for the coal mined in its source area.

A final possible type of carrie may well include currently contemplated coal slurry pipelines. Private carriers, which are common carriers only in the terminology of ICA, and whose services are not needed by others to cure competitive imbalances within the relevant industry, cannot be converted to common carriers-for-hire by ICC. **It may** be argued that pipelines which in fact operate to serve exclusively a few selected shippers pursuant to a private contract were not intended to be within the reach of ICC regulation as common carriers-for-hire. Assumption of common carrier duties by such coal slurry pipelines may disrupt exclusive shipping agreements, require that lines be rebuilt to accommodate added Volumes, or reduce overall efficiencies by requiring construction of higher volume lines initially and operation at less than design capacit y.

States also impose common carrier duties on some pipelines. Generally a pipeline must be devoted to public service, that is, operated as a common carrier-for-hire, to acquire State governmental privileges, such as eminent domain power.

The traditional duties of common carriers are:

1. to furnish the transportation services they offer to the public to al I who seek them;
2. to furnish services and facilities adequate for satisfactorily fulfilling their transportation obligations;
3. to establish reasonable rules and regulations governing how they fulfill their transportation obligations;
4. to establish reasonable rates and charges for their transportation services; and
5. to treat equally all shippers, freight, and **locations** served which share similar characteristics.

These duties were established to ensure that all persons engaged in providing transportation services for the public operate in ways that best serve the public interest consistent with achieving a reasonable return on their investments in transportation facilities.

A number of factors can preclude pipelines from operation as common carriers. Lack of shipper connections and lack of connecting, receiving, or delivery facilities are frequent problems limiting access to pipelines. Some States require pipelines to furnish connections for shipper facilities, but Federal activity in this area is minimal. For such facilities to be required of coal slurry pipelines, the requirements should be imposed prior to construction so as to properly measure, in advance, the volume of throughput a pipeline will handle. If a pipeline must contain excess capacity for the benefit of future shippers, its present efficiency will be diminished since a coal slurry pipeline operates more efficiently at the throughput for which it is designed. Common carriers faced with transportation demands exceeding the capacity of their transportation system must attempt to serve all shippers without discrimination. This service is usually accomplished one of two ways: 1) by serving shippers on a first-come, first-served basis; or 2) by prorating the pipeline shipping capacity among the shippers on the basis of the amount of throughput each shipper represents to the total throughput tendered. For coal slurry pipelines shipping to coal-fired eletric powerplants, either method of nondiscriminatory service could result in a decrease of power availability in the area of service of the power company.

Minimum tender requirements are rules specifying the minimum quantity of a particular commodity that a carrier will accept for shipment from a specified origin point to a specified destination point. Large minimum tender requirements tend to disfavor small shippers whereas low minimum tender requirements tend to prejudice the ability of a pipeline to function at maximum capacity in a stable environment.

A 1976 **ICC ruling on pipeline** ratemaking uncovered so many significant challenges to the rationality of the ICC ratemaking practices that a comprehensive evaluation was undertaken to determine future ratemaking policy. The reevaluation was still in progress in 1977 when the Department of Energy Organization Act (P. L. 95-91) transferred regulation of petroleum pipelines from ICC to the Department of Energy (DOE). Whether the current, or even revised methods of calculating fair rates of return for pipelines will apply to coal slurry pipelines is unknown. Case law illustrates the desirability of adopting fair rates of return more tailored to the needs of pipelines as a separate class.

The present ICC ratemaking practices for pipeline employ a public utility approach. This approach is considered reasonable since there is little pipeline-to-pipeline competition. Public utility ratemaking entitles the regulated company to set rates calculated to cover its costs of providing public services plus a fair return on fair value of the property the company dedicates to public service. Rate-of-return percentages are established for categories of pipelines rather than for each individual pipeline based on its own individual needs. The Interstate Commerce Commission employs 8 and 10 percent as reasonable rates of return for crude oil and petroleum product pipelines respectively. No reasonable rate of return has been established for coal slurry pipelines. The Interstate Commerce Commission uses the method for valuation of carrier property prescribed by section 19a of ICA as a basis for pipeline rate determinations. This annual calculation takes into account the original cost of all lands and rights-of-way used by the carrier in delivering its services, and the original cost, cost of replacement both new, and less depreciation of all other property the carrier dedicates to public service. The method also includes ICC'S consideration of working capital and going-concern value.

The relevant rail rates for comparisons with coal slurry pipeline rates are those on the unit train concept. Unit train rates are lower than other types of rates (e. g., carload, multicar, train load) because they include volume discounts, and discounts for other cost-reduction factors such as elimination of loading, unloading, and car-switching operations. The major difference between ICC'S railroad ratemaking and its pipeline ratemaking is that the reasonableness of railroad rates is judged without reference to a fair rate of return. A value-of-service consideration is applied to railroads, under which the rate is determined by consideration of

1. the level of the proposed rate compared with established rates for similar shipments in the territory,
2. the economic effect of the proposed rate on the shippers and their customers,
3. the relationship of the proposed rate and the cost of providing service, and
4. the likelihood that the rate will be compensatory.

The: Interstate Commerce Commission has not given any consideration historically to the railroad's cost of equity capital in making railroad rate decisions. As long as the railroad rate covers its variable cost it is not unlawfully low. Under the Railroad Revitalization and Regulatory Reform Act (the 4R Act), ICC is not to determine the reasonableness of railroad rates by comparison to rate structures of competing modes. This means that in rate competition between railroads and coal slurry pipelines, the railroads will be allowed to go below their fully allocated costs to undercut the fully allocated costs of competing pipelines, even though the coal slurry pipeline may have the lowest overall cost structure.

The Interstate Commerce Commission influences competition among distinct modes of transportation through policies focusing directly on competitive relationships and by regulating each mode differently from the way other modes are regulated. Competition between railroads and slurry pipelines is affected by ICA, subjecting only the railroads to a commodities clause and to entry, extension, and abandonment regulation. Unique features of ICC regulation of railroad rates also produce competitive impacts.

The commodities clause applies only to railroads and prohibits every railroad from transporting any commodity in interstate commerce which is manufactured, mined, or produced by it, or which it may own, in whole or in part. The commodities clause was enacted mainly to prevent railroads from achieving unfair competitive advantages in an unrelated industry by shipping commodities they owned at rates lower than they shipped commodities owned by their competitors It does not directly prevent railroads from being commonly owned with, or being owned by, companies which engage in unrelated industries and then serving them as customers.

The proposed legislation would include a coal slurry pipeline commodities clause that would prevent anyone from having a direct or indirect ownership interest in a coal slurry pipeline who also has a direct or indirect interest in coal or would be a user of coal. This legislation would impose much greater investment limitations on any coal-related firm contemplating ownership of coal slurry pipeline enterprises than does the commodities clause on railroads.

Railroads must acquire certificates of public convenience and necessity before they can enter new markets, or extend or abandon current markets. Coal pipelines are not now subject to any certification requirement, and are therefore free to enter or abandon any market. Entry and extension regulation is designed to **promote the most** efficient carrier service **possible in each area** served by a common car**rier.**

Coal slurry pipelines will make arrangements with shippers by throughput and deficiency agreements or ship-or-pay contracts. Although these arrangements can serve valid business purposes, they also impose a restraint on trade. If a restraint on trade is unreasonable, it is subject to antitrust action.

Throughout and deficiency agreements are essentially financing agreements designed to provide lenders to pipeline companies greater security in return for the best possible financing terms. The parties to the agreements are the pipeline company and the shippers, of which the latter agrees to guarantee the debt service obligations of the pipeline.

Ship-or-pay contracts are analogous to requirements contracts in the sense that they bind shippers to transporting a specified volume of traffic through a pipeline for a fixed period of time. The valid business purposes of ship-or-pay contracts are:

1. to guarantee the debt service of the pipeline by securing a fixed level of revenue in order to procure favorable financing,
2. to guarantee that the pipeline operates at its design capacity so as to achieve full efficiency, and
3. to provide a stable source of transportation in a predictable volume at a reasonably stable price.

Balanced against these valid purposes are the **restraints of trade which include:**

1. **foreclosure of the traffic of** the partici**pating shippers from use of** competing modes of transportation, and
2. foreclosure of committed pipeline capacity from use by other, nonparticipating shippers.

The extent, duration, and cost of reduced competition, relative strengths of the parties, structure of the relevant industry, and other factors will determine whether the restraint of trade is reasonable.

WATER LAW

From a survey of the water aspects of coal slurry pipeline development, several important considerations emerge. This section will briefly summarize the most important of them.

Most of the significant issues of State law influencing coal slurry pipeline development are related to prior appropriation jurisdictions in the western part of the country. However, the riparian system and the principal of reasonable use characteristic of Eastern States present two significant problems to a pipeline operator. First, under the riparian system, the use of water for a coal slurry pipeline may not be permitted, because the riparian system traditionally limits the use of water to the land adjoining the stream or body from which it is taken. Second, even if use for a coal slurry pipeline is considered a riparian use, the riparian system is characterized by a sharing of water with all other riparian users from the same source. Thus, under conditions of heavy demand relative to supply, the pipeline operator may not be able to obtain enough water for the pipeline. Since most riparian jurisdictions are characterized by abundance of water and infrequency of litigation over water matters, the use of water for a coal slurry pipeline may not raise significant problems for any pipeline in the East.

In a prior appropriation jurisdiction the threshold consideration is the availability of water not already in beneficial use, assuming that the use of water for a coal slurry pipeline is otherwise permissible. There are some inherent limitations on the sovereign right of a State to make water available for a coal slurry pipeline. Some of the limitations arise because a particular water source is shared with another State, and some arise because of the constitutional allocation of power between the States and the Federal Government.

Within the limits of its own sovereign power, a State may influence the availability of water in a number of significant ways, First, the policy adopted by some States for water resource management, in particular with respect to ground water resources, allows the State to permit ground water mining or permit water to be withdrawn only to the extent the water supply in the aquifer from which the water is withdrawn is replenished from natural sources. A second way in which some States influence the availability of water is by withdrawing water from present, private use to accomplish conservation, planning, and future development objectives,

Once it is determined that water is available, the next consideration is whether State water policy permits the use of water for a coal slurry pipeline, which depends upon whether the use of water for a coal slurry pipeline is a beneficial use, one which would be found to be in the public interest, under applicable State law. Guidelines under case law and under most State statutes are insufficient to resolve this question, although the legislatures of those States which have focused on the issue have generally taken a negative attitude toward water for coal slurry pipelines.

If the use of water for coal slurry is permitted, then State administrators may impose conditions on the use. Any State prohibition or unusual restriction on the use of water for coal slurry may be attacked as an unconstitutional discrimination against interstate commerce in coal. However, *unless* the restrictions were severely discriminatory against the transportation of coal out of State, the constitutional issue would probably be resolved by the courts in favor of the State determination.

Two specific State restrictions merit special mention. First, the application of the use preference policy of a State may make a water right for coal slurry somewhat uncertain. A use preference policy, either through the use of conditions in the operator's water permit or by force of statute, can invert normal priorities and require the pipeline use of water to yield to uses initiated after the pipeline was operational. In most States, a statutory use preference, as opposed to one imposed administratively, can be enforced only through the exercise of the power of eminent domain to condemn the water by a preferred user.

The second restriction of special significance is the restriction or prohibition against the exportation of water out of State. Although the movement of coal slurry out of State might be treated as the exportation of coal slurry, a manufactured product, as opposed to the exportation of water, State I imitations on the exportation of water may be applicable. Serious constitutional objections to such State I imitations exist, however,

In addition to the preceding issues of State law, some less-significant issues which may become significant in certain situations should be examined. Attention must be given to the effect on other users of water from the same water source if existing water rights are obtained and their use changed to a use for coal slurry. Another issue is the uncertainty of the water supply if the source chosen is byproduct water. Whether byproduct water sources will be used depends upon whether existing demands, or rights to make demands on natural water sources, will preclude the use of natural water sources without the acquisition of existing rights.

The important issues of Federal law do not relate to the constitutional power of Congress to make water available for use in a coal slurry pipeline. Constitutional power is adequate to do that, whether the source of the power is the inability of a State to thwart Federal policy through inconsistent enactments, or the power of Congress over certain water resources, notably navigable waters and water from

Federal water projects. Under the reserved rights doctrine, water under Federal control also includes unappropriated water appurtenant to lands reserved by the Federal Government to the extent necessary to accomplish the purpose of the reservation. The most significant limitation on Federal constitutional power requires that the Federal authority respect private rights, but this I imitation does not apply to Federal allocation of navigable waters. The ability of the Federal Government to make reserved water appurtenant to Federal lands available for a coal slurry pipeline may be limited if the pipeline does not contribute to the purpose for which the land has been reserved.

The significant policy issues of Federal law concern the extent to which Congress will exercise its constitutional powers over commerce, property, and the general welfare. First, Congress must decide the extent, if any, to which water under Federal control should be made available for coal slurry pipelines. If Congress wishes to make Federal water available, then, at the very least, legislation should make it clear that use of water in a coal slurry pipeline is a use for which administrators of Federal projects may allocate Federal water.

The second **issue facing** Congress is the extent to which State control of water resources for a pipeline survives the enactment of legislation authorizing Federal certification and regulation of pipelines. Federal judicial treatment of Federal statutes (specifically, Federal Power Act, § 9(b), and Reclamation Act, § 8), whose design was on its face to maintain State control over water, suggests that the pending Federal legislation, in its present form, may leave little scope for State regulation of water for a coal slurry pipeline. If the intent is to preserve meaningful State regulation beyond the mere determination of the existence of vested rights in a water source, then legislation should express in specific terms exactly what State administrators may do to control water for the pipeline.

The third issue facing Congress is closely related to the second, and affects the extent to which the Federal Government must respect State law in distributing water from sources under Federal control, such as Army Corps of Engineers and Bureau of Reclamation projects. The legislative measures necessary to confer upon the States a meaningful voice in the distribution of Federal water are the same measures as those which permit State regulation to survive Federal certification and regulation of a pipeline, namely, specific expression of State authority.

An additional issue must be faced with respect to navigable waters. Congress must decide the extent to which a coal slurry pipeline operator must compensate, if at all, other private users of water from a source which is also a source for water for use in the pipeline.

In conclusion, although traditionally, water allocation is primarily a matter of State law, increasing competitive water needs and responsive Federal and State legislation create some uncertainty as to present law affecting water. Resolution of the uncertainty as to the present law affecting water sources for coal slurry pipelines may cost the pipeline operators in time and money. Some of this uncertainty could be resolved by a policy decision that water is to be made available for coal slurry. However, if a decision is made on the Federal level, then the long-standing integrity of State control of State water resources and the ability of State water administrators to implement State evaluations of regional water priorities would be compromised,

ENVIRONMENTAL LAW

The major Federal environmental legislation affecting coal transportation by coal slurry pipelines and railroads are the National Environmental Policy Act (NE PA), and the

Federal Water Pollution Control Act of 1972 (FWPCA). Additionally, the Safe Drinking Water Act of 1974 (SDWA) and Resource Conservation and Recovery Act of 1976 (RCRA) apply to prevent contamination of many ground water sources, Federal laws also protect members of the public and workers from other possible health and safety impacts of construction and operation of railroads and pipelines.

The National Environmental Policy Act applies to some activities in the construction and operation of both coal slurry pipelines and coal unit trains which involve Federal action and requires at least an environmental evaluation to determine whether an environmental impact statement is necessary. Activities common to both coal slurry pipelines and unit trains which involve Federal action and may require an E I S include: 1) crossing Federal lands, 2) crossing '(navigable waters of the United States" or '(waters of the United States, " 3) discharging pollutants into "waters of the United States, " and ***4)*** being a part of the transportation element of a Mine Plan for development of a coal lease.

Under ICC regulation, rail line construction may have a significant impact on the environment, and in application to ICC the railroad must include a detailed environmental impact report, which may be incorporated into an E IS. Actions which affect the operation of a railroad line or general rate increases may also require EISs.

The exercise of regulatory power attendant to the grant of eminent domain in some of the presently pending legislation, may constitute sufficient Federal action to require an assessment of whether an E I S is necessary. Even where major Federal action is absent, State environmental regulations may require an E I S for State action or regulation.

Under various provisions of the FWPCA, "waters of the United States" are protected from pollutant discharges. jurisdiction of the FWPCA includes essentially all surface waters of the United States. Two provisions are especially applicable to coal slurry pipelines: 1) issuance of discharge permits under the national pollution discharge elimination system and, 2) control of point source accidental pollution discharges.

The national pollution discharge elimination system, in FWPCA, requires that a discharge permit which regulates the amount of pollutant in the discharged water be obtained. Coal preparation plants at coal slurry pipeline sources and slurry recycle and reuse plants at pipeline termini are subject to permit requirements. Accidental spills from, for example, a ruptured pipeline would subject the pipeline operator to potential liability for a discharge of toxic pollutants or hazardous substances without a permit if the discharge entered a water of the United States.

Underground waters are protected by the SDWA and RCRA. The SDWA regulates injections of fluids underground as well as the use of holding ponds, thereby limiting disposal of slurry waste water by either of these methods. The objectives of RCRA are to encourage development of solid waste management plans, prohibit open dumps, regulate handling and disposal of hazardous waste, and develop guidelines for solid waste disposal protection. Other than unusable sludge, for example, the dewatered slurry from an accidental spill, coal slurry pipelines will produce very little disposable sol id waste.

EMINENT DOMAIN

The power of eminent domain is an inherent power of a sovereign. The Federal and State constitutions do not grant the power but rather limit its exercise to a taking of property for public purposes upon payment of just compensation to the owner of the property. The sovereign may delegate the power to non-governmental entities. The power is limited to the territorial jurisdiction of the sovereign and may be subject to statutory I imitations in connection with a particular grant of the power. The power is exercised through condemnation proceedings which award the landowner just compensation and put the condemnor in possession of the property. A prerequisite to condemnations for a pipeline may be a determination of an acceptable pipeline route after public hearings.

The coal slurry pipeline bills presently before Congress take one of two approaches. One approach is to grant Federal eminent domain authority to coal slurry pipelines upon the attainment of a certificate of public convenience and necessity from a Federal agency and to regulate them as common carriers. The other approach is to leave the matter of eminent domain to the States and to regulate coal slurry pipelines as common carriers under ICA. Under this approach right-of-way conflicts would be resolved by ICC, which could order another regulated carrier to grant an easement to a coal slurry pipeline.

Six Western States (Louisiana, Texas, Oklahoma, Montana, Utah, and North Dakota) have specifically granted eminent domain to coal slurry pipelines, and five States have no statutes which could be interpreted to include such a grant. In eight more States through which pipelines may pass, a coal slurry pipeline is not assured **of the power of eminent domain because of ambiquity** in the statutes. Some recent State legislation granting eminent domain to coal slurry pipelines limits the use of State water and subjects the pipelines to State regulation as common carrier.

For the valid exercise of State eminent domain by an interstate coal slurry pipeline within the State granting such power, the activities of the pipeline must constitute a public purpose in the State. In a "State of origin," where the pipeline picks up coal for transportation, and an "intermediate State, " where a pipeline passes through the State without picking up or delivering coal, it is arguable that the pipeline may not be performing a public purpose. **In a "State of destination" where a** delivery of coal is made by the pipeline, the pipeline would be serving a public purpose under most circumstances.

In order to place the need or lack of need for a grant of the power of eminent domain in legal perspective, the acquisition of legal rights-of-way without the power of eminent domain is relevant. Except for certain protected lands, rights-of-way may be granted without the exercise of eminent domain to coal slurry pipelines over Federal public lands, national forest lands, and Indian lands; however, on Indian lands, the written permission of the Indian owners must be obtained. The acquisition of rights-of-way for a pipeline across a State without either Federal or State eminent domain authority will be more expensive if recalcitrant landowners refuse to grant easements or if opportunist landowners ask hold-up prices.

In the absence of State or Federal eminent domain, an organized opposition to a coal slurry pipeline might prevent the construction of the pipeline across areas of land owned in fee by that opposition. A landowner with a fee title may prevent the pipeline from crossing under the land by refusing to grant a right-of-way. If, however, the member of the organized opposition possesses only an easement interest in the land, that person cannot prevent the pipeline from obtaining a right-of-way. Whether the present landowner has acquired fee title or an easement is dependent upon the specific language of their deed to the land.

In the Western States many of the early railroad rights-of-way were acquired under the Pacific Railroad Acts of 1862 and 1864, and the type of ownership, either in fee or as an easement, established thereunder is in dispute. Although it has been held that a railroad received only a limited fee, which would not enable it to prevent granting an easement to a slurry pipeline, further litigation may be required before a definitive conclusion is reached.

The treatment of other pipelines provide no general conclusion as to whether coal slurry

pipelines require the grant of eminent domain. The extensive network of interstate oil pipelines, ammonia fertilizer pipelines, and railroads have been built with only State eminent domain authority. Federal eminent domain authority was granted to interstate natural gas pipelines by the 1947 Amendment to the Natural Gas Act because

1. it was believed that crossing a State without distribution of gas therein would not be a public benefit to that State,
2. some desired to protect the exclusive jurisdiction of the Federal Power Commission (F PC) over such pipelines, and
3. it was believed that these pipelines were different from other modes of transportation because their movement of natural gas from fields to distant markets did not require them to be common carriers.

The grant of Federal eminent domain came 9 years-after interstate natural gas pipelines had come under the jurisdiction of FPC, which regulated the transportation, supply, and some elements of the price of natural gas dedicated to interstate commerce.

The Cole Pipe Line Act granted Federal eminent domain authority to interstate oil pipelines for 2 years as a part of emergency legislation aimed at overcoming delays in construction of oil pipelines caused by railroad opposition and refusal of the Georgia legislature to grant them eminent domain.

The comparison of interstate coal slurry pipelines with interstate natural gas pipelines indicates that although the granting of Federal eminent domain to gas pipelines does not mandate such a grant to coal slurry pipelines, it does furnish a possible legal precedent if Congress finds such grant to coal slurry pipelines to be in the national interest.

A comparison of interstate coal slurry pipelines with interstate natural gas pipelines yields the following similarities:

1. Each usually operates pursuant to long-term supply and or transportation contracts.
2. Each will often transport its commodity from field or mine to a distant market or user and in the process may traverse one or more States in which it neither picks up nor delivers any portion of the commodity transported.
3. Each has limitations on its ability to act as a common carrier in the States it traverses.

Coal slurry and natural gas pipelines, however, have the following dissimilarities:

- Gas pipelines own most of the gas transported while coal pipelines apparently will not own the coal transported although it appears there is nothing in the existing laws which would prohibit such ownership.
- Gas pipelines are subject to FPC regulation which extends to the price and supply of natural gas dedicated to interstate commerce and requires insulation from State regulation. Interstate coal pipelines are presently subject to minimal ICC regulation, and regulation under proposed legislation will not extend to the price and supply of coal transported.

A comparison of interstate coal slurry pipelines with interstate crude oil and petroleum products pipelines illustrates their dissimilarity as to:

1. Ownership of commodity shipped.
2. Length of term of supply contracts and transportation contracts.
3. Physical capabilities to act as a common carrier or common purchaser in States traversed.

The comparison of interstate coal pipelines with interstate crude oil and petroleum products pipelines does not establish that State eminent domain authority for coal slurry pipelines will be insufficient but does indicate that it may not be as effective in meeting needs of coal slurry pipelines as it has been for oil pipelines.

The basic option to Federal policy makers is whether or not to grant Federal eminent domain authority to coal slurry pipelines. If Congress elects not to grant eminent domain authority to coal slurry pipelines, such pipelines must rely on eminent domain authority from those States which have granted or will grant in the future such authority to the pipelines. In order to exercise eminent domain authority granted to it, a coal slurry pipeline, in most States, will:

1. be required to obtain a license or certificate of public convenience and necessity from a State agency,
2. be designated as common carrier or public utility, and
3. be subject to State regulations which do not unduly burden interstate commerce or interfere with Federal regulation of such pipeline.

Under the "public purposes" requirement, circumstances in a "State of origin" and in an "intermediate State" may preclude a pipeline from being considered as serving a public purpose within the State or being a common carrier in fact, and thereby prevent the valid exercise of State eminent domain authority by such pipeline.

A further consequence of not granting Federal eminent domain authority to coal slurry pipelines is the possibility that one or more States traversed by the pipeline might not grant eminent domain authority to the pipeline. This could lead to costly and inefficient routing of the pipeline to avoid recalcitrant or opportunist landowners, costly delay in negotiations, increased cost of rights-of-way, and possible inability to construct a pipeline across a State due to organized opposition.

If Federal eminent domain authority is granted to coal slurry pipelines, the pipelines may rely on that authority to obtain necessary rights-of-way in each State traversed by the pipeline. Construction of the pipeline will have been deemed to constitute a national public purpose justifying the exercise of Federal eminent domain authority. The pipeline will not be required to obtain a license or certificate from the State agency in order to construct its pipeline or to exercise Federal eminent domain authority. If the grant of Federal eminent domain authority requires that the practice and procedure of State courts be followed, as is required by the Natural Gas Act, then it would seem that landowners within a particular State would be protected by the same due process requirements for determining "just compensation" as are applicable to a taking of their property under State eminent domain authority.

A possible alternative to simply granting or withholding Federal eminent domain authority for coal slurry pipelines would be a conditional grant of such authority. Such a grant would be conditioned upon a showing that a particular State to be traversed by the pipeline had not granted eminent domain authority to coal slurry pipelines or that the State authority, though granted, could not be validly exercised in such State because of a lack of public purpose within the State. Federal legislation granting a conditional eminent domain power would allow each State the opportunity to grant eminent domain authority to coal slurry pipelines on conditions which the State deemed necessary to the protection of State interests. Such State legislation and the regulations thereunder could not unduly burden interstate commerce or interfere with Federal regulation of the pipeline.

In drafting a conditional grant of Federal eminent domain authority, a period of time should be allowed for States to grant eminent domain authority to coal slurry pipelines. The circumstances which would constitute a lack of public purpose within a State and thereby entitle a pipeline to exercise the Federal eminent domain authority should also be set forth. A potential problem with such legislation is that it might subject coal slurry pipelines to duplicative Federal and State legislation. Careful drafting of legislation could minimize this problem.

Also, Congress could elect to grant the power of eminent domain for individual pipeline projects through specific legislation. This approach would be cumbersome, but it would allow Congress to determine in each case the degree to which the national interest is served.

In conclusion, the decision among the foregoing alternatives depends on two principal factors. The first is the degree to which coal slurry pipelines are desirable or not, in the light of all of the considerations discussed in this assessment. The second is the extent to which national or local priorities should be reflected in the conditions under which the power of eminent domain can be exercised.

APPENDIX:
Baseline Rail Revenue and Cost Projections

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RAIL REVENUE PROJECTIONS

Regional revenue shares were projected for 10 commodity groups, at the two-digit standard industrial classification (SIC) level. Interviews and a literature search established the necessary data base. A series of correlations and regressions were then run using Class I aggregate and individual railroad data in order to find the most effective explanatory variable for use in the forecasts. Data were available in adequate detail for the period 1964-74 to permit testing a number of relationships at the regional commodity level.

The best statistical fits (R^2) and highest T values were provided by time-trending via the logarithmic equation:

$$\ln \frac{N_{ijk}}{1 - N_{ijk}} = a_{ijk} + \frac{b_{ijk}}{t} \qquad (1)$$

where N_{ijk} is the share of national railroad revenues earned by region j through transport of commodity i in year k. The coefficients *a* and b were determined through regression analysis of historical data. Equation 1 was then employed to project regional revenue shares in future years, e.g., 1985 and 2000. Table A-1 presents historical regional shares data, and the projected regional commodity shares for 1985 and 2000 based on the regression analysis.

[1]The data were taken from *Moody's 1976 Transportation Manual;* and *Operating and Traffic Statistics 1964-1975*, Association of American Railroads

Forecasting of revenues was considerably more complicated than that of shares. Revenue calculation requires that actual shipments of specific commodities be forecast, including their production quantities and the allocation of shipments among rail and other transport modes, such as truck, barge, pipeline, or air After carefully examining a number of forecasting methods and models, the TECNET[2] model was employed to predict national commodity outputs and transportation modal shares. In simplest terms, TECNET is a computerized input-output model designed to disaggregate transportation-related data and forecasts into a level of detail considerably greater than that provided by a model of the overall economy—INFORUM. Starting from a base year of 1971, TECNET projects national transportation requirements by

[2]TECNET was developed by International Research and Technology Corporation under sponsorship of the Department of Energy. The acronym stands for Transportation Energy Conservation Network. It projects economic activity within 185 sectors through the year 2025 using the INFORUM input-output model developed under Clopper Almon's direction at the University of Maryland, as modified by William Watson at Resources for the Future. (INFORUM stands for "Interindustry Forecasting Model of the University of Maryland," and is described in his book titled, *1985: Interindustry Forecasts of the American Economy*, Lexington Books, 1974.) The transportation sector is broken into modal shares, i.e., rail, barge, truck, auto, etc., so that the effect of introducing energy-conserving technologies, into these segments can be evaluated. It is used in this study only to estimate the railroad shares of transportation revenues for nine commodities and the "all other" group. As explained in the text, coal forecasts were made separately. For additional description of TECNET, see *Transportation Energy Conservation Network*, Ralph M. Doggett, et al., IR&T Report 485-R, Sept. 15, 1977

Table A-1. Historical and Projected Regional Revenue Share by Commodity

(Percent of national commodity revenues)

SIC code	Title and region	Historical 1966	1970	1974	Projected 1985	2000
01	**Farm Products**					
	East	16.7	14.0	13.4	8.5	4.7
	South	10.2	9.9	9.3	8.2	5.6
	West	73.1	76.1	77.3	83.3	89.7
11	**Coal**					
	East	74.9	70.9	62.5	36.5	25.2
	South	17.0	19.2	19.8	19.8	22.9
	West	8.1	9.9	17.7	43.8	52.0
14	**Stone and Minerals**					
	East	32.4	32.0	28.5	24.5	18.4
	South	25.8	26.6	27.5	31.6	31.4
	West	41.8	41.4	44.0	44.5	50.2
20	**Food**					
	East	32.0	30.3	27.5	21.3	16.5
	South	14.6	15.1	15.5	16.8	17.7
	West	52.9	54.6	56.9	61.9	65.8
24	**Lumber and Wood**					
	East	15.0	14.0	13.6	12.0	10.2
	South	16.0	17.8	19,6	23.2	30.0
	West	69.0	68.2	66.8	64.8	59.8
26	**Pulp and paper**					
	East	36.9	34.1	32.4	26.6	19.8
	South	22.7	24.9	25.4	29.7	34.8
	West	40.4	41.0	42.2	43.7	45.4
28	**Chemicals and plastics**					
	East	31.6	29.0	25.0	18,3	10.8
	South	20.4	22.1	23.1	26.9	31.5
	West	48.0	48.9	51.9	54.8	57.7
32	**Cement and glass**					
	East	35.9	33.9	31.0	25.5	18.9
	South	23.6	25.0	25.5	29.7	34.5
	West	40.4	41.1	43.5	44.8	46.6
33	**Primary metals**					
	East	49.2	50.0	45.8	41.5	34.6
	South	10.3	11.6	11.3	14.7	18.5
	West	40.5	38.4	42.9	43.8	46.9
37	**Transportation equipment**					
	East	48.9	48.6	46.5	44.2	40.0
	South	10.2	11.2	12.3	16.4	23.1
	West	40.9	40.2	41.2	39.4	36.9
— A	**Another**					
	East	36.9	35.1	35.5	30.3	18.8
	South	12.9	15.4	15.1	24.6	29.9
	West	50.2	49.5	49.4	45.1	51.2
•*	**All commodities**[a]					
	East	38.1	36.5	33.9	27.5	20.2
	South	15.4	17.1	17.4	21.1	25.5
	West	46.5	46,5	48.7	51.4	54.4

[a]All commodities total may not add due to rounding.

Source: Historical data obtained from Moody's 1976 Transportation Manual. Projections made by IR&T.

mode and economic sector through the year 2025 based on an assumed rate of GNP growth of 2.90 percent before 1985 and 2.95 percent afterward. The national railroad revenues obtained from TECNET were allocated to railroad regions using the share projections presented in table A-1, The resulting regional revenue projections are given in table A-2. The rate of overall traffic growth represents a departure from long-term trends in that it approximately equals the expected rate of increase in gross national product. On the other hand the projected growth is considerably lower than that forecast by the U.S. Department of Transportation and endorsed by the Association of American Railroads.[3]

The coal railroad revenue forecasts presented in table A-2 were developed exogenousy from TECNET. This was done because appraisal of two coal transportation alternatives is the central focus of this study, hence this commodity merits more detailed consideration than achievable through use of the general model. In order to establish the coal-related revenue projections, it was necessary to undertake three steps:

1. Project coal production by railroad region between 1980-2000.
2. Estimate the railroad share of coal shipments in the three regions over the same time period.
3. Convert the originating tonnage estimates in each region into ton-miles and railroad revenues.

Coal supply projections for the years 1985 and 2000 were obtained for the three railroad regions by grouping data provided in the Department of Energy's (DOE) Annual Environmental Assessment Report (AEAR).[4] The AEAR projections identify the energy content of future coal supply from 10 Federal regions. The currently mandated environmental regulatory situation, following passage of the Clean Air Act (CAA) Amendments of 1977, was assumed in forecasting as the coal supply baseline. The DOE coal supply figures were converted into tons of coal, using the average energy content of coal in each Federal region. The resulting coal supply projections for the years 1985 and 2000 are presented in the following table:

COAL SUPPLY PROJECTIONS By RAILROAD REGION –1985 and 2000
(Milliions of short tons)

Region	1975	1985	2000
East	3445	3983	4942
South	1686	1806	3282
West	1032	4435	8084
Total U S	6163	1,0224	1,6308

There are a number of interesting aspects of the coal production projections. By the year 2000, national coal production is estimated to increase by a factor of 2.6 relative to its 1975 level. Western coal production, however, is projected to increase nearly eightfold, so that by 2000 it will account for approximately half of the national total. Eastern coal output is projected to increase much more slowly, rising by 43.5 percent relative to its 1975 value. As a result, eastern coal's participation in the national total will decline from 55.9 percent in 1975 to 30.3 percent in 2000. The production of southern coal will follow a middle course, nearly doubling between 1975-2000, and it will continue to produce the least of the three regions.

Projections of railroad shares of regional coal shipments were based on analysis of historical trends, adjusted by anticipated shifts in regional coal production. The historical data indicate that railroads' share of eastern and western coal movements (including mine-mouth usage) steadily declined over the 1964-74 period, while southern railroads gained an increasing share of coal movements in that region.[5] The reasons underlying the

[3] Association of American Railroads, *Yearbook of Railroad Facts, 1977*

[4] *Annual Environmental Analysis Report,* prepared for the Assistant Administrator of Environment and Safety, DOE, by MITRE Corporation, Consad Research Corporation, Control Data Corporation, and International Research and Technology Corporation, September 1977

[5] Analysis of U S Bureau of Mines data provided in *The Minerals Yearbook* for the years 1969 to 1974

Table A-2. Baseline Regional Railroad Revenue Projections

(Millions of 1971 dollars)

SIC code	Commodity	1980	1985	1990	1995	2000
01	Farm Products					
	East	$ 107.83	$ 89.20	$ 80.37	$ 70.41	$ 64.70
	South	92.13	86.10	86.11	89.27	77.00
	West	846.99	874.30	981.76	1,097.12	1,233.80
	Total	1,046.95	1,049.60	1,148.24	1,257.40	1,375.50
11	Coal					
	East	887.94	1,009.30	1,034.30	1,060.02	1,086.33
	South	392.39	550.99	668.84	811.90	985.57
	West	549.53	1,218.22	1,492.06	1,821.27	2,241.04
	Total	1,829.86	2,778.51	3,195.20	3,696.19	4,312.94
14	Stone and minerals					
	East	109.76	133.70	132.71	150.84	184.90
	South	125.30	169.20	185.80	233.64	315.50
	West	266.13	242.90	362.08	435.30	504.40
	Total	501.19	545.80	680.59	819.78	1,004.80
20	Food					
	East	417.03	380.90	405.45	402.75	465.60
	South	265.23	300.40	334.25	378.67	499.50
	West	985.85	1,107.00	1,238.13	1,407.44	1,856.70
	Total	1,668.11	1,788.30	1,977.83	2,188.86	2,821.80
24	Lumber and wood					
	East	144.81	148.30	153.94	156.45	160.00
	South	239.46	286.80	338.68	399.84	470.50
	West	756.01	801.00	846.05	892.39	937.80
	Total	1,140.28	1,236.10	1,338.67	1,448.68	1,568.30
26	Pulp and paper					
	East	267.18	264.70	280.60	295.78	311.40
	South	257.08	295.60	265.24	448,40	547.20
	West	393.89	435.00	513.66	606.42	714.00
	Total	918.15	995.30	1,059.50	1,350.60	1,572.60
28	Chemicals and plastics					
	East	260.79	282.50	287.82	290.16	290.10
	South	308.32	415.30	529.23	669.61	846.00
	West	649.55	845.80	1,039.89	1,272.26	1,549.70
	Total	1,218.66	1,543.60	1,856.94	2,232.03	2,685.80
32	Cement and glass					
	East	268.13	275.40	306.43	338.61	368.70
	South	269.09	320.80	414.74	530,49	695.90
	West	420.39	483.80	599.66	743.33	906.90
	Total	957.61	1,080.00	1,320.83	1,612.43	1,971.50
33	Primary metals					
	East	482.37	476.00	496.47	556.36	600.50
	South	149.70	168.70	202.40	260.04	321.10
	West	476.82	502.40	574.12	695.46	813.90
	Total	1,108.89	1,147.10	1,272.99	1,511.86	1,735.50
37	Transportation equipment					
	East	434.08	500.30	577.89	668.37	768.70
	South	139.59	185.60	251.14	333.38	443.90
	West	382.45	445.90	521.18	608.78	709.10
	Total	956.12	1,131.80	1,350.21	1,610.53	1,921.70

Table A-2. Baseline Regional Railroad Revenue Projections—Continued

SIC code	Commodity	1980	1985	1990	1995	2000
	All other					
	East	1,068.70	1,208.00	1,233.50	1,259.50	1,286.10
	South	580.90	978.10	1,250.50	1,599.00	2,044.40
	West	1,421.90	1,795.20	2,242.60	2,801.80	3,500.80
	Total	3,071.50	3,981.30	4,726.60	5,660.30	6,831.30
•*	Commodities					
	East	4,448.62	4,768.30	4,989.47	5,249.25	5,587.03
	South	2,819.19	3,757.59	4,526.93	5,754.24	7,246.57
	West	7,149.51	8,751.52	10,411.19	12,382.17	14,968.14
	Total	14,417.32	17,277.41	19,927.59	23,385.66	27,801.74

Source: IR&T estimates.

declines in the East and West differ markedly. In the East, the decline–from 71.6 percent to 63.1 percent—was due to modest increases in market penetration by barges, trucks, and mine-mouth generation. There is essentially no barge transport in the West, and truck transport of coal fell from 13.9 percent in 1969 to 4.0 percent in 1974. Furthermore, recent indications are that for both environmental and economic reasons mine-mouth generation will expand only slightly in the future.[6] Therefore, it is anticipated that coal supply growth in the West will be transported primarily by the railroads. On the basis of historical trends, it is estimated that railroads will capture 86.0 percent of western coal shipments (originating tons) in 1985 and 90.4 percent in 2000. The comparable estimates for the East are 59.8 and 53.7 percent, respectively and 80.8 and 84.7 percent for the South.

participation of unit trains in coal shipments is also of interest In the East, unit train participation was nearly constant between 1969-74 at about 36 percent, while in the South and West unit train participation approximately doubled –from 16.1 to 29,3 percent in the South and from 28.2 to 578 percent in the West. It is projected that unit train participation will continue to increase in these two regions — to 40 percent by 1985 and 45 percent by 2000 in the South, and to 75 and 80 percent in those 2 years in the West. It is assumed that economic pressures will motivate some growth in eastern unit train participation. The estimates are that participation will rise to 40 percent in 1985 and 45 percent in 2000.

Coal shipment revenue projections were made by translating the originating tonnage forecasts into ton-miles, then multiplying by estimated revenues per ton-mile for regular and unit trains. The average haul distances in each region were estimated to be 650 miles in the West, 235 miles in the East, and 300 miles in the South.[7] Revenues per ton-mile were estimated from historical data, assuming that regular train rates are double unit train rates, on the average.[8] The railroad coal-transpor-

[6] One potentially offsetting factor would be the construction of a significant number of coal conversion facilities near the mine mouth. It is anticipated that coal conversion facilities will encounter some of the same objections as mine mouth generation. In this study, the assumption was made that three 250 million standard cubic feet per day synthetic natural gas plants will be brought onstream in the West by 1985. By 2000, six more will be added in the West and two each in the East and South.

[7] Review of coal origin and usage regions in the South indicates that present hauls tend to be short, averaging 200 miles. However, national goals for future coal distribution would extend usage into the more Southern States. On this basis, it was estimated that by 1985 the average southern haul will have increased to 300 miles.

[8] *National Power Survey Report* as referenced in *Factors Affecting Coal Substitution for Other Fuels in Electric Power Production and Industrial Uses*, Congressional Research Service report to the Senate Committee on Interior and Insular Affairs, 1975.

tation revenue projections given in table A-2 were then obtained for each region by multiplying the coal production in that region by the railroad share of originating tonnages, the average haul distance, and by the revenues per ton-mile, weighted by regular and unit train participation. The results indicate that western railroads, although accounting for 76.5 percent of the ton-miles, will receive only 52.0 percent of the revenues in 2000. This is because unit trains are employed on a larger fraction of the western shipments than in other regions, and because the basic rail rate is lower in the West, averaging only 35 percent of that charged in the East. The regional difference in rates is primarily related to:

1. the short-haul distances in the East and South which means that turnaround times are a larger fraction of the total shipment period,
2. the greater market value of underground mined eastern and southern coal, and
3. logistical advantages for the less heavily traveled western rail system.

RAIL OPERATING EXPENDITURE FORECASTS

Three major operating cost categories were studied in depth: maintenance of way and structures, maintenance of equipment, and nonmaintenance operating expenditures. Twenty-five railroads were selected for cross-sectional statistical evaluation on the basis of operating size (more than 1,000 miles of track) and data availability. One thousand miles of track operation was the minimum size included because larger railroads are expected to account for most of the coal shipments, and these large railraods experience different operating economies than the smaller railroads. The inability of cross-sectional analysis to capture time trends was countered by running the regressions for a series of years, 1970-75. This permitted an evaluation of how the regression coefficients change over time.

Maintenance of Way and Structures

The variables tested to explain historical variation in maintenance of way and structures operating expenditures included: miles operated, ton-miles, average haul, freight car miles, tons per car, and commodity mix, the latter to see if cost patterns could be related to changes in relative importance of commodities hauled. The best explanatory variables, in terms of statistical meaning and reliability, were found to be combinations of ton-miles and miles of track operated. The regression equation selected was the logarithmic form:

$$\ln \text{MWS} = a + b \ln \left(\frac{\text{ton-miles}}{\text{miles of road}} \right) + c \ln (\text{miles of road}) \qquad (2)$$

where MWS is maintenance of way and structures, and miles of road refers to track miles operated. This equation assumes an interaction between intensity of use, as reflected in ton-miles per mile of road, and cost per mile of road. It suggests that economies of scale persist over broad ranges of ton-miles per mile of road operated, with the coefficient *b* acting as the elasticity of supply for ton-mile services. The coefficient c acts as the elasticity of supply for miles of road operated.

Mean values for the coefficients *b* and c over the period 1970-75 were 0.74 and 0.94 respectively. The resulting maintenance of way and structure costs is:

$$MWS_T = k \times MWS_{1971} \times \left[\frac{\left(\frac{\text{ton-miles T}}{\text{miles of road T}}\right)}{\left(\frac{\text{ton-miles 1971}}{\text{miles of road 1971}}\right)} \right]^{0.74} \times \left(\frac{\text{miles of road T}}{\text{miles of road 1971}} \right)^{0.94} \quad (3)$$

where *k* is a wage and productivity factor, MWS is maintenance of way and structures operating expenditures, and T is the year to be computed. Since *b* is less than 1, economies of scale are present, i.e., for every l-percent increase in traffic or ton-miles, costs will go up by **0,74 percent. The ton-mile forecasts** used to project maintenance of way and structures expenditures for the years *1980-2000* were obtained from the revenue forecasts given in table A-2 by use of regional commodity revenues per ton-mile coefficients.

Miles of road operated was assumed constant over the forecast period, hence the final term drops out of the equation. The results obtained using this form of the equation should be interpreted as reflecting the cost to the railroads of maintaining current levels of road operated. The *k* factor adjusts for changes in the productivity of labor and the real wage **rate.** An empirical expression was developed for k: $k = 0.5 + 0.5(1.0012)^{T-1971}$ The first parameter, 0.5, is the nonlabor share of maintenance of way and structures costs in 1971. The non labor share was assumed to vary directly with ton-miles and miles operated as indicated by the overall regression equation. The labor share, in contrast, is multiplied by $(1.0012)^{T-1971}$ to account for changes in real wages and productivity over time. The factor (1 .0012) was determined by dividing the rate of real wage changes for railroad employees with respect to the GNP deflator by the rate of productivity changes for maintenance of way and structures, as reflected in reductions in MWS labor-hours per unit railroad output, i.e., ton-miles.

Maintenance of Equipment

A number of relationships were tested to explain maintenance of equipment operating costs. The variables employed included: ton-miles, tons per freight car, and freight car miles. The most effective equation was found to be:

$$\ln ME = a + B \ln (\text{freight car miles})$$

where *ME* is maintenance of equipment costs. Regression analysis using this equation resulted in the following expression for projecting maintenance of equipment operating expenditures:

$$ME_T = k \times ME_{1971} \times \left(\frac{\text{freight car miles T}}{\text{freight car miles 1971}} \right)^{0.96} \quad \textbf{(4)}$$

where k is a wage and productivity factor, and T is the year for which data are to be computed. The scale factor 0.96 is the mean-regression coefficient over the 6-year period, 1970-75. It indicates that an 0.96-percent increase in cost will result from a l-percent increase in freight car miles relative to their 1971 level. The wage and productivity factor, k, is

$$k = 0.45 + 0.55(1.0061)^{T-1961}$$

where 0.45 is the non labor fraction of maintenance of equipment expenditures in *1971,* and the second term defines the variation of the labor share over time. Freight car miles were calculated from tons per car estimates for each region, and the revenue ton-mile projections employed in the maintenance of way and structures analysis. Ton-mile weighted averages for tons per freight car for the Nation and for each railroad region were calculated by aggregating estimates of tons per freight car for individual commodities. Projections for freight-car loadings by commodity in 1985 and 2000 were made on the basis of past trends and extensive interviews with railroads, their customers, and their suppliers as to maximum practicable weight, height, and length (to clear overpasses and negotiate curves) per car. The resulting tons per car projections for the Nation in 1985 and 2000 are presented, with comparative historical data, in table A-3. Loadings are projected to grow 23.1 percent from 1974 to 1985, and 10.7 percent more by 2000. The increase in coal traffic is an important factor in this growth, since this commodity makes the single largest contribution to the commodity-weighted averages.

A major change now underway that affects freight car and train capacities is the growth of intermodal service, i.e., mixing such transportation modes as truck and rail via use of flatcars and piggybacked trailers. This approach offers a number of advantages traditional boxcars cannot. For example, the time usage rate of many old freight boxcars is 10 percent, while that for a piggyback or flatcar is 80 percent. Also, pickup and delivery by the customer with a truck cab at the terminal is usually more cost effective and convenient than the traditional switching of individual rail cars onto customer's tracks. The full implications of this new-style intermodal railroad-truck service are not yet clear, but certainly it will tend to reduce the number of cars needed, and probably reduce the value of the cars to be bought.

Nonmaintenance Operating Expenditures

Nonmaintenance operating expenditures include traffic, transportation, miscellaneous,

Table A-3. Historical and Projected Freight Car Loadings by Commodity

(Tons per car)

SIC code	Commodity	Historical				Projected	
		1968	1970	1972	1974	1985	2000
01	Farm Products	51.2	56.5	62.0	66.9	85.0	93.0
11	Coal	72.4	76.4	80.2	83.3	90.0	95.0
14	Stone and minerals	73.1	74.1	75.1	77.6	90.0	93.0
20	Food	38.0	40.7	42.9	44.9	60.0	80.0
24	Lumber and wood	46.4	49.8	50.9	53.5	57.0	62.0
26	Pulp and paper	33.9	35.5	37.6	39.4	55.0	70.0
28	Chemicals and plastics	53.3	58.2	63.0	66.7	75.0	80.0
32	Cement and glass	56.4	57.7	60.0	60.3	85.0	90.0
33	Primary metals	54.5	55.3	62.7	63.6	77.0	85.0
37	Transportation equipment	22.2	22.8	23.3	23.6	28.0	32.0
•*	All commodities, total	51.8	54.9	56.3	58.4	71.9	79.6

Source: Projections made by IR&T. Historical data obtained from Moody's *Transportation Manual, 1977,* p. a18.

and general categories. The equation used to forecast nonmaintenance expenditures was:

$$NME_T = k \times NME_{1971} \left(\frac{\text{freight car miles T}}{\text{freight car miles 1971}} \right)^{0.87} \quad (5)$$

where *NME* is nonmaintenance expenditures, T is the year to be computed, and the wage and productivity factor, k, is:

$$k = 0.44 + 0,56\ (1.0068)^{T-1971}$$

The scale factor 0.87 is the mean-regression coefficient over the 6-year period, 1970-75.

Total Operating Expenditures

Projections for the three operating expenditure categories and their totals are presented for the period 1980-2000, by region, in table A-4. The productivity improvements, achieved primarily through increasing tons-per-car loadings, tend to outweigh the effects of increasing traffic volumes for maintenance of equipment and nonmaintenance expenditures. The effect of these reductions can be directly oberved in the East, but they are obscured in the South and West. The rate of productivity improvements slows after 1985, since most of the gains will have been achieved by that time.

Table A-4. Projections of Class I Railroad Operating Expenditures

(Millions of 1971 dollars)

	1980	1985	1990	1995	2000
EAST					
Maintenance of way and structures . . .	$ 601.45	$ 628.01	$ 651.10	$ 675.68	$ 710.10
Maintenance of equipment	679.18	595.07	609.55	624.37	638.91
Nonmaintenance expenditures.	1,947.93	1,754.90	1,820.93	1,891.09	1,961.52
Total	3,228.56	2,977.98	3,081.58	3,191.14	3,310.53
SOUTH					
Maintenance of way and structures . . .	427.23	511.44	597.98	703.58	837.63
Maintenance of equipment	452.33	486.10	585.15	704.37	847.00
Nonmaintenance expenditures.	1,022.44	1,107.91	1,330.76	1,599.85	1,920.89
Total	1,902.00	2,105.45	2,513.89	3,007.80	3,605.52
WEST					
Maintenance of way and structures . . .	1,054.85	1,347.59	1,553.55	1,780.35	2,065.55
Maintenance of equipment	1,139.43	1,184.93	1,383.09	1,614.36	1,882.37
Nonmaintenance expenditures.	2,745.86	2,888.62	3,373.66	3,943.60	4,604.00
Total	4,940.14	5,421.14	6,310.30	7,338.31	8,551.92
U.S.A.					
Maintenance of way and structures . . .	2,083.53	2,487.04	2,802.62	3,159.62	3,613.28
Maintenance of equipment	2,270.94	2,266.10	2,577.79	2,943.10	3,368.29
Nonmaintenance expenditures.	5,716.22	5,751.44	6,525.35	7,434.54	8,486.42
Total	10,070.69	10,504.58	11,905.76	13,537.26	15,467.99

Source: IR&T.

CAPITAL INVESTMENT REQUIREMENTS

Rolling Stock

Investment requirements over the **1975-2000** period were determined for three classes of rolling stock: coal hopper cars, noncoal freight cars, and locomotives. These investment requirements are the capital expenditures necessary to expand the equipment stock in response to increased business volume and to replace retired equipment. The growth in equipment requirements was determined from the revenue projections of table A-2. As described previously, the revenue projections were converted into freight car mileage projections by use of the estimates for revenues per ton-mile and tons per car, The freight car mileage projections were then converted into freight car requirements in each year by use of an estimate for car utilization rate, that is, miles per car per year. Locomotive requirements were then estimated as a function of total freight car requirements, Freight car and locomotive investment requirements were determined for the new vehicle requirements in each category, taking into account estimated vehicle retirement rates.

It was estimated from carloadings of coal relative to loading of mineral ores and of stone and gravel that in 1973, coal cars represented 62.2 percent of the total U.S. open-top hopper car fleet. On this basis, there were 207,682 coal hopper cars in 1973, Since there were 1,460 mill ion coal-related freight car miles in that year, the average utilization rate was 7,030 miles. Regression analysis of historical utilization-rate data over the period 1962-769 revealed that a 1.13 percent compound annual growth in utilization rate had been achieved. **It was** assumed that the historical trend in car utilization rates will continue over the period of this study, except in the case of long-haul unit train shipments. For the latter shipments, the analysis described in chapter IV indicated that 50,000 loaded miles per year per car can be reasonably expected. Since long-haul unit trains are anticipated to account for 50.6 percent of coal shipments in 2000, improved utilization of such cars has a significant effect upon coal-related car requirements. For example, in 2000 the nonlong-haul coal car utilization rate was projected to be 9,521 miles per year per car, and coal shipments to amount to 620.9 billion ton-miles. At an estimated 95 tons per car, these shipments correspond to 6,535 million freight car miles, 50.6 percent of which are via long-haul unit trains. Using the car utilization rates established for each type of shipment, a total coal hopper car requirement of 405,000 in 2000 was determined. This result is 41 percent less than the number of cars that would have been required to ship the same amount of coal without the utilization rate gains achieved in the long-haul shipments.

Annual retirements of coal hopper cars were calculated assuming a 15-year average lifetime. This is a shorter lifetime than for noncoal cars because of the higher utilization rate in unit train service. Coal car investment requirements were determined as that necessary to accommodate growth in total requirements and replacement of retired cars, at an average cost of $13,000 per car (1971 dollars). The estimated coal car requirements for the period 1975-2000 are presented in table A-5.

Noncoal car requirements were calculated in a similar manner to that employed for coal cars. Mean noncoal car utilization over the 1973-75 time period was 10,877 miles, and the historical 1.13 percent annual growth rate was assumed to hold over future years for all cars. Retirement of noncoal cars was estimated with the help of the following age distribution and retirement rate data, based on a 22-year average car life: [10]

NONCOAL FREIGHT CAR AGE CHARACTERISTICS

Age (years)	Car age distribution (in 1975)	Retirement rate (per year)
0-10	40%	2.5%
11-20	30%	15 %
21 +	.30%	70 0%

[9] Association of American Railroads, Yearbook 01 *Railroad Facts*, 1977

[10] "Long Term Freight Car Forecasts, American Freight Car Institute, 1975

The new car requirements were then determined, with the corresponding investment costed at $16,000 per car. The results for non-coal freight car requirements are presented in table A-5 The requirements decline between 1975 and 1985 as a result of the fairly rapid increase assumed for tons per freight car loadings Beyond 1985, the effect of increasing traffic volume predominates. The number of locomotives required in each year was estimated to be 1.8 percent of the total freight car requirements This is a higher ratio of locomotives to freight cars than prevailed in the past because of the increasing car loadings. On the basis of historical trends, an annual increase in locomotive hauling capacity, approximately 1,65 percent, was taken into account in estimating the overall dependence of locomotives upon freight car requirements. Locomotive retirements were assumed to follow the noncoal car schedule. The resulting locomotive capital investment requirements, based upon $246,000 per car [1971 dollars), is given in table A-5.

Table A-5. Rolling Stock Investment Requirements, 1975-2000

Category	Year	Required stock (# cars)	Annual retirements (# cars)	Annual new car requirements (# cars)	5-year investments requirements (thousands of 1971 dollars)
Coal hopper cars.	1975	226,000			
			15,000	19,400	$ 252,200
	1980	248,000			
			15,000	20,000	260,000
	1985	273,000			
			15,000	22,800	296,400
	1990	312,000			
			19,400	28,000	364,000
	1995	355,000			
			20,000	30,000	390,000
	2000	405,000			
Non coal freight cars.	1975	1,301,000			
			68,800	40,600	649,600
	1980	1,160,000			
			54,400	29,400	470,400
	1985	1,035,000			
			45,200	60,400	966,400
	1990	1,111,000			
			48,800	61,400	982,400
	1995	1,194,000			
			45,600	63,200	1,011,200
	2000	1,282,000			
Locomotives	1975	27,523			
			1,459	1,023	215,658
	1980	25,344			
			1,157	797	196,062
	1985	23,544			
			1,091	1,556	382,776
	1990	25,866			
			1,070	1,595	392,370
	1995	28,494			
			1,070	1,686	414,756
	2000	31,572			

Source: IR&T.

Way and Structures

Way and structures investment projections were made by evaluating the requirements associated with three shipment categories: long-haul coal movements considered within four case studies, other long-haul coal movements, and all other commodity movements.

Four in-depth case studies were conducted for unit train movement of western and southern coal to five States: California, Texas, Minnesota, Wisconsin, and Florida. These case studies are described in chapter IV. The cumulative investment requirements for the case study coal movements for intervals between 1975 and 2000 are presented in table A-6. The set of "other specific long-haul" coal shipments are those described in chapter IV amounting to more than 5 million tons per year over distances greater than 500 miles. The investment requirements for these other specific long-haul shipments were estimated by applying a ton-mile adjustment to the investment requirement identified in the case studies. The other specific long haul and the total specific long-haul coal investment requirements are shown in table A-6.

A review of historical trends in "all other" way and structures investment indicated that these have remained relatively constant at approximately $431 million per year (1971 dollars). Other studies such as Clopper **Almon's 1985** *Interindustry Forecasts of the American Economy* have produced regression equations that suggest way and structures investments are more strongly influenced by real interest rates than traffic volumes.[11] Since real interest rates are not varied within this study, the "all other" way and structures investment was held constant at its recent historical value.

On the foregoing basis, the following results are obtained for total Class I railroad way and structures investment over the 1975-2000 period:

ANNUAL WAY AND STRUCTURES INVESTMENT REQUIREMENTS

(Millions of 1971 dollars)

Shipment categories	1975-1985	1985-1990	1990-1995	1995-2000
Specific long-haul coal*	70	39	22	25
Other commodities	**431**	**431**	**431**	**431**
Total	**501**	**470**	**453**	**456**

*** See table V-6**

[11] Almon's equation, p 92, for railroad Investment is

$$I = 331.7 + 0.00068Q - 23.18R$$
$$T = (2.4)\ (0.06)\ (5.1)$$
$$R^2 = 0.51,\ A\ W = 0.85$$

where *I* is Investment, Q is rail traffic, *R* is the real rate of interest, and the numbers in parentheses are the *T* scores This equation Indicates that Q has very little impact on *I*, while *I*? impact is significant

Table A-6. Cumulative Way and Structures/Investment Requirements for Specific Long-Haul Coal Shipments

(Millions of 1971 dollars)

	1975-1985	1975-1990	1975-1995	1975-2000
California	**$ 44**	**$ 64**	**$117**	**$144**
Florida	**95**	**116**	**116**	**166**
Minnesota	**5**	**5**	**5**	**5**
Texas	**108**	**260**	**316**	**361**
Wisconsin	**7**	**7**	**7**	**7**
Subtotal[a]	**259**	**452**	**561**	**683**
Other specific long-haul coal shipments	**435**	**435**	**435**	**435**
Total	**$694**	**$887**	**$996**	**$1,118**

[a]These shipments pertain to the case studies described in chapter IV.

[b]Other specific long-haul coal shipments are those identified in chapter IV amounting to more than 5 million tons per Year over distances greater than 500 miles. They represent a portion of all utility steam coal, and they tend to come onstream by 1985 and not increase much beyond that time.

Source: IR&T.

Leasing

For tax and accounting purposes, there are obvious differences between direct investment, e.g., purchases of cars and locomotives, compared with l ease/rental arrangements. Direct investment purchases are financed through either debt or equity. Debt service charges, i.e., interest and amortization, come out of net railway operating income. Equity-based purchases, on the other hand, are financed out of retained earnings or stock issues on which dividends are paid, with both retained earnings and dividends coming out of after-tax net income. If equipment and track are leased or rented, the expenditures come from net railway operating revenue. The actual choice between direct purchase versus rental/leasing is complicated by tax, risk, return on investment, and capital market considerations. Since the investment and capital issues addressed in this study mainly concern the need and ability to generate sufficient funds to maintain and expand rolling stock and way and structures, it was assumed that the annual cost to the railroads of providing appropriate capital stock via leasing is roughly equivalent to the cost of direct purchase.

The capital requirements determinations have not included investments in loading and unloading facilities. These are usually shipper- and receiver-owned. Shipper-leased equipment is also excluded. These both represent a transportation-related cost to society in that they absorb real resources, even if not directly paid for by the railroads Financing ownership of unloading facilities may be easier for public utilities than **for railroads.** The former often have more favorable access to capital markets, and are guaranteed a specific rate of return on investments by public utility commissions. Likewise, major shippers that provide their own loading facilities may be able to obtain capital at a more attractive rate than the railroads. The growth in ownership or leasing of rolling stock by the shippers, and in the case of utilities by the receivers, has reduced capital requirements for the railroads. This has also lowered the rate railroads can charge per ton-mile. The advantages to the lessees of such arrangements are greater certainty in availability of equipment. Full-service leases relieve the lessees of the logistics of maintenance.

EMPLOYMENT AND COMPENSATION

Labor compensation was estimated during specification of the operating expenditure projections, as discussed previously. The k factor for each expenditure category allocated the costs between labor and nonlabor shares. The resulting labor compensation projections for 1980-2000 (in 1971 dollars) are given by region in table A-7. Compensation in the East declines between 1980 and 1985 because of the equipment productivity gains projected, but after that, traffic-volume increases lead to higher levels of compensation. Compensation in the South and West increases throughout the period.

The compensation projections were employed to estimate employment requirements. Compensation was divided by the average wage rate in each year to determine total employee hours, the total hours were divided by the average annual hours per employee to determine the number of employees. The average wage rate in future years was estimated by the expression: $4.52(1\ .0304)^{T-1971}$, where ***4.52*** was the 1971 average railroad employee compensation in dollars per hour, and real wages were assumed to increase annually by 3.04 percent. The average annual hours per employee in recent years has been 2,440 hours, which includes the effect of overtime. Using these two factors and the compensation estimates of table A-7, regional estimates for Class I railroad employment were obtained for the period 1980-2000. These employment estimates are presented in table A-8.

A decline in employment is observed

Table A-7. Class I Railroad Labor Compensation Projections, 1980-2000

(Millions of 1971 dollars)

	1980	1985	1990	1995	2000
EAST					
Maintenance of way and structures . . .	$ 303.99	$ 319.32	$ 333.05	$ 347.71	$ 367.62
Maintenance of equipment	378.96	334.70	345.59	356.84	368.08
Nonmaintenance expenditures.	1,159.45	1,080.55	1,159.85	1,246.05	1,337.01
Total	1,842.40	1,734.57	1,838.49	1,950.60	2,072.71
SOUTH					
Maintenance of way and structures . . .	215.93	260.05	305.88	362.06	433.64
Maintenance of equipment	252.93	273.41	331.76	402.56	487.96
Nonmaintenance expenditures.	608.58	682.18	847.63	1,054.15	1,309.31
Total	1,076.90	1,215.64	1,485.27	1,818.77	2,230.91
WEST					
Maintenance of way and structures . . .	533.15	685.20	794.68	916,17	1,069.33
Maintenance of equipment	635.77	666.46	784.11	922.63	1,084.43
Nonmaintenance expenditures.	1,634.39	1,778.62	2,148.87	2,598.47	3,138.17
Total	2,803.31	3,130.28	3,727.66	4,437.27	5,291.93
NATION					
Maintenance of way and structures . . .	1,053.07	1,264.57	1,433.61	1,625.94	1,870.58
Maintenance of equipment	1,267.12	1,274.57	1,461.51	1,682.02	1,940.47
Nonmaintenance expenditures.	3,402.40	3,541.36	4,156.36	4,898.68	5,784.50
Total	$5,722.59	$6,080.50	$7,051.48	$8,206.64	$9,595.55

Source: IR&T.

Table A-8. Class I Railroad Employment Projections, 1980-2000

(Thousands of people)

	1980	1985	1990	1995	2000
EAST					
Maintenance of way and structures . . .	21.05	19.04	17.09	15.36	13.99
Maintenance of equipment	26.24	19.95	17.74	15.77	14.00
Nonmaintenance expenditures.	80.29	64.42	59.53	55.07	50.87
Total	127.58	103.41	94.36	86.20	78.86
SOUTH					
Maintenance of way and structures . . .	14.95	15.50	15.70	16.00	16.50
Maintenance of equipment	17.48	16.30	17.03	17.79	18.57
Nonmaintenance expenditures	42.14	40.67	43.51	46.58	49.81
Total	74.57	72.47	76.24	80.37	84.88
WEST					
Maintenance of way and structures . . .	36.92	40.85	40.79	40.48	40.68
Maintenance of equipment	44.03	39.73	40.25	40.77	41.26
Nonmaintenance expenditures	113.18	106.04	110.30	114.83	119.39
Total	194.13	186.62	191.34	196.08	201.33
NATION					
Maintenance of wayand structures . . .	72.93	75.39	73.59	71.85	71.17
Maintenance of equipment	87.75	75.99	75.02	74.33	73.83
Nonmaintenance expenditures.	235.61	211.14	213.34	216.48	220.07
Total	396.29	362.52	361.95	362.66	365.07

Source: IR&T.

throughout the forecast years in the East, and between 1980-90 in the South and West. This phenomenon is directly traceable to the car-loading assumptions used to derive the freight car miles. Car productivity was projected to grow quite rapidly through *1985,* then to slacken off between 1985 and 2000 as physical limits to car and track capacities are encountered. Thereafter, even though labor productivity assumptions are positive, i.e., assumed to grow at 2.91 percent compounded annually for maintenance of way and structures, at 2.88 percent for maintenance of equipment, and at 2.34 percent for non-maintenance expenditures, an overall increase in railroad employment is projected in each region.

TAX FORECASTS

Projections were made for payroll, State, local, and Federal taxes. The payroll tax projections *were* obtained from the labor compensation projections, assuming an increase in effective tax rate from 15 percent in 1976 to 17 perc ent in 1980 and 0.30 percent in 2000. The resu lts are given in the following table:

PAYROLL TAX PROJECTIONS
(Millions of 1971 dollars]

	1980	*1985*	*1990*	1995	2000
East	31321-	381. 61	44124	52666	62181
South	183.07	267.44	356.46	491.07	66927
West	476. 56	68866	89464	1,19806	1,58758
USA	97284	1,33771	1,692.36	2,'215	791,87866

The Railroad Revitalization and Regulatory Reform Act of 1976 specifically prohibits the continuation of discriminatory tax practices against the railroads, which have often been taxed more heavily than other taxpayers in equivalent legal circumstances. Balanced against this presumed downward pressure on State and local taxes, especially property, franchise, and public utility taxes, is the weight of history during which taxes have been growing as a percent of assets, income, and revenues. State and local taxes are, on balance, not expected to change very much from their present relationships with operating income. Regressions testing several potential explanatory variables for State and local taxes on Class I railroads resulted in the hypothesis that only about 40 percent of these taxes were operating revenue-dependent For lack of better information, State and local income taxes were projected to be about 1 percent of net operating revenue (the difference between operating revenue and operating cost) while other State and local taxes were projected to remain constant in real terms over time. The composite result is shown in the following table for State and local taxes, by region, over the 1980-2000 time period,

RECIONAI STATE AND LOCAL
RAILROAD TAX PROJECTIONS
(Millions of 1971 **dollars)**

	1980	*1985*	1990	1995	2000
East	12318	126.50	12880	131.51	135.02
South	5740	67.16	75.17	87.93	10345
West	191 52	20818	225.44	145.94	272.83
USA	372.10	401.84	429.41	405.38	511.30

The marginal effective Federal tax rate actually applied to railroads seems to be approximately 25 percent, and the 1969-72 average effective rate was considerably lower, ranging between 13 and 20 percent. Federal taxes were calculated on the basis of a tax rate of approximately 20 percent for the scenarios employed in the present study.