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Lead Time for Assessing Land Use: A Case Study

Precritical conditions are examined in Running Creek (Box Elder) watershed on the Front Range of Colorado.

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In 1975 an estimated 14 million hectares of agricultural lands were lost to urbanization at a time of growing global food scarcities (*1*, *2*). Such trade-offs in land use are not yet well understood, and the next 25 years will provide a valuable lead time to balance available supplies against demand on the basis of interactions between environment, energy, and population.

In this article I describe a study of precritical conditions in a small area of the western United States as an example of the kind of information gathering that is possible while such a lead time exists. The area is the Running Creek (Box Elder) watershed, on the Front Range piedmont of the Interior Rocky Mountain West. As defined here, the Interior Rocky Mountain West includes eight states: Colorado, Montana, New Mexico, Utah, Wyoming, Arizona, Idaho, and Nevada (*3*). In the study an overlay method has been used to show the physical characteristics of the area and the patterns of land use developing there. No attempt has been made to project far into the future and predict what the character of the Running Creek (Box Elder) watershed will be in 25 years, and in this sense the study reaches no conclusion. Instead, it provides the kind of information needed for assessing land-use tradeoffs.

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The Interior West

With its image of trout streams, ski slopes, hunting grounds, and gold, the Interior West enjoys an enthusiastic constituency at the national and even the international level. Yet the region suffers from special problems created by an influx of population, limited water supplies, and a unique distribution pattern of settlements where sparse populations are separated by long distances. Although the land area of the Interior West comprises approximately 24 percent of the total U.S. land area, the 8.5 million people who live there represent less than 4 percent of the total U.S. population. The region is one of the fastest growing areas in the United States; its population increased by 20.8 percent between 1960 and 1970, an increase well above the 13.3 percent national average. Almost 45 percent of the population of the area results from in-migration. Urban dwellers in the Interior West constitute 73.1 percent of the population, a figure comparable to the 73.3 percent national average. Conversely, the national average shows 22.2 persons per square kilometer, while in the Interior West there are only 3.8 persons per square kilometer. Such an oasis-type urbanized population, enjoying the freedom of open space, will continue to be subjected to growth impacts for years to come.

Two million people, more than 25 percent of the population of the Interior West, live on the Front Range piedmont, which extends from north of Cheyenne, Wyoming, south through Colorado to Las Vegas, New Mexico. Historically, in the westward migration to the Pacific Coast many people stopped midway across the continent, along the eastern Front Range slope of the Rocky Mountains, and settlement spread northward and southward. The area of settlement is a long corridor connected by the Pan American Highway. Within this corridor there are pockets of agricultural lands, three major military installations (*4*), and a few scattered recreation areas.

The climate on the Front Range is semiarid. The annual precipitation from year to year ranges from 23 to 48 centimeters. In addition, the region is subject to droughts of varying intensity and agricultural production is restricted to grazing, irrigated cropping, and dryland farming. Such marginal agricultural lands affect the social and economic stability of the region. Two eastward-flowing rivers, the Platte and the Arkansas, are tapped for as much surface water as possible under interstate compact; large amounts of water are siphoned through four diversions from the western slope of the Rocky Mountains to the cities on the Front Range (*5*).

The urban nuclei of the Front Range are supported by a diverse economic base. National corporate headquarters for light and heavy industry, scientific laboratories, government agencies and military bases, small businesses, packing houses, commercial enterprises, and agricultural operations provide the economic backbone for a diverse population. Educational institutions on the Front Range number 15 senior colleges. At the center of this activity is the city of Denver.

Running Creek (Box Elder) Watershed

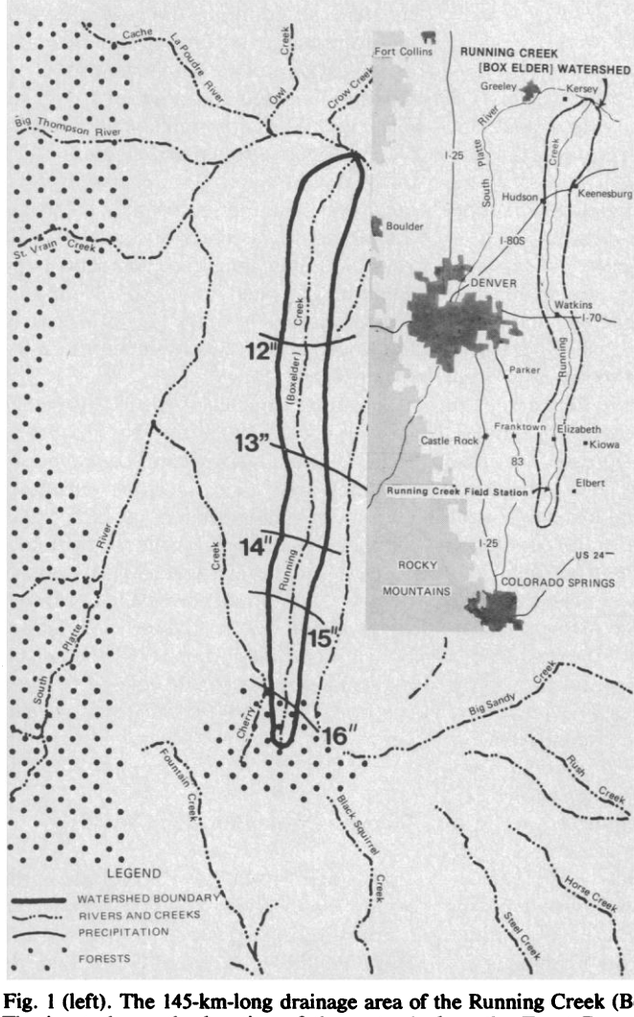
On the Front Range of Colorado in the South Platte River basin a number of northward-flowing creeks run along the High Plains. One such creek and its drainage area, Running Creek (Box Elder) watershed, has been observed since April 1972 by a group of graduate stu-

dents and professional investigators working at Running Creek Field Station (*6*). The watershed drains approximately 1150 km² of land from the Monument Divide 145 km north to the South Platte River. The principal focus for common concern along this environmental unit is found in the shared history of floods. Although the entire watershed is a primary agricultural production area and shares similar impact problems, a variety of political jurisdictions regulate its interests.

In Figs. 1 to 5 an overlay method has been used to show the physical characteristics and resources, cities and towns, land-use patterns, and new developments in Running Creek watershed. The overlay method of recording data can be used as a tool for exploring overlapping uses in land planning, or it can be used as it is here to graphically note change so that significant interrelationships between a variety of components can be studied. An inventory of the physical resources of the watershed in Fig. 1 shows general surface-water flow, precipitation levels, and forested mountainous areas. Native vegetation on the watershed includes both mixed grass and short grass prairies interrupted intermittently with islands of montane and foothill flora and fauna. Elevations range from 2250 meters at the headwaters to 1400 meters at the confluence of Running Creek and the South Platte River. The more arid regions of the watershed are found to the north where alluvial soils make the land more suitable for irrigated cultivation.

Figure 2 shows the locations of mineral deposits (coal, oil, gas, sand, and gravel) that underlie the watershed. The coal deposits are of low lignite quality and, where shown in Fig. 2, are estimated to be more than 0.6 m thick with less than a 45-m overburden. These deposits have been classified as strippable by the Federal Bureau of Mines (*7*). An estimated 13 billion tons of coal under ~ 370,000 hectares are found in the Denver Basin (*8*). The low economic potential of the coal may not be a deterrent to strip mining in this region. The presence of kaolinite above coal deposits is an added attraction to the mining of economically marginal lignite coal. It has been said that the estimated 400 million tons of kaolinite in this area (*7*, p. 41) could compete with the supply of bauxite imported from the Caribbean (*9*). Bauxite and kaolinite are the mineral base for aluminum and certain ceramics. Sand and gravel deposits are spotted throughout the watershed. Further refinement of the data shown in Fig. 2 would include historical data on mineral development in the area as well as recorded information on insolation, cloud cover, and wind patterns to determine an alternative energy potential.

The locations of cities, towns, and county and school district boundaries in the watershed are added in Fig. 3. Studies of prehistoric settlement indicate north-south routes of 9000-year-old Folsom man in the area. Old pioneer trails, however, begin to cross the watershed on an east-west line. Historically, the



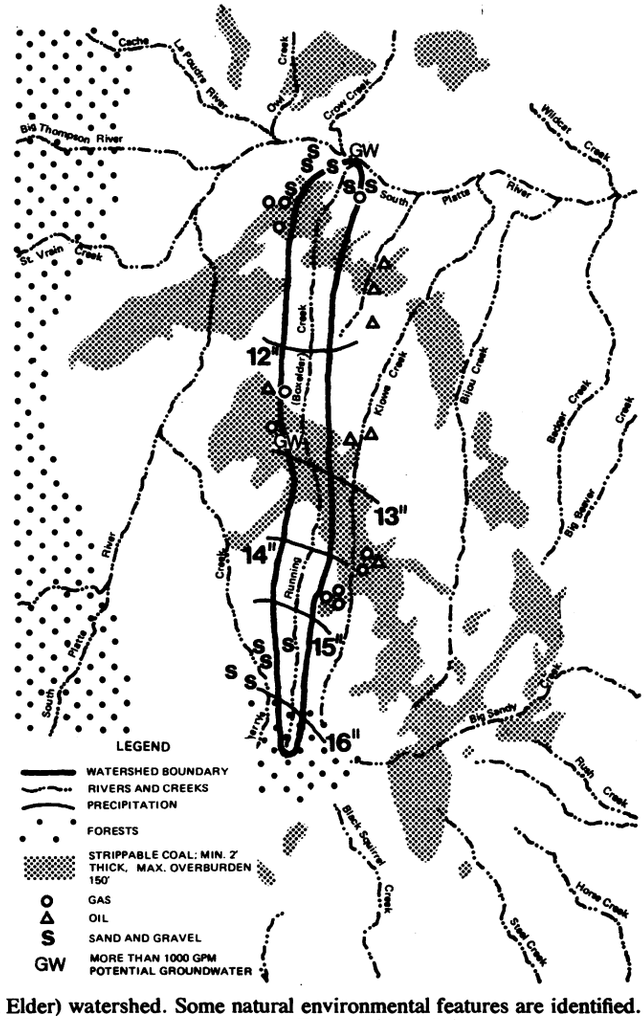


Fig. 1 (left). The 145-km-long drainage area of the Running Creek (Box Elder) watershed. Some natural environmental features are identified. The inset shows the location of the watershed on the Front Range of Colorado east of Denver. Fig. 2 (right). Mineral resources and groundwater in the watershed are added to some natural environmental features.

three towns on the watershed, Elizabeth, Watkins, and Kuner, were on railroad lines—the Denver and New Orleans, Kansas Pacific, and Union Pacific railroads. Today railroads pass through Kuner and Watkins; the railroad through Elizabeth was discontinued after the flood of 1935. Only Watkins and Kuner are located on major roads leading out of the larger metropolitan areas to the eastern plains. In 1971 the population in the entire 145-km-long watershed area was less than 4000. Each of the three towns (and nearby Kersey) had less than 500 people. By 1974 the population in the town of Watkins had increased from 100 to 466, in Elizabeth from 493 to 690, and in Kersey from 474 to 800. Patterns of settlement in this area emphasize reliance on relatively direct income; growth is a reflection of nearby metropolitan growth. Studies of the multilayered local, county, regional, state, and federal jurisdictions show a proliferation of special institutional arrangements.

In Fig. 4, where land-use patterns are added, the overlay shows that rangelands are predominant on the watershed, irrigated croplands occur in the northern area, and dryland farming is spotty. A review of current Soil Conservation Service aerial photographs confirms a 1962 report (*10*) that showed 25 percent of the watershed in croplands, 1 percent in roads and farmsteads, and 74 percent in grasslands. Weld County is second in the nation in crop and livestock production. Additional refinement to the overlay information might include land ownership patterns, income and source of income records, and visual amenities to show the nature of land turnover and economic structure. The relationships in these instances might provide indicators of the quality of life. Airshed maps coupled with vegetation studies and crop yields would begin to show the effects of atmospheric conditions on the watershed. Habitat and animal migration studies would reveal a still more comprehensive use of the area. The mapping of groundwater tapped by wells (shown in Fig. 4) begins to identify aquifers. A study of the geology shows a large amount of water under the Arkose formation. Maps showing septic tank limits (not shown in Fig. 4) would indicate the porosity of the soil.

Figures 1 to 4 have shown a preliminary inventory of the physical environment, with added historical and social factors. In Fig. 5, new urban-type developments are indicated. In early 1972 subdivisions began to creep along the old railroad lines toward Elizabeth. School districts were aligned with the growth as new settlement appeared to seek out areas where modern schools existed. Demographic studies showed a young population on the move out to subdivisions. In 1972 land prices began to increase sharply. Sales of land and changes in market prices began to show a "higher" value for agricultural lands, and lands within 40 km of the metropolitan areas began to be eliminated as grazing or croplands (*11*). By 1973, near the town of Watkins, the type of leapfrog and fill-in development characteristic of the larger metropolitan cities on the Front Range was in the early stages. The larger portion of a 1780-ha tract in Watkins was purchased by an investment company for the sum of $3,215,000. The 18 water wells in the purchase were estimated to produce more than 95 million liters per day, enough to serve 125,000 people. A bond issue, passed in 1973, ensured that Denver would begin to use the old Lowry Bombing Range site on the watershed for a waste disposal system. The sewage was to be used as a nutrient for winter wheat and other crops.

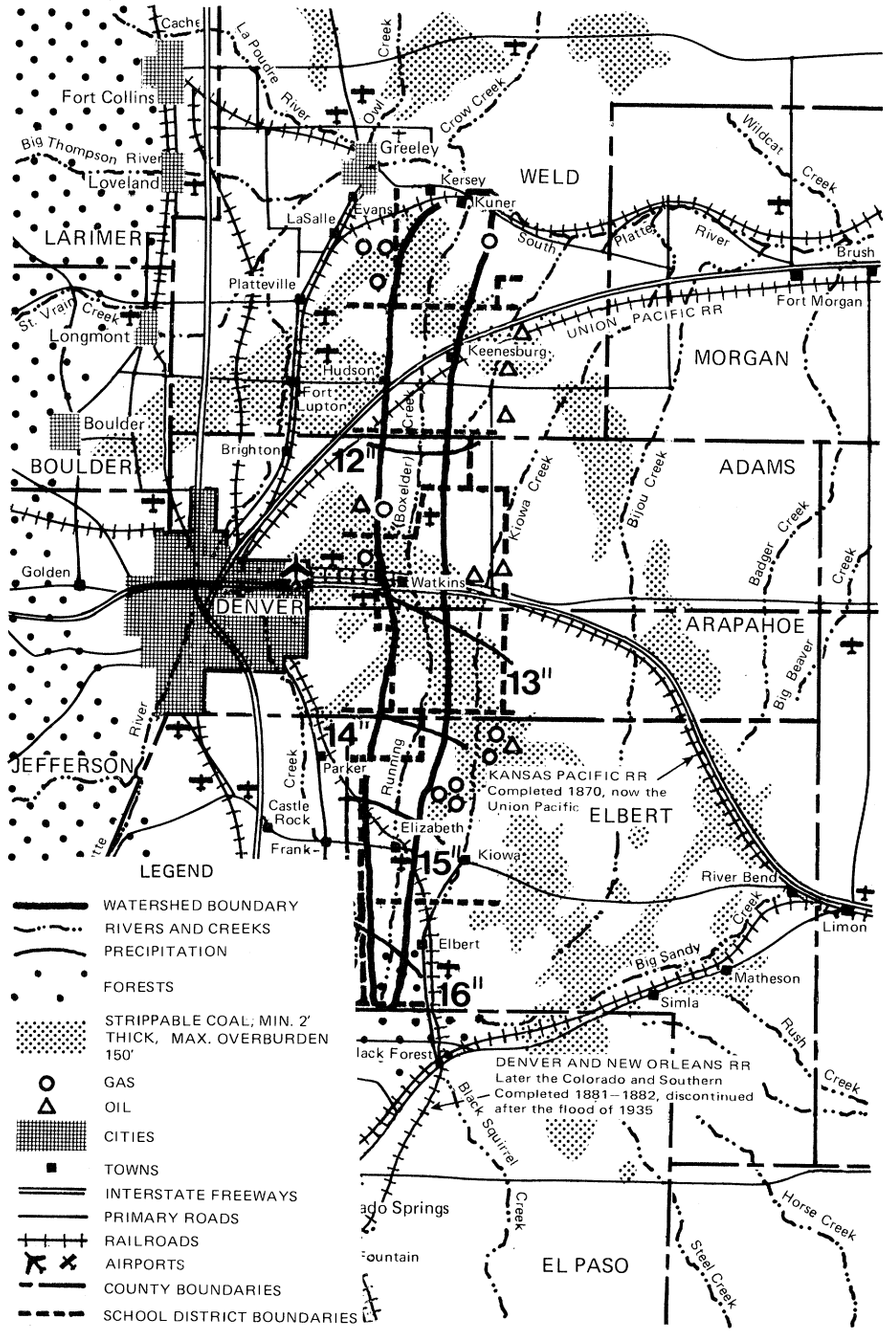


Fig. 3. Existing cities, towns, transportation routes, and various political boundaries are overlaid on some natural environmental features.

Development Proposals for the Watershed

In the face of the energy crisis in 1974, and the President's goal of mining 1.2 billion tons of coal by 1985, parts of the Running Creek (Box Elder) watershed area gained new significance in the national economy. The issue of coal, and particularly strip mining, is probably the most serious one the Interior West must confront. Most coal lands are in private ownership in the West (*12*). In Running Creek (Box Elder) watershed, preference-right leases were filed by Consolidated Coal and Mintech on 26 March 1974 for ~21,000 ha of land near Watkins and Kiowa.

In August 1975, a listing of energy projects in Federal Region VIII (*13*) included 86 mine projects and 19 coal conversion projects in Colorado, with the following four projects on the Front Range in and adjacent to the watershed.

1) A coal gasification plant projected by Mintech Corporation for the Watkins area in the Denver Basin would produce 7000 m^3 of synthetic natural gas per day. The present status indicated that public meetings were being held by the company to explain the project. The completion date was set for 1980.

2) A Station Creek Project at Elbert, Colorado, southeast of Kiowa, involved plans to produce 1 million tons of coal per year. The seam thickness of the deposits ranged from 2.4 to 3.0 m. Exploratory drilling has been completed. The completion date was projected to be 1980.

3) A coal gasification plant in Adams County near the city of Watkins has been proposed by Kerr-McGee Corporation, Oklahoma City.

4) A surface-mine gasification project is projected for the production of 8 million tons of lignite coal per year in Adams County by Cameron Engineers. Its location would be in township 3 south, range 65 west; township 3 south, range 64 west; township 4 south, range 64 west. The seam thickness is 7.5 m. Engineering studies are under way.

In 1975, in a series of county meetings, officials and interested parties began to debate the development of a new town of 55,000 persons near Watkins. A government report on the impacts of energy development on communities in Colorado published in May 1975 (*14*) failed to mention a single community on the Front Range, although the chronology of development proposals in Running Creek (Box Elder) watershed indicated accelerated activity.

In 1975 a subdivision zoning request, H-C (34-75), was made to the Adams County Planning Commission to divide the 1780-ha tract purchased in 1973 near the town of Watkins into 16,691 units. Reactions to the request in March 1975 expressed concern over water use in the proposed project (*15*), pointing out that limited aquifer water was available (*16*) and that the development water would be taken from the agricultural sector and converted to municipal use (*17*). On 1 April 1975 the Tri-County District Health Department questioned water use and sewage treatment in the H-C (34-75) proposal and recommended that approval be withheld (*18*). At the Adams County Commissioners' hearing on 29 September 1975 the subdivision rezoning request was tabled until further information on the development was available; it was disclosed by J. Cavey, Jr., of the Box Elder Investment Company that 80 ha in the proposed development would provide a site for the Mintech Corporation coal gasification plant. In October 1975 the Adams County Planning Department noted that a general aviation airport was being considered near Watkins and that deadlines for proposals from consultants for a sludge reuse program and a coal development regulation program in Adams County would be 31 October.

The timetable for these developments has been less than 4 years. On the broader geologic time scale, it has taken 4000

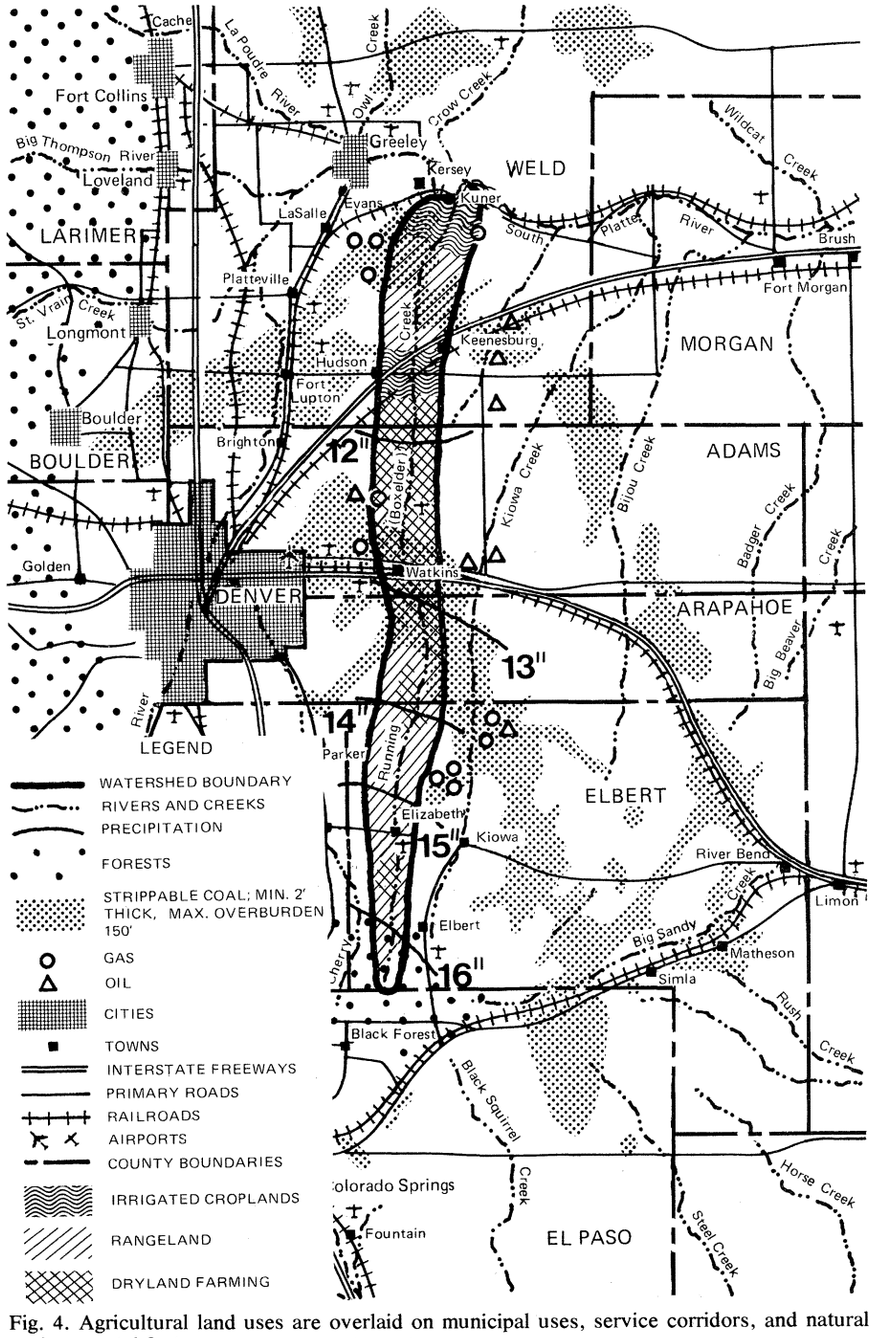


Fig. 4. Agricultural land uses are overlaid on municipal uses, service corridors, and natural environmental features.

years to develop soil, 1 million years to complete the earth's surface geology, 63 to 135 million years to develop coal since the Cretaceous period, and 4½ billion years, the age of Earth, to develop deep-seated aquifers. In this setting 4 years is a very short lead time to assess land use and the exploitation of resources that have taken thousands to millions of years to develop.

Nonetheless, it is possible to note that this long, narrow watershed contains elements of virtually all the problems facing the Interior West, as well as many other regions in the nation: urban pressures on agricultural land, recoverable energy resources, proximity to a major metropolitan area, potential as a corridor for transportation and transmission, serious water constraints, increasing potential for environmental deterioration, unequal distribution of goods and services, jurisdictional conflicts for land-use planning, heavy dependence on weather, and marginally productive lands.

Development of the watershed will continue; the nature of development involves important decisions yet to be made. It may be well to note that the use of strip-mined coal only buys time until the transition to other sources of energy, such as solar, geothermal, and nuclear (fusion), can be made. It may also be important to note that the world is now facing shortages in all of the four basic agricultural resources—land, water, energy, and fertilizer. All of these factors will play an important role as the grasslands of Running Creek (Box Elder) watershed, across which generations have trekked since 1680 and where coal was once removed with a less sophisticated technology, are pressured for new uses during the next 2 years at three historic crossings. At Kuner, agricultural production will undoubtedly be intensified; at Elizabeth, as population increases, citizens will have to decide between becoming a bedroom community or an economically viable new city. At Watkins, the trade-offs will be more critical.

Future Prospects

Today, as the pressures mount on the watershed, it may be too late to influence mineral extraction and new town development that has already begun. It may not be too late to study the patterns of development to bring insight into the decision-making process. It may not be too late to place a high value on conservation principles that protect land in marginal areas, to place a high priority on design that deals with open space, to identify ecosystems that need protection, and to recognize new values in the marketplace that would enhance the quality of life in the region. In terms of future use of the watershed, extremes may yet be avoided. Both the approach of halting all land development and that of meeting all demands for exploitation of resources are unacceptable. Some middle ground is necessary.

Although in the next quarter-century new energy needs may be met by doubling U.S. coal production, efforts by cities such as Colorado Springs to harness solar energy may prove to be an important advance contribution. Redeveloping and reclaiming lands, denuded by mining operations, for grazing or intensified agriculture should definitely be planned. Efforts to reclaim land may need to take into account the consequences of soil compaction, loss of topsoil, excess dissolved salts in water, alkaline leaching, increased sediment loads, and possibly increased trace metal concentrations (*19*). The use of modular integrated utility systems might be considered for new towns and high-density enclaves. Patterns of new town settlement may contribute to building a strong regional atmosphere. In addition, it has been estimated that agricultural employment may increase nationally as much as

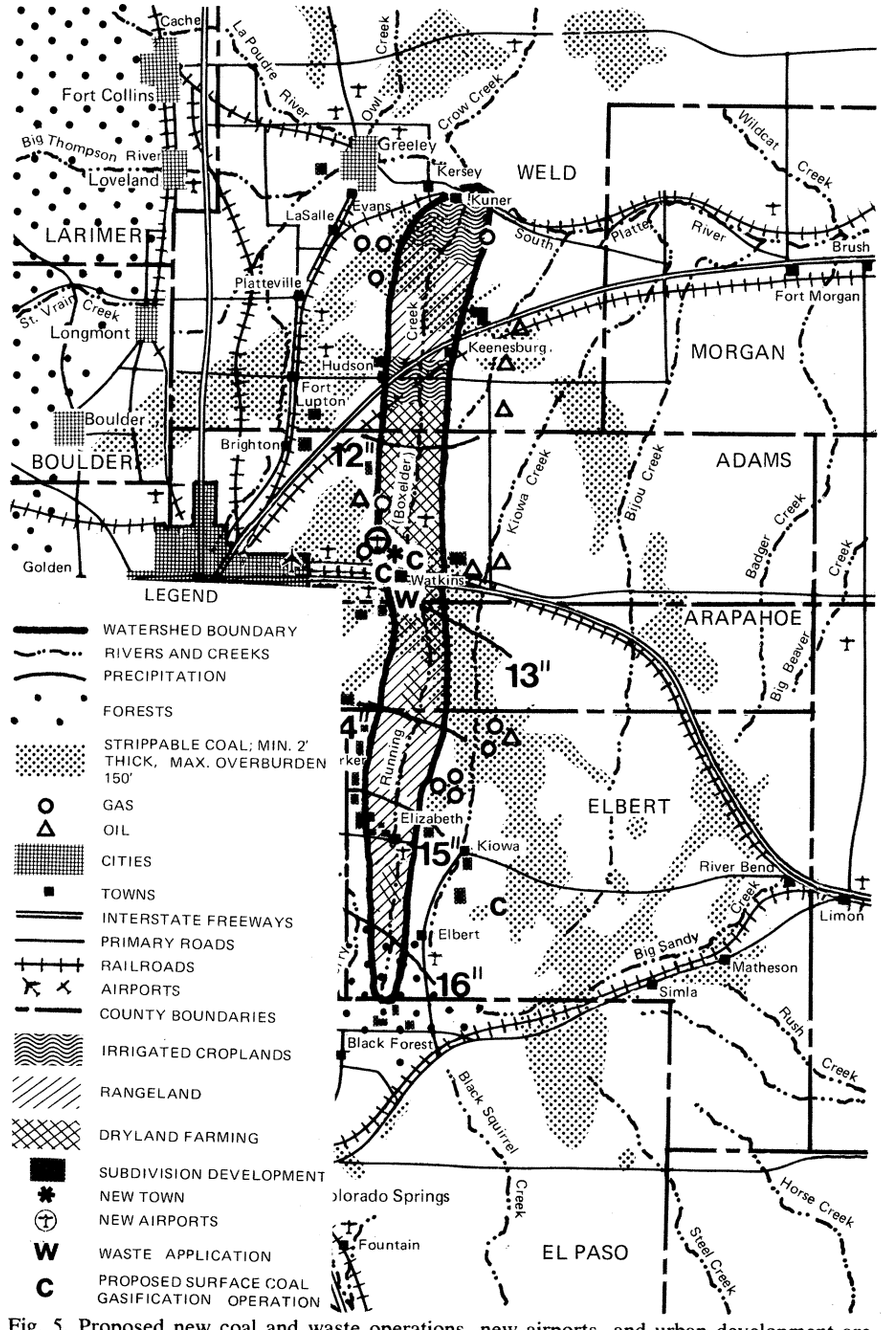


Fig. 5. Proposed new coal and waste operations, new airports, and urban development are overlaid on agricultural land uses, municipal uses, service corridors, and natural environmental features.

14 percent in the next 25 years. Such employment could reenergize existing rural towns on the Front Range.

Agriculture on the Front Range will be closely tied to the increase of national and international food demands in the next 25 years. In order to feed an expanded population in the United States by the year 2000 a twofold increase in crop production will be needed; a fourfold increase will be required at the world level (*2*). The dependence of increases in food production on petrochemicals, particularly nitrate fertilizers, as well as water supplies may preclude crop intensification at the level anticipated, particularly on the Front Range where competing demands for the limited water available can be expected. Accelerated pressures, however, on land that has agricultural potential will be worldwide. It is possible that controlled agriculture, intensive research on forage crops, waste recycling and utilization, water reuse, and better storage and handling of food and food reserves will contribute to increased food production in areas like the Front Range of Colorado, which are already productive as grazing lands. The balance of land-use options may be shifted to favor agriculture, croplands, and grazing on the Front Range of Colorado.

Open space, which ultimately gives definition and direction to urban expansion, will be needed, as will corridors to link isolated wildlife habitats created by inroads of civilization. Providing for the migration of animals may prove to be more important than providing bicycle paths for people.

In all of the possible future prospects the persistent demand for goods and services may hinder the development of alternative solutions. For decision-makers, the danger of having to meet crisis on crisis tends to encourage the modification of statistics to meet demands which satisfy only short-range or vested interests. Forced to define parameters too narrowly, society not only loses the opportunity for objective inquiry, it forces the rejection of major areas of concern. While no society, particularly one predicated on choice and preference, can expect to avoid crises, the study of cause and effect should be given as high priority as programs for responding quickly to urgent situations. Lead time to gain historical perspective, develop a comprehensive information base, study trade-offs, and order choices before hard-line decisions become necessary would help to reduce the high social costs and waste that are characteristic of actions responding to 11th-hour pressures.

While the problems of the Front Range are regional, they have national and even global implications. Land is the ultimate resource, and all land is, in a sense, in a precritical state. The options may be the most complex in human history as society is forced to balance human demands against the destruction of millenniums of nonrenewable resources.

References and Notes

1. In 1975 an estimated 14 million hectares was lost to urbanization and 20 million hectares to erosion, or a total of 34 million hectares (*2*).
2. E. W. Ingraham, *Query into the Quarter Century* (Wright-Ingraham Institute, Colorado Springs, Colo., 1975).
3. The Interior Rocky Mountain West is defined here as eight states: Colorado, Montana, New Mexico, Utah, Wyoming, Arizona, Idaho, and Nevada. The first five comprise the Federation of Rocky Mountain States. The Western Governors Regional Energy Policy Office involves ten states, including all of the above, except Idaho, and adding North Dakota, South Dakota, and Nebraska.
4. These are the U.S. Air Force Academy, Rocky Mountain Arsenal, and Fort Carson. Other military installations, such as Ent Air Base, NORAD (the North American Air Defense Command), and Lowry Field, do not have vast open land holdings.
5. The transmountain diversions are the Big Thompson Project, the Homestake Project, the Blue River Project, and the Arkansas Frying Pan Project. There are altogether 24 tunnels or ditches in these projects. Colorado River basin diversions to the Platte River basin were 420×10^6 m^3 from October 1973 to September 1974, and to the Arkansas River basin were 150×10^6 m^3 for the same period. [U.S. Geological Survey, *Water Resources Data for Colorado* (Denver Federal Center, Lakewood, Colo., 1974).]
6. Running Creek Field Station is the Wright-Ingraham Institute's 388-ha grasslands campus for graduate level study of natural and human-made systems. It is located in the Running Creek (Box Elder) watershed.
7. C. N. Speltz, *Strippable Coal Resources of Colorado* (Preliminary Report 195, Denver Federal Center, Lakewood, Colo., 1974).
8. In *Energy Development in the Rocky Mountain Region: Goals and Concerns* [(Federation of Rocky Mountain States, Inc., Denver, Colo., July 1975), p. 17], it is stated that "40 percent of the nation's coal deposits lies untouched beneath the surfaces of Colorado, Wyoming, Utah, Montana, New Mexico, and North Dakota."
9. F. Driscoll, *Rocky Mountain Journal*, 26 June 1975, p. 1.
10. Soil Conservation Service, *Preliminary Investigation Report: Running Creek* (U.S. Department of Agriculture, Beltsville, Md., December 1962), p. 4.
11. W. Hecox (paper presented at the Grasslands Seminar, Running Creek Field Station, Elbert County, Colo., 27 July 1974) stated that "Explosive population growth along the Front Range is acting as a signal via the marketplace for a 'higher' use of lands in close proximity, such as Running Creek (Box Elder) watershed."
12. S. Wynkoop, Denver *Post*, 15 May 1974, pp. 3 and 4.
13. *A Listing of Proposed, Planned, or Under Construction Energy Projects in Federal Region VIII* (Subcommittee to Expedite Energy Development of the United States, U.S. Bureau of Mines, and Committee on Socioeconomic Impacts of Natural Resource Development, Enviromental Protection Agency, Region VIII, Denver, August 1975).
14. R. W. Fitch, *Report of the Committee on Socioeconomic Impacts of Natural Resource Development, Mountain Plains Federal Regional Council, Region VIII* (Federal Energy Administration, Denver, Colo., May 1975), table 1.
15. H. Fukaye, chairman, West Adams Soil Conservation District, memo to the Adams County Planning Commission, 21 March 1975. Problems with flood damage were noted, and the project was not recommended.
16. J. A. Danielson, Colorado Division of Water Resources, letter to R. N. Fleming, Adams County Planning Commission, 28 March 1975.
17. G. Palos, M. W. Bittinger & Associates, letter to J. Eger, Central Colorado Water Conservancy District, 31 March 1975.
18. D. W. Berve, letter to the Adams County Planning Commission, 1 April 1975.
19. National Academy of Sciences, *Rehabilitations Potential of Western Coal Lands: A Report to the Energy Policy Project of the Ford Foundation* (Ballinger, Cambridge, Mass., 1974); G. Atwood, *Sci. Am.* **233** (No. 6), 28 (1975).

20. I thank my colleagues who have made this article possible. The interdisciplinary study and investigation teams on land-use research projects since 1972 have included the work and ideas of David Deppen, Timothy Tregarthen, George Innis, Walter Hecox, C. Allan Blomquist, George Van Dyne, Victor Hornbein, Brendan Doyle, Alan Merson, and William Lord. The following professors at Running Creek Field Station facilitated the inventory approach: F. Martin Brown, Jerrold Dodd, and Lynda Spickard. Graphics for this paper were done by Frank Miller and John Torborg.