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ABSTRACT

A land use unit using information from space programs is intended to help secondary teachers develop, plan, and implement land use programs in the social studies classroom. The subject of this unit is a flood control dam in Colorado. Interdisciplinary curriculum includes activities in mapmaking, environmental and mathematical studies, local community history, and physical geography. The project may be used in its present form or altered to fit a land use investigation in an existing curriculum. The publication is divided into three major parts. Part I describes the multidisciplinary unit concept, provides a curriculum outline, specifies objectives, suggests other land use studies, and outlines learning activities involving aerial photographs, drainage basins, flood threats to a community, water volume during a flood, location of flood control dams types of dams, and effects of dam construction. The second part gives advice on where to obtain and how to use data for surveys. Part III provides information on factors that influence land use and suggests class activities. Topics discussed include rural and urban land use, transportation, commerce, agriculture, forestry, recreation, and environmental protection. Maps, aerial photographs, and a bibliography are included in the document. (Author/DB)

what's the use of land?

A SECONDARY SCHOOL SOCIAL STUDIES PROJECT

National
Aeronautics and
Space
Administration

what's the use of land?

A SECONDARY SCHOOL SOCIAL STUDIES PROJECT

by
The Jefferson County, Colorado, Public Schools
with an Interdisciplinary Environmental Education Team
under the direction of Anthony J. Petrillo

National Aeronautics and Space Administration
Washington, D.C. 20546 October 1976

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CONTENTS

Foreword

It has been said that America's space program awakened mankind to the significance of the warning of conservationists and environmentalists that the Earth is indeed finite. It was Christmas Eve, 1968, that NASA's Apollo 8 rounded the Moon and took pictures of the Earth, pictures that thrilled TV viewers the world around. The sight inspired Archibald MacLeish to write in the December 26, 1968 New York Times:

> "For the first time in all of time, men have seen the Earth: seen it not as continents or oceans from the little distance of a hundred miles or two or three, but seen it from the depths of space; seen it whole and round and beautiful and small . . . a tiny raft in the enormous empty night."

The sight brought home to man for the first time the importance of his giving careful thought to making the best use of his resources on this "tiny raft."

It has also been said that America's space program provides man with the promise of solving the problems concerned with his wise husbanding of the Earth's resources.

The flights of NASA's weather satellites and its Geminis and Apollos showed man the possible uses of Earth observations from space. The flights of NASA's Skylab plus those of its LANDSAT 1 and 2 made clear that this potential could be realized. From the information gained by such observations, mankind might successfully plan its future use of Earth's resources in such pursuits as land-use planning, agriculture, water resources management, fishing, forestry, transportation, and mining.

This publication, *What's the Use of Land?*, is one of the first efforts in social studies teaching to show how NASA's space observations can integrate with other data sources in social studies, as well as in environmental education. It is a valuable, pioneering effort in curriculum literature of the social studies.

The idea for undertaking a social studies instructional unit in this little-understood but important area of mankind's progress grew out of a NASA-sponsored conference conducted by NASA's Educational Programs Division and the National Council for the Social Studies at the Marshall Space Flight Center in June 1974. Present were NASA scientists and educationists who discussed the social implications of science and technology with selected curriculum leaders of the social studies.

Among those present were Anthony J. Petrillo, Director of Secondary Education, Jefferson County, Colorado, Public Schools, and Francis I. Tallentire, a member of the Skylab Education Program team at neighboring Denver's Martin Marietta Aerospace, who was serving as a Conference consultant. After their discussions together and later with colleagues, a committee from the Jefferson County Schools assisted by Martin Marietta personnel developed and used this teaching unit.

For those social studies educators interested in environmental education, not only as an area of societal concern but also as a field for interdisciplinary instruction and school-community involvement, this how-it-can-be-done guide should provide useful ideas and helpful suggestions.

Appreciation is expressed to Dr. William C. Schneider, NASA's Deputy Associate Administrator for Space Flight, and Mr. Tom Hanes of his staff, who served as the Skylab Educational Program contact, whose interest and support made the Marshall Conference possible; to Dr. Frederick B. Tuttle, Director of NASA's Educational Programs, and Mr. Robert S. Tiemann, Educational Programs Officer, NASA, for coordinating this publication activity; and to Dr. Ted Paludan, of the Earth Resources Office at the Marshall Center, whose work with the Conference inspired this effort.

We appreciate the initiative and creativity of the Jefferson County Public Schools in conducting this project, particularly the contribution of Mr. Petrillo and his colleagues, Mr. William White, Social Studies Coordinator; Ms B. J. Meadows, Environmental Education Coordinator; Mr. Harold J. Pratt, Science Coordinator; Mr. Alan B. Swanson, Science Teacher, Columbine High School; Mr. Calvin G. Johnston, Social Studies Teacher, Bear Creek Senior High School; and Mr. William C. Von Vihl, Social Studies Teacher, Carmody Junior High School.

For evaluation of the publication, we thank Dr. Wendell F. McBurney, Director, Office of Sponsored Programs, Indiana University-Purdue University at Indianapolis; Dr. Lee Summerlin, Associate Professor, School of Natural Sciences, University of Alabama in Birmingham; Mr. Edward C. Stoever, Jr., School of Geology and Geophysics, University of Oklahoma; and Dr. James R. Wailes, Professor of Science Education, University of Colorado.

To the Army Corps of Engineers, particularly Major Peter J. Novembre and Mr. Larry S. Buss, appreciation is expressed for assisting the project with information on dams and the 1965 Colorado Flood.

To Martin Marietta Aerospace, Denver, appreciation is expressed for the involvement of its Skylab Education Program team in this worthwhile education project, particularly for the services of Mr. Francis I. Tallentire, who provided initial inspiration and continued assistance, and his associate Mr. Gayle A. Parker.

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Washington, D. C. 20546

December 1976

Preface

In 1973 the National Aeronautics and Space Administration published a series of books with the general title of "Skylab Experiments." The objective of these books was to show the educational community that scientific information derived in the NASA Skylab space station program would be available for use in the schools of the nation.

There are many ways in which information from space programs can be used in education. The most readily appreciated way is to use the results of an investigation to up-date science curricula.

The same results, or the information used by the investigator in reaching the results, also can be applied to educational needs. Information obtained from programs dedicated to observation of Earth from high altitudes is particularly applicable.

The three crews who manned NASA's Skylab spacecraft between May 1973 and February 1974 obtained thousands of photographs of Earth. Similarly NASA's two LANDSAT spacecraft have been photographing Earth since mid-1972.

This document, prepared as a part of the ongoing educational activity of the National Aeronautics and Space Administration, shows how these pictures of Earth can be combined with information from several other sources to aid in teaching several school curriculum topics. It also provides an example of the value of using information from many sources in the process of evaluating events and making decisions.

I. Introduction

The first ideas for this book developed at a meeting at the George C. Marshall Space Flight Center in Huntsville, Alabama. The National Aeronautics and Space Administration (NASA) invited several members of the National Council for the Social Studies to a meeting where the objective was to discuss ways and means for NASA to better serve the social studies branch of the teaching profession.

At this meeting, a NASA Earth resources scientist described a nationwide land use survey made by a large number of students in Great Britain using data from on-site studies in the field. That scientist also showed the results of a survey of the state of Tennessee made by two people in only a few days using remote observations from Earth orbital satellites. The thought that students could make similar surveys stimulated the writing of this publication.

The concept of a student land use survey was discussed with the curriculum development team of the Jefferson County Public Schools in Colorado. In these discussions it soon became apparent that the curriculum potentials included much more than a classroom activity involving mapping the features on the ground in the area of study.

A new flood control dam to be located in the area of Denver, Colorado, became the central topic in a program involving a wide variety of curriculum fields, such as mapmaking, local community history, physical geography, mathematics, and environmental studies. Consequently, a prototype of a multidisciplinary unit concept was developed for later incorporation by the Jefferson County curriculum team. This study concept is the major part of this publication. By describing in detail, the cross-disciplinary activities that result from this specific study, similar activities may be stimulated in programs of other schools. In fact, enough detail on every study aspect is included so that any study group can conduct this same land use investigation by only using the data contained herein.

This publication is divided into three major sections. Section III describes the multidisciplinary unit concept, and includes suggestions for other land use studies. Section IV gives advice on where to obtain data for surveys and how to use the data. The third major section is an appendix that discusses the different factors that influence the use of land. This is included as a reminder of the factors that should be considered in making local land surveys.

II. Objectives

The prime objective of this publication is to stimulate in the mind of the educational reader an awareness of the role that can be played in educational programs by information generated in advanced technology programs, such as aircraft or spacecraft land surveys.

Using data from such programs, educational materials can be prepared that are valuable adjuncts to existing curriculum materials. The application of such data can enrich curricula by providing more up-to-date information than published texts may achieve, and can foster studies of local features to a level of detail that standard texts can never achieve.

A second objective is to show the reader how to get the information needed and suggest ways in which the information can be applied.

While the main thrust of the document is directed to the educators, it has equal potential as a guide to members of noneducational professions. Local community planners may benefit from the knowledge of available information and its application potential.

III. Land Use Studies

A. A Concept

The administrators for the Jefferson County Public Schools near Denver, Colorado, are contemplating a land use unit using information acquired from space programs as an addition to their curricula. The unit is designed, not only as an exercise in the use of data from many sources including advanced technology programs, in land use studies, but also as an introduction to the investigative processes that are necessary to reach sound conclusions. To be able to define the objectives of a study, to be able to identify what data are required and analyze the data, and to recognize and evaluate the interactions between elements of a study are all indispensable steps along the way to rational solutions of problems.

A flood control project near Denver, Colorado, was selected as the subject of this unit.

Table 1 is a matrix that shows how various school disciplines can be applied in the study of three aspects of the dam. It shows what curriculum elements apply to the evaluation of the need of such a flood control project. It shows how other elements are applicable to a study of this location of the dam and to a study of the effects of the dam on the natural and man-made environments.

This flood control project is now in work; construction work has started and property in the area is being relocated. Therefore, the students can actually verify some of their classroom conclusions by observations in the field.

Table 1 The Need, The Location, The Effect

	IS THE DAM REALLY NEEDED?	WHERE SHOULD IT BE LOCATED?	WHAT IS THE EFFECT OF THE DAM?
SOCIAL STUDIES			
MAPPING SKILLS	SOURCES OF FLOODING. DRAINAGE BASINS.	FACTORS INFLUENCING LOCATION.	CREATION OF A NEW LAKE. RELOCATION OF ROADS, ETC.
PHYSICAL GEOGRAPHY			SOURCES OF MATERIALS.
CLIMATE	WEATHER STATISTICS	STATISTICS DETERMINE RESERVOIR CAPACITY	
PRE-HISTORY		TRACEABILITY OF EARLY INHABITANTS.	POSSIBLE OBLITERATION OF SITES.
MAN & THE ENVIRONMENT	HISTORY OF THE COMMUNITY. IMPACT ON THE URBAN AREA. STATUS OF CURRENT ECOSYSTEM.	ADVANTAGE/DISADVANTAGES OF OTHER LOCATIONS.	RELOCATION OF PEOPLE & PROPERTY. NEW RECREATION AREAS. URBAN IMPROVEMENT. IMPACT UPON ECOSYSTEM.
EARTH SCIENCE			
GEOLOGICAL HISTORY			GRAVEL INDUSTRY. EROSION IN CANYON. DEPOSITION AT MOUTH.
PHYSICAL SCIENCE	DEFINITION OF THE FLOOD THREAT	RIVER FLOW RATES. DAM STRUCTURES.	
MATHEMATICS		ANALYSIS OF MAPS. VOLUME OF VALLEYS.	

An outline of the multidiscipline study developed by and for the Jefferson County Schools is presented in the following section.

The outline is divided into four areas: A. the major goals of the unit; B. the ultimate outcomes of the unit; C. the topics to be taught; and D. evaluation.

As a guide to teachers and curriculum developers, the first part of section B has been developed in some detail. Descriptions of the study activities are given. Copies of the data necessary for the study have been included, together with illustrations of some of the techniques to be employed. Additional copies of the illustrations in this section have been provided in full page format as tear out pages at the back of the book so that they can be used as originals for classroom work sheets or for transparencies for overhead projectors.

1. CURRICULUM OUTLINE

(TITLE) COMMUNITY PROBLEMS AND METHODS OF SOLVING THEM

(UNIT PROBLEM) WHAT ARE THE PROBLEMS THAT ARISE FROM THE FLOODING OF URBAN AREAS?

Unit Description: Students who take this unit will develop a recognition that the solution of community problems requires information and skills from many different disciplines and fields of human activity. The protective measures being undertaken to prevent disasterous flooding of the Denver Metropolitan area will be used as an example of the ways that several disciplines must be applied to understand and solve a community problem. In the search for solutions to the various aspects of this problem, students will apply various fields of study: mathematics, physical science, Earth science, social studies, and others.

A. Major Goals of the Unit:

1. To establish student awareness of the potential flooding problems that may exist in many urban areas, and of the processes that must be applied to understand the uses and misuses of land.
2. To develop student understanding that problems may have many aspects and that their solution requires the application of information and skills from many fields of human activity.
3. To develop the students' ability to recognize the environmental effects of natural and human activity.
4. To develop student understanding of the natural and man-made environments.
5. To develop student awareness of the responsibilities implicit in man's use of land to fulfill his needs or desires.

B. Ultimate Outcomes of the Unit:

1. Knowledge or information to be learned. To complete the study the students should be able to:
    - a. Identify the main features on aerial photographs and different types of maps.
    - b. Determine the sizes of the drainage basins of river systems that flow into the metropolitan area.
    - c. Determine the volume of water that can flow into the metropolitan area under flood conditions.
    - d. Define the threat to the community posed by flooding.
    - e. Define the factors that influence the location of flood control dams.
    - f. Understand the different types of dams and how they support loads.
    - g. Understand the immediate and long-range effects of the construction of a dam on the natural and man-made environments.
2. Attitudes to be developed. At the conclusion of this unit the students should be able to:
    - a. Demonstrate an awareness of the value of different sources of information in the solution of problems.

b. Demonstrate an ability to objectively evaluate large-scale environment-affecting events in a manner that shows awareness and understanding of the many aspects of the situation.

c. Demonstrate the ability to evaluate the factors that influence the use of land.

d. Understand the ways that different value orientations influence the use of land.

3. Skills to be used studying the unit. At the conclusion of this unit the students should be able to:

   a. Demonstrate interpretation of maps and photographs.

   b. Demonstrate the ability to analyze maps and photographs to determine the size, areas, and volumes of features.

   c. Identify the types of information required to conduct land use surveys.

   d. Demonstrate awareness of the characteristics of the local ecosystem.

C. Topics To Be Taught:

1. The different types of maps, and how can they be used.
2. The human, geological, and climatic history of the community.
3. The prevailing climate in the region.
4. The environment of the area under study, and the conditions of the natural and man-made environments.
5. The effects of building or not building the dam on the natural and man-made environments.
6. Calculating the volume of the valleys in which dams might be built.
7. The main types of dam used throughout the world.

D. Evaluation:

1. Examination of map reading and photograph interpretation, e.g., determine scale, size, areas, and elevations of valleys, streams, cities, etc.
2. Examination of understanding of the relevance of physical science and mathematics to community problems.
3. Essay examination on how to make a particular type of land use study. Given a problem and information from various sources, the student should be able to use the necessary analytical skills to derive an objective solution.
4. Essay examination on the many features and interactions that make up what is called "the environment."
5. Examination of the students' understanding of the application of different skills and information in the general problem solving process.

2. EXAMPLES OF STUDY ACTIVITIES

The following are examples of specific activities listed in Section B.1 of the preceding curriculum outline. These activities are designed to make the student familiar with some of the studies and decisions that must be made before any flood control project can begin. These activities are based on the development of the Bear Creek dam to be built southwest of Denver, Colorado. All of the specific activities are in such detail that gro[illegible] in other areas can use the dat[illegible] room exercise without any a[illegible] If a group desires to perfor[illegible] tive to local conditions, th[illegible] obtain the appropriate maps and photographs of the local area.

In some cases the information provided relates specifically to the dam under construction in Colorado. In other cases discussion themes are given that could be applied to any area.

a. Identify the main features on aerial photographs and different types of maps. The materials required are U.S. Geological Survey (USGS) maps of the area of interest; aerial photographs of the same area; and, possibly, other maps such as oil company maps that will show a larger area in a more convenient form than the requisite number of USGS maps (you may need more than one USGS map).

The Department of the Interior provides aerial photographs at several scales at reasonable cost. It will be best to buy the USGS map and then ask for photographs at the same scale. Depending on the region of the country to be studied, there might be significant differences in the dates when the map was drawn and the photographs were taken. Detailed comparison of both will reveal the changes that had taken place in the time between the two presentations.

Figures 1 and 2 are, respectively, an aerial photograph and a portion of a USGS map of the location of the flood-control dam project at the same scale.

Detailed examination of both images will reveal many similarities and differences. As would be expected, the photograph shows much more detail. Trees, the shapes of houses, driveways, and the shapes of fields and their cultivation patterns are all visible in the photograph and could not be expected to be included in the map. For example, cultivation patterns might vary from year to year and would therefore be quite inappropriate for inclusion on a map.

Other differences can be recognized. Some roads and streets do not appear on the map because the map was prepared in 1965 and the photograph was taken in August 1971.

To aid in the comparison of the two figures, a transparency can be made of the map (Fig. 2) to use as an overlay on the photograph. The type of transparency used on an ov[illegible]rojector will be ideal.

b. Determine the sizes of the drainage basins of river systems that flow into the metropolitan area. The materials required in this activity are: USGS maps of the areas that drain into the metropolitan photographs such as those available from Skylab or LANDSAT, and relief maps of the area, if available. This material can be obtained as explained in item a. above and in Section 4.A "Where to Obtain Remotely Sensed Data."

The extent of a river drainage basin is defined by the ridges that divide the flow of water to the river under study or to the neighboring river. The technique used to identify this boundary on a map is to follow each river upstream from a starting point, such as the point where the river enters the metropolitan area.

Each tributary should be followed to its source. After a few tributaries have been traced, it will be easy to recognize the general pattern of tributaries instead of having to trace each stream.

A relief map of the area is easier to interpret in this activity. The shading used to represent valleys and mountains shows the ridges very clearly.

If a relief map is not available, the flow direction in a drainage system and the divides between drainage systems can be determined by carefully analyzing the direction of the contour lines along the course of a river.

Figure 3 is a simplified example of the shape of contour lines in a valley and along a ridge. A valley can be recognized by the way the contour lines make a V pointing toward the higher altitudes. The contour lines defining a ridge make V's pointing the other way.

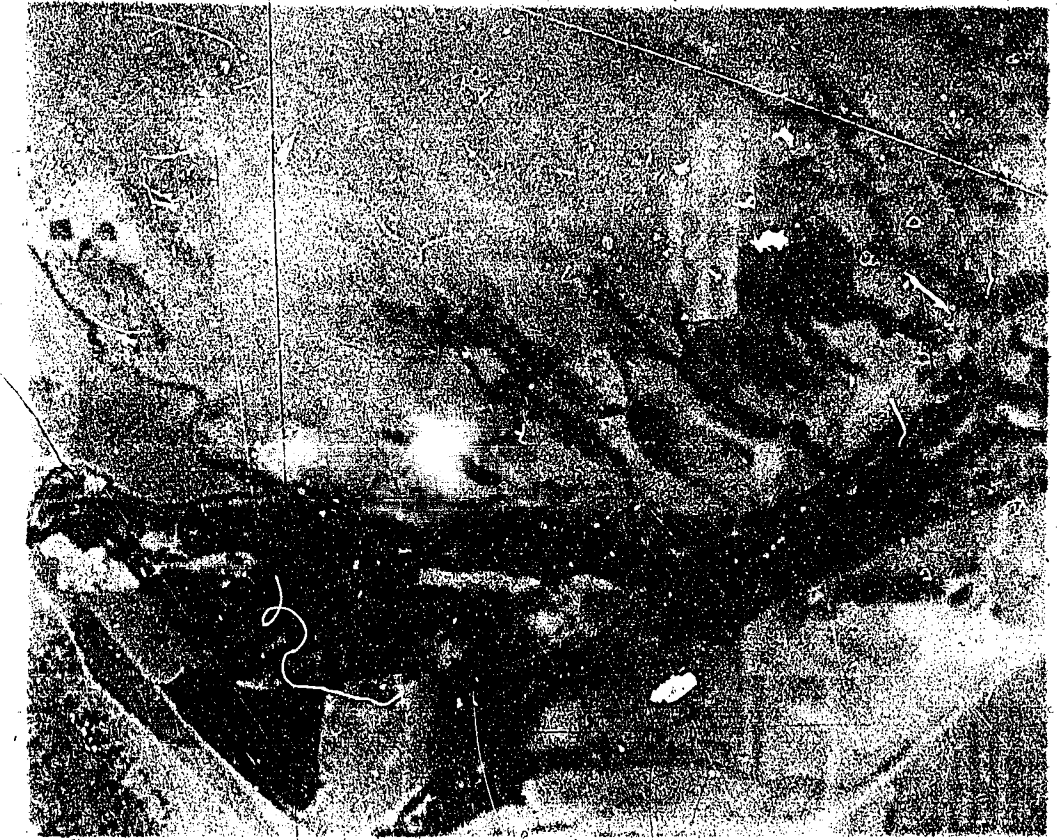


Figure 1 Aerial Photo of Bear Creek Dam Site, August 4, [illegible]

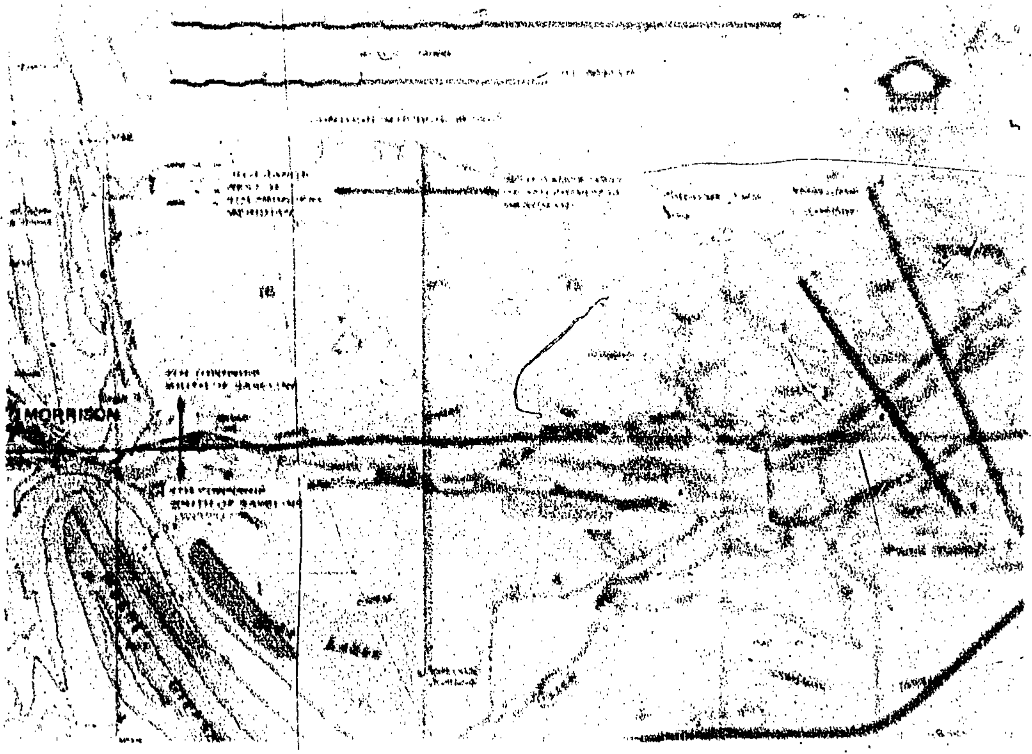


Figure 2 USGS Map of Bear Creek Dam Site, [illegible]

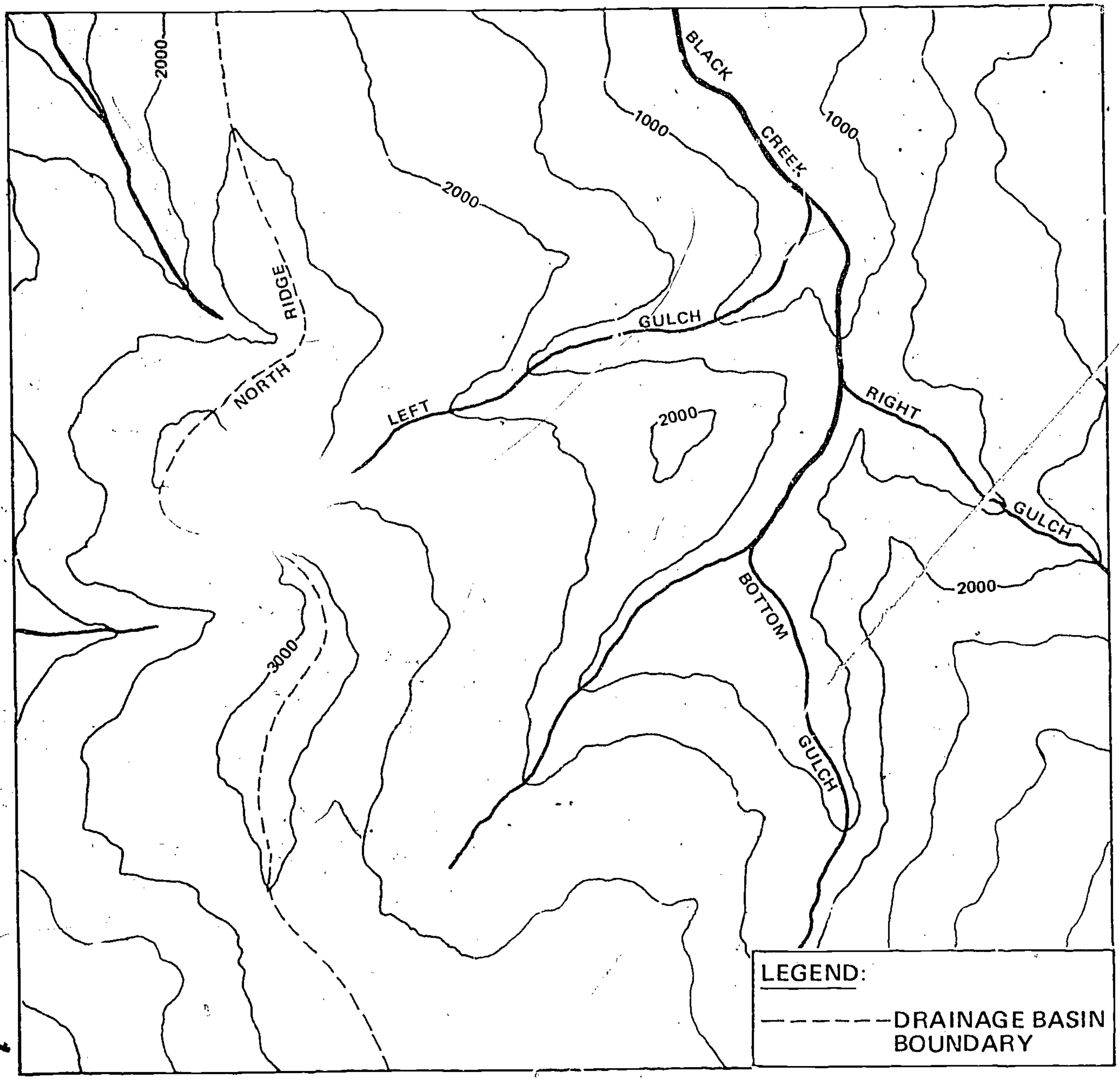


Figure 3 Schematic of Drainage Systems

Real maps are not quite as simple as this. The contour lines wander about much more than the example shows and require much more careful tracing.

Having plotted the boundaries of the drainage areas, it is easy to find the area. The area of the shapes on the map can be measured by overlaying a grid and counting the squares.

The area in square kilometers is given by the expression:

$$\frac{\text{Map Area (square centimeters) x Map Scale}^2}{100{,}000^2 \text{ (number of centimeters in kilometer)}^2}$$

Figure 4 is a USGS relief map of part of Colorado. It shows the river systems that drain into the Denver metropolitan area. The river valleys and the ridges between are very easily recognized.

Figure 4 USGS Relief Map of Central Colorado

Figure 5 is a photograph of part of the same area taken from NASA's Skylab space station at an altitude of over 4[illegible] kilometers. This can be compared to the relief map to help trace the courses of the rivers, the tributaries, and the ridges between. Copies can be made of the "tear out" copy of Figure 4 on which the students can plot the outlines of the four drainage basins upstream of Denver. The river systems of interest are, reading clockwise from the city, Cherry Creek, Plum Creek, South Platte, and Bear Creek/Turkey Creek.

Dams are shown across the Cherry Creek River southeast of the city (Cherry Creek Lake) and the South Platte southwest of the city (Chatfield Lake). The Chatfield Lake Dam is located immediately downstream of the confluence of the South Platte and Plum Creek. The flood threat from these two drainage basins is now diminished because of Chatfield and Cherry Creek dams.

A one-centimeter grid can be superimposed on the student's plots of the drainage basins as shown in Figure 6. Students can estimate the areas of the drainage basins by counting squares.

Figure 6 is a plot of the four drainage basins. Only the main channels of each of the rivers have been included. A transparency, such as an overhead projector transparency, can be made from the "tear out" copy of Figure 6, and this can be used as an overlay to simplify the task of checking the students' drainage area plots.

The Cherry Creek and South Plate/Plum Creek drainage areas shown on Figure 6 have been terminated at the Cherry Creek and Chatfield Dams, respectively. The Bear Creek/Turkey Creek drainage area has been terminated at the site of a new dam that is under construction.

Figure 5 Skylab photograph of Central C

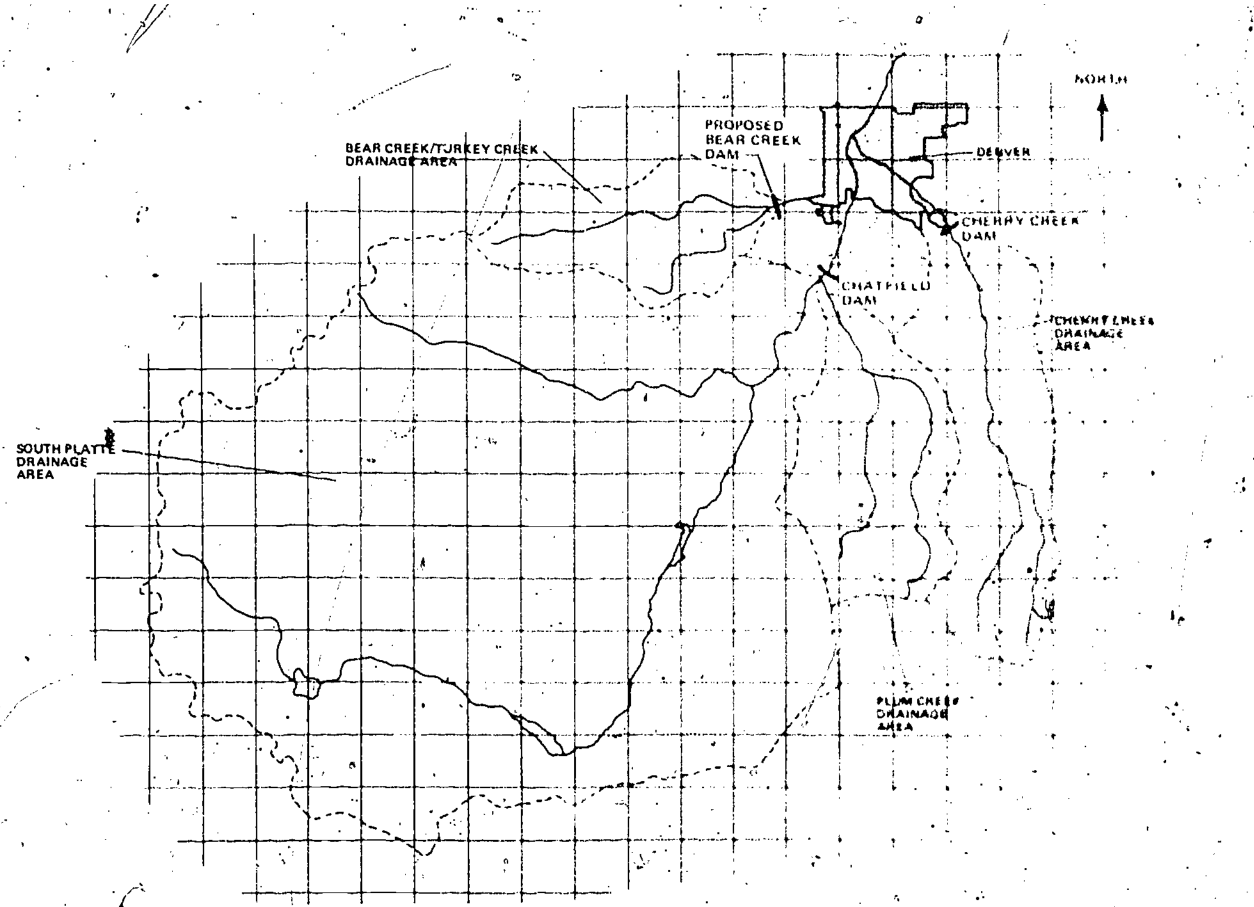


Figure 6 Watershed Areas Draining Into Denver

The scale of Figures 4 and 6 is 1:779,500, i.e., 1 centimeter represents 7.795 kilometers. Using the above equation the areas can be calculated. The values listed in the following table also can be used to check the students' answers.

DRAINAGE AREA AT DAM SITE	MAP AREA, sq cm	FULL SIZE AREA	
		sq km	sq miles
CHERRY CREEK:	15.1	918	354
PLUM CREEK:	13.35	811	313
SOUTH PLATTE:	110.38	6707	2590
BEAR CREEK/ TURKEY CREEK:	10.23	622	240

c. Determine the volume of water that can flow into the Metropolitan Denver area under flood conditions. The estimation of water flow at a point in a river system is complicated. It involves several variables. First, rainfall amounts must be determined for the area being studied to estimate the volume of water collected.

Rainfall data can be obtained from the National Weather Service. The nearest office of this service should be listed in the white pages of the telephone directory under the heading "United States Government—Commerce, Department of."

The National Weather Service publishes average rainfall data for all official weather stations. The service also computes statistical values of maximum rainfall for the purposes of evaluating flood hazards.

The Corps of Engineers of the U.S. Army also has developed a statistical method of estimating storm rainfalls and floods. Their method uses a plot of storm rainfall intensities across the country. Figure 7 is a copy of a plot of equal rainfall lines (isohyets) for the United States east of the Continental Divide. The rainfall values represent the maximum average depth of rain falling in 24 hours over a 200-square-mile area. This is called the "index rainfall." Another graph is used to factor the 24-hour index rainfall to make allowance for different durations of rainfall and different sizes of storm areas. Figure 8 is a copy of this graph

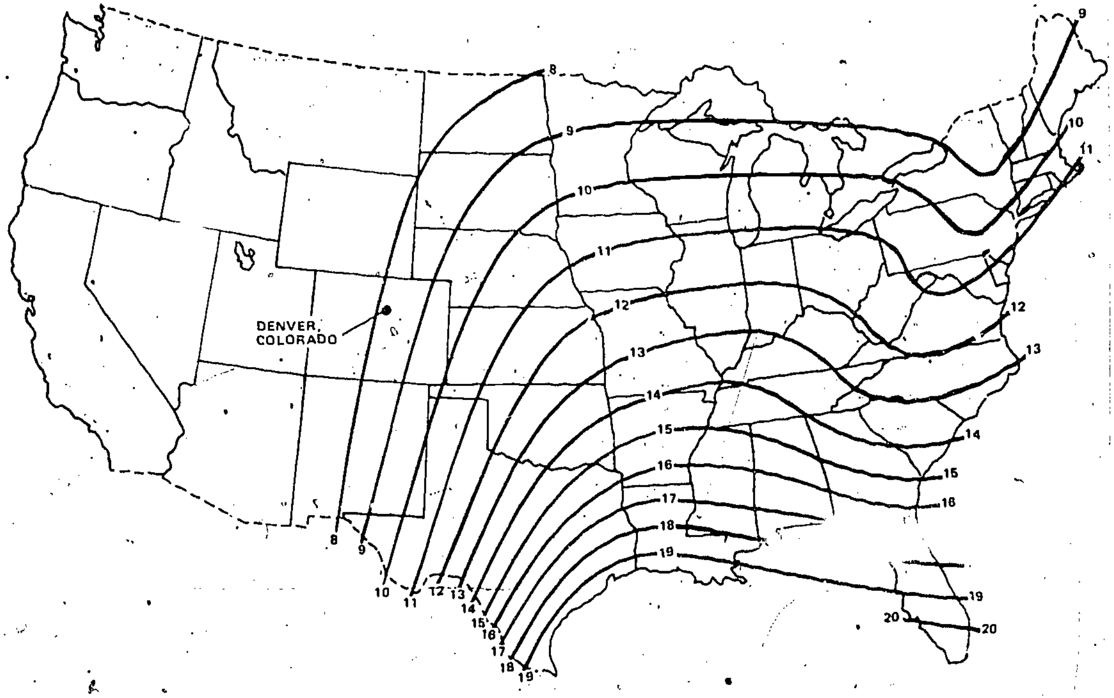


Figure 7 Index Rainfall Plots East of Continental Divide

These two figures can be used in the following way to find the rainfall over the drainage basin areas derived in the preceding activity. From Figure 7 an index rainfall value of 8 inches can be derived for the Denver area. Then, entering Figure 8 at an area representing the Plum Creek drainage basin—approximately 300 square miles—and a storm duration of 48 hours, a ratio of about 110% can be obtained. This gives a theoretical rainfall depth value of 8.8 inches. Using this figure and the area of 313 square miles, the volume of water collected can be calculated:

$\frac{\text{8.8 inches Rainfall}}{\text{12 inches in a foot}} \times$ 313 square miles x

5280^2 (feet in a mile)^2 =

6.399×10^9 (6.399 billion) cubic feet.

Another variable to be considered is the rate of runoff—that is, the rate at which the rain water drains into the rivers. This is influenced by many factors. The wetness of the ground determines how much water is soaked up by the soil and how much

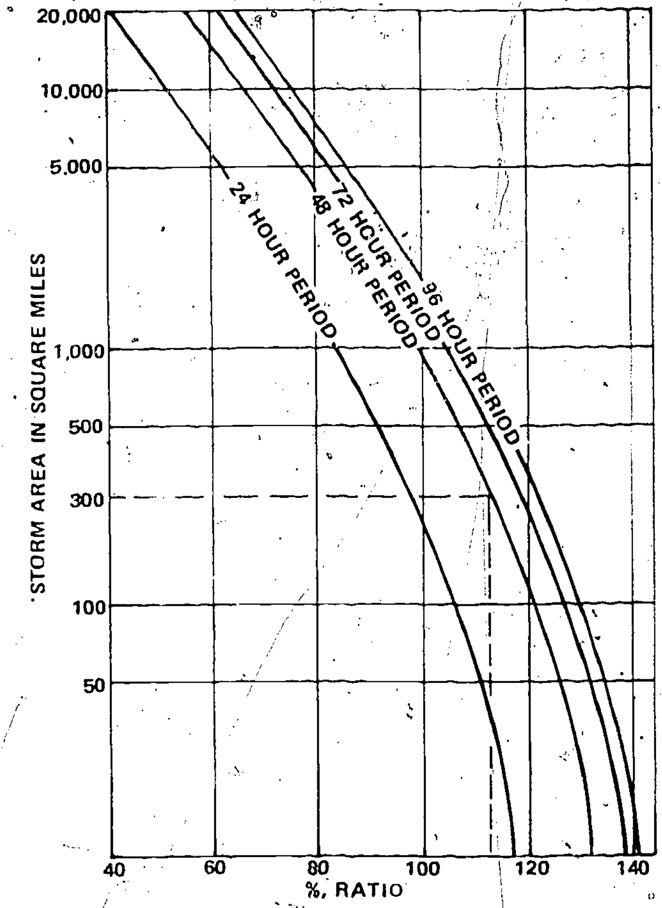


Figure 8 Index Rainfall Ratio (In Percent)

can run off. The slope of the terrain—hillsides, valleys, etc.—governs the velocity with which the water runs off.

Also the shape of the terrain in the flood plain greatly influences the nature of the flood. If the river runs through a narrow, steep-sided valley, the water will retain its high velocity and will sweep away structures in its path. If the terrain is flat, the water will spread over a wide area, and the velocity will be very low. Mud and silt will be deposited, and the damage suffered by the community in the flood plain will be the result of soaking.

Because of the many variables, estimation of flow rates is beyond the scope of the student. However, the students will have developed some awareness of the amount of water involved in a major storm.

To give the student an indication of the way a heavy storm becomes a serious flood, an example of one flood is included. A serious storm in June 1965 caused considerable damage to the City of Denver and to the South Platte Valley all the way downstream to the Missouri River. Figure 9 is a plot of rainfall depths recorded in the head waters of the valley in the two days of the storm. Measured discharge rates in some of the rivers have been included on the plot to show how runoff can be related to rainfall. A flow rate of 154,0[illegible]ond was recorded on Plum Creek. For comparison, the highest flow rate recorded the previous year was 290 cubic feet per second. The high-

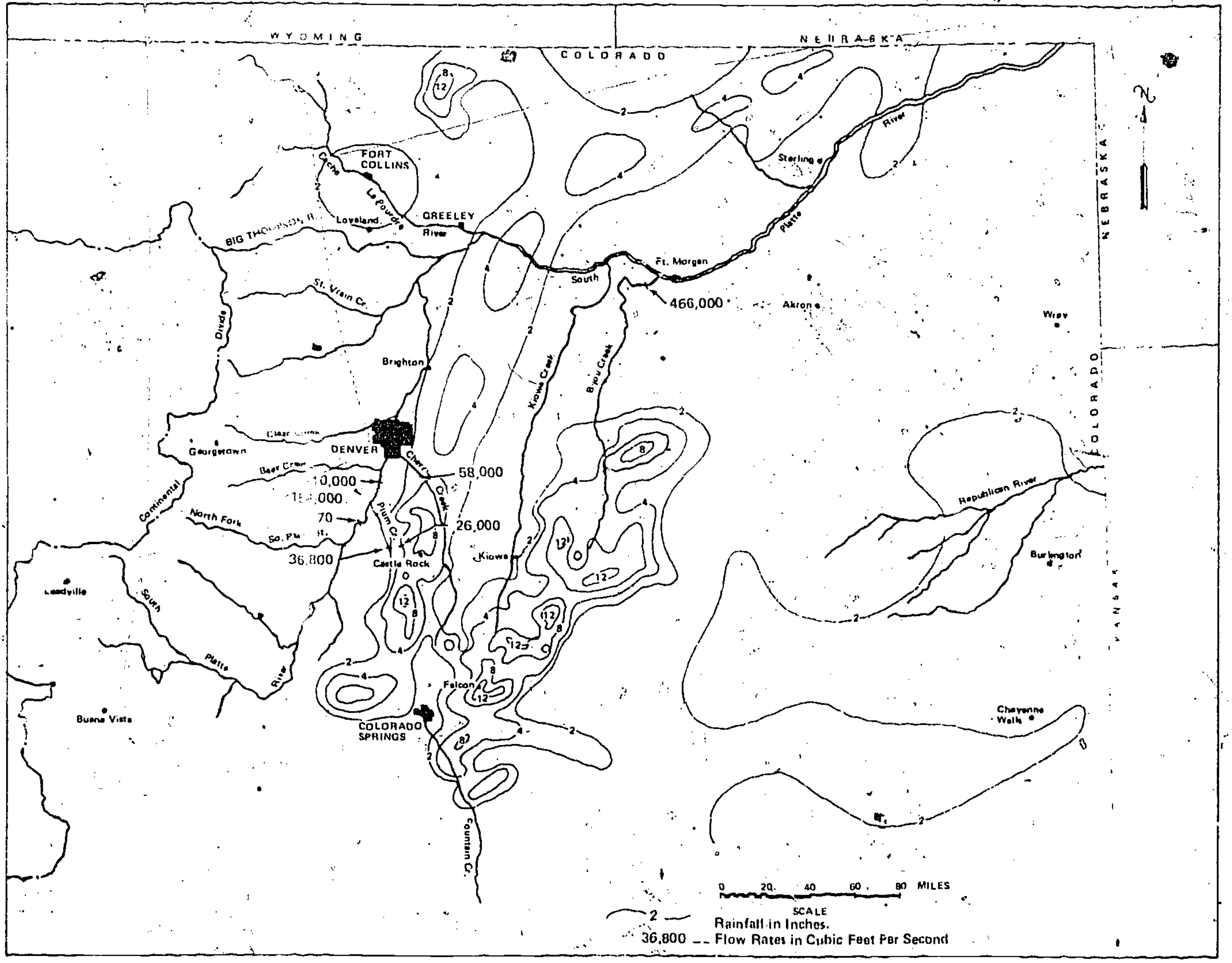


Figure 9 Rainfall Depths and River Flow Rates, June 1965 Flood

est measured flow rate for the whole area was on Bijou Creek (466,000 cubic feet per second) Fortunately this flow missed the City of Denver. The interesting aspect of this information is that Bijou Creek is normally bone dry.

d. Define the threat to the community posed by flooding. A flood in a river basin can pose a threat to a community if there is a possibility of structural damage, economic loss, or loss of life among the residents of the flood plain.

The best way to illustrate this concept is to study a specific case—the flood that occurred in June 1965 in the valley of the South Platte in Colorado and Nebraska. The study begins by briefly describing the flood plain area in terms of potential damage. Then, a description of the weather conditions that precipitated the flood follows. Lastly is a description of the types of damage that occurred, with a summary of the economic cost of the flood to the communities in the flood plain.

1. *Description of the flood plain area:* The thirty communities that experienced flooding in June 1965 had a total population in 1960 of about 1,000,000. These communities ranged in size from metropolitan Denver (population 929,383) to three towns of less than 100 persons each. Outside of metropolitan Denver, the largest communities that experienced flooding were Greeley, Colorado (population 26,314), and Sterling, Colorado (population 10,751).

Metropolitan Denver ranks as the twenty-fifth largest metropolitan area in the United States. It serves as the marketing and distribution center of the Rocky Mountain area, and the commercial, financial, manufacturing, professional, and cultural hub of this vast region. Its leading industries by order of rank are manufacturing, retail trade, wholesale trade, tourism, public utilities, service industries, construction, finance, and mining. In 1960, there were 353,823 persons employed in the Denver metropolitan area.

The South Platte River basin contains approximately 15.5 million acres of land and water—12.7 million acres are in farms and ranches (of which 980,000 acres are irrigated and 11,720,000 acres are nonirrigated. Livestock and livestock products make up 48 percent of the value of all farm products produced in the basin. Field crops produce 39 percent of the value of farm production, and the remaining 13 percent result from dairy operations, poultry, and fruit and truck crops. The major field crops produced are winter wheat, alfalfa, corn, barley, sugar beets, field beans, hay forage sorghum, grain sorghum, oats, potatoes, rye, and spring wheat. Irrigation provides the stable base for the rural economy of the basin.

[illegible] interstate highways, [illegible] U.S. highways, [illegible] 56 state highways traverse the South Platte River basin. Traffic densities on the interstate routes range from 12,000 to 50,600 vehicles daily.

The basin is served by six railroads. The Union Pacific; the Chicago, Burlington and Quincy; and the Chicago, Rock Island and Pacific Railroads traverse the basin along east-west routes. The Atchison, Topeka and Santa Fe; the Denver, Rio Grande and Western; and the Colorado and Southern Railroads cross the basin along north-south routes. All of the railroad routes converge on Denver, Colorado.

Colorado's high mountains and incomparable scenic beauties, vast forests, numerous fishing and boating waters, and winter sport areas make the state a year-around vacation land for millions of visitors annually. In 1964 more than 6 million visitors spent an estimated $505 million in the State of Colorado. The number of visitors of all vacation categories increased about 30 percent from 1960 to 1964 and their spending increased about 29 percent.

2. *The weather conditions.* During the afternoon of June 16, unprecedented amounts of rain (estimated up to 14 inches in a few hours at Larkspur, Colorado, and 10 inches near Castle Rock, Colorado) fell on the drainage areas of East and West Plum Creeks in the foothills of the Palmer Lake area. The average 6-hour rainfall over 1,000 square miles was 4.8 inches. Again, on the 17th of June, heavy rains occurred across eastern Colorado. A series of 12- to 14-inch centers were reported in the Falcon, Peyton, and Fords, Colorado area northeast of Colorado Springs. Average 6-hour rainfall values of 18 inches or more during this period were reported near Two Buttes and Holly, Colorado (see Fig. 9).

Unsettled weather continued until July 26, 1965, with repeated rainfall and runoff in areas of earlier flooding. During the period July 23 to 26, the storm pattern also extended over the foothills areas of the Bear Creek and Clear Creek watersheds.

3. *The [illegible]* The streams of the [illegible] Platte R[illegible] which flooding occurr[illegible]ing June and [illegible] shown on Figure 10. Flooding began on the northern tributaries on June 14. As the storm moved southward, major flooding occurred on Plum Creek, Cherry Creek, Sand Creek, and Toll Gate Creek on the South Platte River and its downstream tributaries—the Cache La Poudre River, the Big Thompson River, and on the right bank tributary streams (Box Elder, Kiowa, Bijou, Badger, and Beaver Creeks). The Plum Creek and Bijou Creek basins received the more intense rainfall and experienced the higher peak discharges. During July, Plum Creek, Cherry Creek, Sand Creek, and the Bijou Creek basins experienced repeated flood runoff that hampered recovery operations and caused additional damage, particularly to temporary stream crossings constructed to accommodate traffic after the bridge destruction in June. Moreover, Bear Creek and Clear Creek, in the metropolitan area of Denver, experienced flooding during the July storms. These two streams had been outside the area of major storm runoff in June.

In terms of total damages, the damages inflicted by the flood runoff of the northern tributaries of the South Platte River were limited to road closings and moderate damages to farmlands,

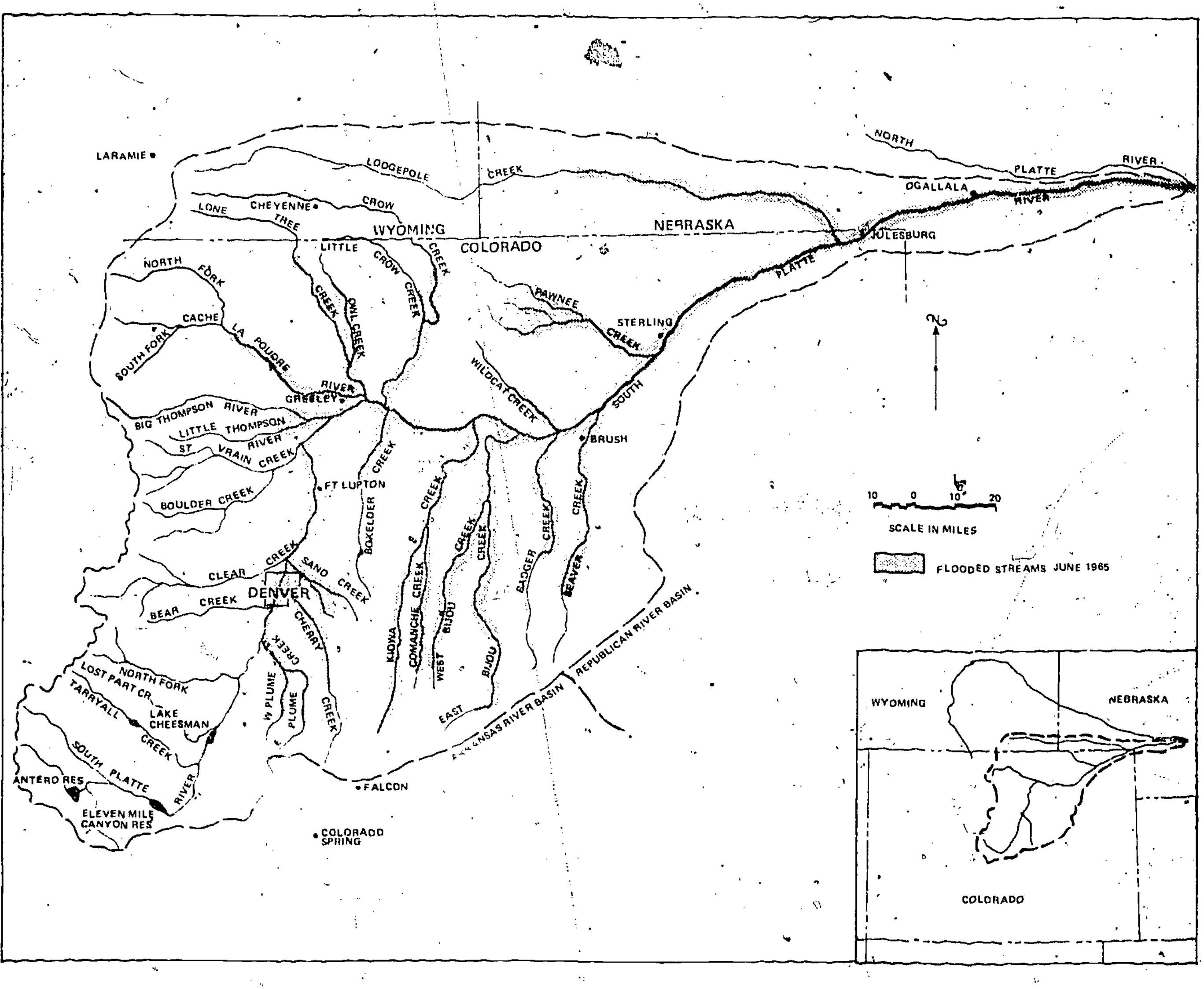


Figure 10 Rivers Draining Into South Platte

roads, bridges, and urban property. The flood damages experienced on the streams that received the full brunt of the storm runoff defy adequate description without an intimate knowledge of preflood conditions and the benefit of personal inspection. In the Plum Creek basin, interstate highway bridges and sections of highway, which by reasonable standards were adequate to pass major flood flows, were demolished by the extremely high discharges and stages. Heavy road construction equipment such as road graders, huge dump trucks, and cranes which had been parked in the Plum Creek flood plain were almost completely buried under masses of sediment. Farther downstream, farm buildings located as much as a quarter of a mile away from the stream bank were carried away. New stream channels appeared where the buildings formerly stood. As the flood proceeded downstream, heavy debris, consisting of huge uprooted trees, parts of structures, cars, trucks, fuel tanks, and trailers, was carried on the crest of the flood wave and slammed into other structures. When the Plum Creek flood entered the South Platte River, it spread out into the wider South Platte valley. While this valley storage served to reduce the flood crest, the damages inflicted on metropolitan Denver suggested initially that no appreciable reduction in the flood crest had occurred. Houses, bridges, trucks, trailers and cars, as well as large quantities of material from commercial and industrial inventories, were added to the destructive force of the flood crest. After the flood wave passed downstream, the aftermath of debris, silt, and mud presented a scene of desolation that could only partially suggest the heartbreak and despair of the flood victims. In many instances, the losses suffered by property owners represented the accumulated capital assets of a lifetime of hard work that were destroyed in a brief period of less than an hour.

Figure 11 is a map of a portion of the city of Denver. On it is indicated the extent to which the South Platte spread. A simple count of the number of buildings that are enclosed by the flooded area will give a strong impression of the extent of damage caused by the flood.

Figures 12 and 13 are photographs taken after the flood had subsided. These illustrate clearly what sort of damage can occur. The areas covered by these two photographs are indicated on Figure 11.

After the Plum Creek flood passed through Denver, it was joined by the flood discharge from Sand Creek which, together with its tributary Toll Gate Creek, had just passed through another sector of metropolitan Denver destroying bridges and private property. The combined flows then passed on downstream in the South Platte valley destroying or damaging roads, bridges, irrigation structures, and agricultural property in the irrigated areas of the valley. The flood flows from the upper South Platte basin were joined successively by the floods coming out of the Cache La Poudre River, Box Elder Creek, Crow Creek, and Kiowa Creek. The flood crest gradually diminished as it passed downstream in the South Platte River valley until it was joined by the flood discharge from Bijou Creek, which was later computed to have been 466,000 cubic feet per second. This flood volume then increased the area of inundation and destruction for an additional 190 miles along the South Platte River and approximately 35 miles along the Platte River valley downstream from North Platte, Nebraska. The volume of flood flow contributed by the upper South Platte River and Bijou Creek was joined by the flood discharges of Badger and Beaver Creeks as the floods proceeded downstream toward the Platte River.

Throughout the South Platte basin, 108 bridges, including federal, state and county highway bridges, as well as city bridges, were destroyed or severely damaged. Nearly every highway and railroad bridge crossing the South Platte River and Plum, Sand, and Toll Gate Creeks was damaged or destroyed. Several state bridges and most of the county bridges across Kiowa Creek, Commanche Creek, and Cherry Creek also were damaged or destroyed. Although many bridge approaches were washed out on Beaver Creek, Lone Tree Creek, Lodgepole Creek, Pawnee Creek, Crow Creek, and the Cache La Poudre River, only a few bridges were totally destroyed in these drainage basins. Railroad damage throughout the entire area was severe, with numerous bridges damaged or destroyed and trackage and ballast washed away. It is estimated that from 700 to 900 miles of highways, roads, and railroads sustained varying degrees of damage.

The floods in the South Platte River basin took 13 lives. Four lives were lost on Plum Creek, three on the Cache La Poudre River, two on Bijou Creek, two on Beaver Creek, and one each on the Big Thompson River and Cherry Creek.

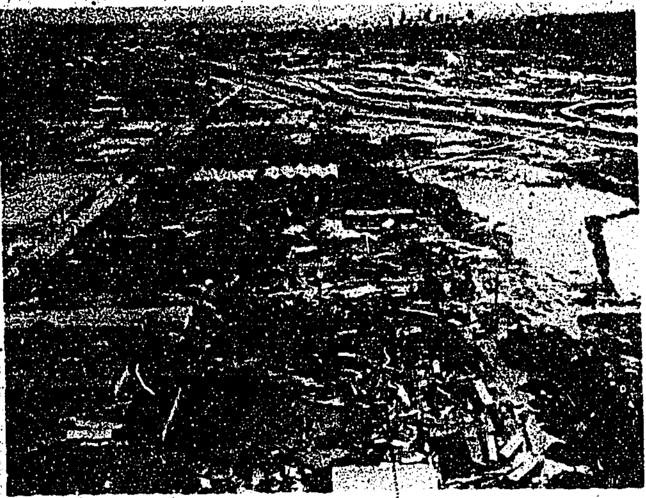


Figure 12 Mississippi Looking North

Figure 13 6th Avenue Looking SW

The costs of urban flood damages in the categories of residential, commercial and industrial, public utilities, publicly-owned facilities, and miscellaneous categories are summarized in Table 2. The miscellaneous categories include such items of damages as public and private cleanup, flood fighting, power and telephone facilities, protection of flooded properties, public relief activities, preservation of public health and prevention of disease outbreaks, and others.

Table 2 also summarizes rural flood damage costs in the categories of farmsteads, livestock, crop and cropland, irrigation structures and equipment, and miscellaneous categories. Miscellaneous categories include damage to rural power and telephone companies, debris removal, fences and equipment lost, pest control, and preservation of health.

Transportation facility damage costs in the categories of city streets and bridges, state highways and bridges, county roads and bridges, railroads and trucking facilities, and cargo and traffic detours and delays, are included in Table 2.

No estimates have been made of the extra man-hours of work required because of the flood, nor of the lost productivity caused by work interruptions, traffic delays, and extra hours required to perform normal activities. Such items as troops assigned to patrol flooded areas in metropolitan Denver, 1000 extra men put to work on initial

Table 2 Summary of Flood Damage in the South Platte Drainage Basin, June 1965

URBAN DAMAGE						
RESIDENTIAL	COMMERCIAL	UTILITIES	PUBLICLY OWNED FACILITIES	MISCELLANEOUS	TOTAL	
$11,280,800	$166,070,600	$ 5,322,200	$ 4,353,500	$ 4,131,500	$191,159,000	
RURAL DAMAGE						
ACRES FLOODED	FARMSTEADS	LIVESTOCK	CROPLAND AND CROPS	IRRIGATION STRUCTURES AND EQUIPMENT	MISCELLANEOUS	TOTAL
252,925	$ 3,993,000	$ 3,689,000	$ 20,962,000	$15,741,000	$ 8,220,000	$52,605,000
DAMAGE TO HIGHWAYS, BRIDGES, AND TRANSPORTATION						
CITY STREETS AND BRIDGES	STATE HIGHWAYS AND BRIDGES	COUNTY ROADS AND BRIDGES	RAILROAD & TRUCKING FACILITIES*	TRAFFIC DELAYS AND DETOURS	TOTAL	
$ 1,202,000	$ 16,573,000	$21,441,000	$125,434,000	$ 6,662,000	$171,312,000	

clean-up of flooded areas, the use of C-119 Flying Boxcars to ferry emergency supplies to the stricken area, and Red Cross relief expenditures of almost $900,000 for immediate relief of over 1400 familes or individuals in Denver alone can only hint at the total amount of related flood costs. In an effort to prevent outbreaks of encephalitis, $300,000 was spent to spray more than 194,000 acres of flooded land; nevertheless, numerous cases were reported. Many communities had to rely on bottled water supplies, and the loss of utilities resulted in widespread and prolonged disruption of normal activities. The destruction or damage to major traffic arteries in metropolitan Denver and throughout the basin caused severe disruptions of normal traffic movement and commerce. Moreover, the disruptive effects of the initial damage and destruction of bridges, highways, and streets were compounded by repeated flooding in July and by damage to the temporary crossings constructed after the June floods.

The flood in the South Platte Valley in June 1965 was a disaster to the metropolitan Denver area and to the smaller communities on downstream. It was a rare occurrence in the history of the city. The last flood of comparable magnitude was in 1864. Because of the dams that have been constructed, or are being constructed, it is unlikely to occur again.

By contrast, consider the situation in the Mississippi Valley. Each year wide areas of the valley are flooded. The economic cost of any of these floods is measured in millions of dollars compared with the mere thousands of dollars in the South Platte floods. Ironically, the Mississippi floods are caused by weather conditions that prevail a thousand miles upstream from the scene of the flood.

Other floods can be caused by the backing up of water in bays, rivers, and estuaries caused by storm conditions over the oceans. For example, the floods in Bangladesh in November 1970 were the result of a cyclone in the Bay of Bengal. A 2330 square-mile area was flooded and about 30,000 persons were killed.

e. Define the factors that influence the location of **flood control dams**. The factors that the dam builder must consider in choosing the site for a dam are best illustrated by discussing a particular example—the Bear Creek dam in Colorado about 10 miles southwest of Denver.

The materials needed for the study are primarily U.S. Geological Survey maps of the area. Figure 2 is a copy of the map of the area where the Bear Creek Dam is planned to be built. The location of the dam is indicated by the heavy line A-A.

The lake to be retained behind the dam can vary in size and depth depending on the amount and flow rate of water coming down the valleys feeding it. The Corps of Engineers, who are the designers of the dam, have identified three water levels that are important in the design of the flood control facility.

These are the multipurpose pool, the flood control pool, and the maximum pool.

The multipurpose pool is the area of water permanently contained behind the dam. It is planned for use as a recreational area, and the altitude of the water surface will be 5558 feet.

The flood control pool, as its name implies, is considered to be the size of lake that will form when a major storm causes serious flooding conditions. The water surface can reach as high as 5635.5 feet.

The maximum pool is an extreme design case and represents the amount of load that the dam is required to support. The water level of this lake is 5684.5 feet.

Using the elevations of the three lake surfaces the students can find the size of each lake by following contour lines on Figure 2.

Having plotted the three lakes, the students could study the location of the dam and determine for themselves if other positions in the area would be more or less practical. For example, an alternative location has been indicated by dashed line B-B. The line crosses the road a quarter mile down from the dam site, and it has been rotated to ensure that the south end contacts Mount Carbon.

Cross sections of the valley can be plotted by measuring the widths across the valley at each contour line. Comparison of the cross sections at A-A and B-B will show that a dam at B-B would have to be about one-third bigger than at A-A and that its top could be no higher than Mount Carbon is at that point, i.e., 5680 feet. Figure 14 is an example of such a plot. The shaded area shows the difference in size.

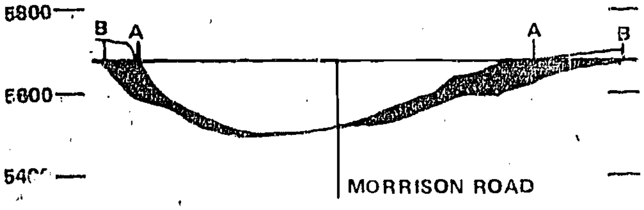


Figure 14 Comparison of Dam Sizes for Two Locations in Bear Creek Valley

Another location could be a quarter mile upstream. The embankment would then be smaller than at position A-A, but the high water mark would extend right up to the edge of the city of Morrison.

Figure 15 shows another location; that is to locate the dam in the narrow canyon above Morrison. The valley is much narrower than below the city so the dam would be shorter. But for that reason the dam must be much higher to retain the same volume of water. Just how much higher the dam must be can be determined by calculating the volume of the valley.

The calculation can be made by plotting cross sections of the valley at various locations, such as at Points 1, 2, 3, 4, and 5 on Figure 15. The lines on the map at these locations extend across the canyon from the 6400 foot elevation on one side to the 6400 foot elevation on the other.

It will help to select a vertical scale that exagerates the depth somewhat. Figure 16 is an enlargement of a plot of the cross section at Point 1. It was plotted on ½ inch grid graph paper. The vertical scale was selected at ¼ inch equals 200 feet or 60.96 meters. The horizontal scale was the same as the map, i.e., 1:24000. Therefore a horizontal quarter inch represents

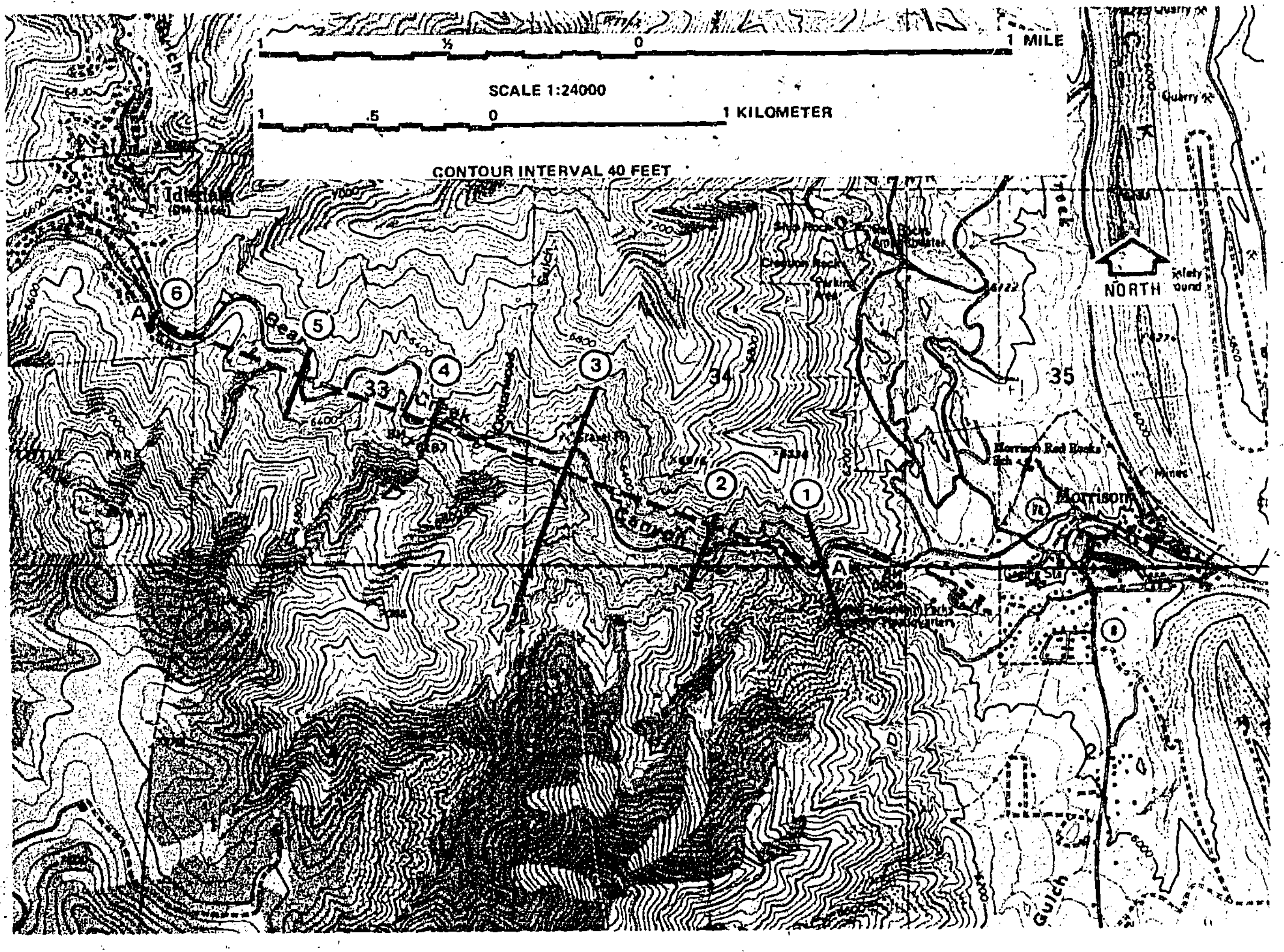


Figure 15 Alternate Upstream Bear Creek Dam Location

$$\frac{0.25 \text{ inches} \times 24{,}000 \text{ (map scale)}}{39.37 \text{ (inches in a meter)}} = 152.4 \text{ meters}$$

Consequently, a quarter inch square on the cross section plot represents a rectangle 152.4 meters wide by 60.96 meters high, 9290.3 square meters in area.

To find the area of the valley cross section it is now only necessary to count how many quarter inch squares are covered. Irregular shapes are "squared off" by counting smaller squares until a total of 25 small squares is reached. The area shown in Figure 16 is about 5.2 "quarter inch squares" or

5.2 x 9290.3 = 48,309 square meters.

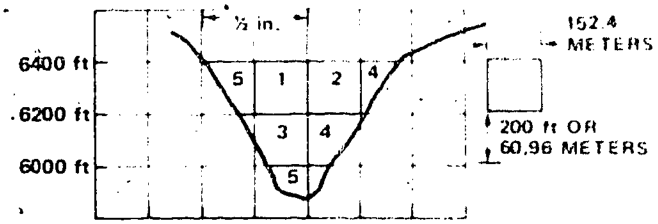


Figure 16 Cross Section at Location 1 in Figure 15

The volume of the valley is obtained by finding the average area at Points 1 through 6. The area at 6 is zero because the 6400 foot contour line crosses the river at this point.

$$\text{Average Area} = \frac{\text{Area}_1 + \text{Area}_2 + \quad \text{Area}_6}{6}$$

The volume is found by multiplying the distance long the line A-A (Figure 15) by the map and by the average area:

Volume (cubic meters)

$$= \frac{\text{Distance A-A (centimeters)}}{100} \times 24{,}000 \times \text{Avg Area}$$

For the valley shown in Figure 15 the calculated volume is approximately 55 million cubic meters.

Calculation of the volume of the Bear Creek Lake can be done in exactly the same way. Assuming an elevation of 5680 for the maximum water level, a volume of approximately 86 million cubic meters was derived.

Thus, a dam in Bear Creek Canyon upstream of Morrison about 500 feet high would only hold about two-thirds the water held by Bear Creek Lake. Increasing the height of this dam would cause the lake to extend into the town of Idledale. So it is evident that the planned location of Bear Creek Dam is the best place it could be.

f. Understand the different types of dams and how they support loads. Dams are classified by the ways they are constructed: timber, rock-fill, earth, and masonry.

Timber dams are rare. They are found where timber is plentiful, where other construction materials are expensive, where performance is not critical, and where the life requirement of the dam is short.

A rock-filled dam is constructed of loose rock with either a watertight upstream face or a watertight core. This dam is economical if the construction material is available in the immediate locality. Because of the looseness of the structure, it is effective in earthquake zones. The dam can be subjected to tremors of considerable magnitude and still retain its capability to hold back the water, while a bonded structure, such as concrete, would fracture and disintegrate. The largest rock-filled dam is the Mica Dam on the Columbia River in Canada. It contains 42 million cubic yards of fill.

An earth dam is probably the most common type of dam because it is constructed of readily available, well-compacted earth. It can be used for both small and large applications. Several methods are used to make the dam less likely to be penetrated by water. It can have a watertight concrete core, it can be lined on the upstream side with concrete, or it can have a water resistant core that is obtained by water-washing the fine sediment in the Earth to the middle of the dam cross section during construction. This fine sedimentation is compacted to form a core that is almost impervious to water.

Fort Peck earth dam in Montana on the Missouri River is the largest dam in the world. It contains over 125 million cubic yards of earth. The Tarbela Dam under construction in Pakistan will contain 186 million cubic yards of earth and rock fill when it is complete.

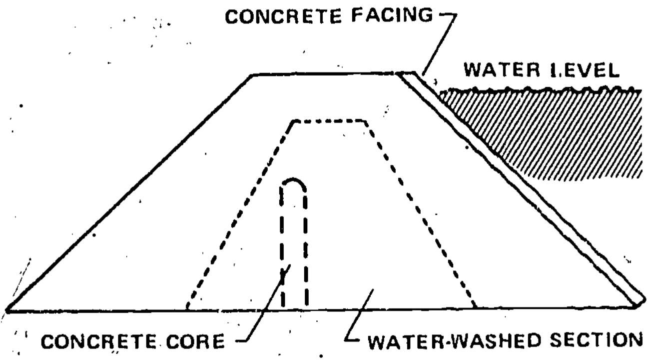


Figure 17 Section of Earth Dam

Masonry dams are classified as either gravity or arch dams. Because these are made of concrete, a dam of this type, with much less fill, can control a reservoir of much greater capacity than if constructed with other materials. Water is supplied to hydroelectric plants from masonry dams because the power plant requirements can easily be integrated into the design of the dam structure, and a clean flow of water can be assured to the turbines.

The gravity dam is massive, and the design depends on the weight of the structure for its strength. This dam is very stable because the resultant force, from the combination of water load and the weight of the structure, is generally in the middle one-third of the base to insure that the total structure is in compression as shown in Figure 18.

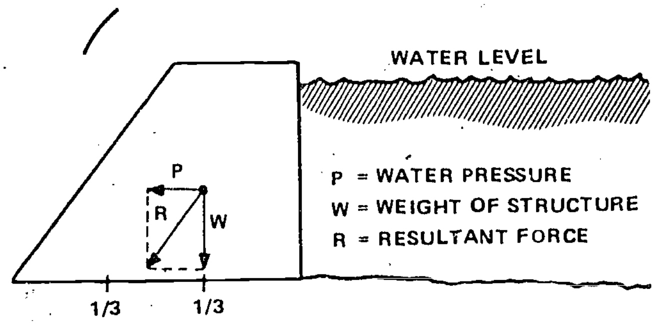
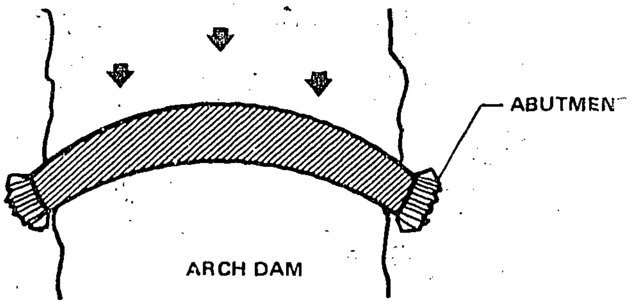


Figure 18 Cross Section of Gravity Type Masonry Dam

An example of a gravity dam is the Grand Coulee Dam on the Columbia River in Washington (shown in the appendix). It has a volume of 10.6 million cubic yards (8.4% of the Fort Peck earth dam) and holds 9.7 million acre-feet of water (50% of Fort Peck dam).

An arch type dam obtains its stability by a combination of arch and gravity action. The sides of the arch are firmly anchored in the canyon walls, and the force of gravity acts downward to add stability to the structure. Good foundations are essential for a gravity dam, but the most important feature of the arch dam is to have firm, reliable supports at the abutments (canyon walls). Many times, the gravity type is built when an arch type would be more economical because the massive size of the gravity dam psycologically is more impressive to the layman.

Hoover Dam on the Colorado River in Nevada is an example of an arch-type masonry dam. The volume of the structure is 4.4 million cubic yards (3.5% of the Fort Peck earth dam) and it holds 29.7 million acre-feet (150% of Fort Peck dam) of water.



There is an interesting list of the major dams all over the world in the World Almanac and Book of Facts. The list gives the height, width (crest length), volume of materials in the dam, amount of water contained, and the type of construction for over a hundred dams all over the world.

g. Understand the immediate and long-range effects of the construction of a dam on the natural and man-made environments. Evaluation of the effects of any construction activity on an environment must start with a definition of what the environment is. In fact, two types of environment must be considered—natural and man-made.

In the case of the natural environment, the student should identify what wild animals and plants live in the region being studied. An approach would be to have the students develop a series of questions such as the following, and then to find the answers from field trips.

Do big game animals such as elk, deer, or bear range through the area? Are there predators like mountain lion, bobcat, or coyote in the region? Do small animals such as rabbit or badger live there? Does the river that is being dammed support families of beaver or otter; or do larger amphibians such as alligator live there?

Are the wild animals in the area protected or controlled hunting permitted?

What natural vegetation [illegible] in the area? Is it a dry sand area with [illegible] vegetation or is it wet [illegible] lush vegetation [illegible] is in the natural [illegible] what is the predominant plant and how does [illegible] interact with others?

Another aspect of the natural environment to be studied is its sensitivity to damage. Is there a risk of forest or brush fires, and is there a danger of permanent damage to the environment? Is there the possibility that the vegetation will grow back again and heal the scars?

Is the terrain the sort that is very sensitive to erosion or to wear by traffic? Is the vegetation irreparably damaged by the passage of half a dozen hikers, or a trail bike?

The term man-made environment refers to the things we humans do to the country in order to live, work, and seek relaxation. Depending on the viewpoint of an observer, the changes we make are necessary, justifiable, or a mess.

We must build houses to live in; factories or offices in which to work; stores where commodites are sold; roads, railroads, and airports for transportation; mines for the extraction of raw materials; and dams for water control. The ways in which we use land are almost limitless and are discussed in more detail in the appendix.

Rather than present detailed descriptions of the environment in the vicinity of the Bear Creek Dam under construction in Colorado, this subject would be better appreciated if the students made their evaluations of their local environments. No verbal description of a natural scene can have the impact that personal experience of an environment can have.

The students should be taken into the field and shown how to find for themselves which plants are natural residents of the area, and which are imported by natural means or by deliberate human action. They should have the opportunity to see, hear, smell, and feel the environment, and to experience for themselves the subtle roles played by insects, animals, birds, plants, and the weather. Not only will this activity provide a basis for evaluating the effects of flooding, but it will also introduce an awareness of the wide variety of factors that interact to preserve the delicate balance [illegible] the natural system.

The effects on the environment result from the activities necessary in the construction of the dam, as well as from the presence of the completed dam.

The construction activities include excavation of the materials for the embankment, transporting them to the site, and dumping and ramming them at the site. A large area of ground is buried under millions of cubic yards of earth or masonary. Other activities that go on at the same time include removal of structures, such as houses, barns, and sometimes factories, from the area where the water will collect. Highways, railroads, and power or telephone lines may have to be rerouted.

The continuing and noisy construction or destruction activity may drive away many of the natural residents and destroy the habitats of many of them. Ironically some wild creatures may not be driven away. Instead they might thrive on the new environment that prevails during construction.

After the dam is complete a new "natural" environment is created. A lake is formed that can become the home where the old residents might return or where new residents, animals or plants, might be attracted.

Depending on the regional planning policies, the dam and its lake may become a beautiful park with facilities for human residents to enjoy recreational activities.

Downstream of the dam, the environment can change. The zoning laws for urban development can be revised to permit construction of buildings in the flood plain so that more efficient use can be made of the land in the city. As a specific case, the city of Denver planning authorities are now contemplating the creation of river valley parks in areas where their periodic destruction by flooding would be inevitable were it not for the protection that is now assured by the flood control dams.

Another aspect related to the effect of the dam is illustrated by an activity that has begun since construction of the Bear Creek Dam started. Intensive excavation of gravel from the valley bottom upstream [illegible] the dam site is now in operation. Two discussion [illegible] arise out of this piece of information. [illegible] the ultimate environmental effect [illegible] excavation?" The answer is that [illegible] the e[illegible] in the area to be filled with water [illegible]ely will be covered. Also, [illegible] has been [illegible] the soil particles that have settled d[illegible] in the [illegible]vel beds are rich in nutrients for the fish population of the lake.

The se[illegible] discussion topic is: "How did the gravel be[illegible]ey are located where narrow steep val[illegible] to the gentler foothill slopes. Evidently [illegible]ial that eroded from the mountai[illegible]ropped by the rivers at the points w[illegible]er velocity decreased suddenly.

The f[illegible]ghts are but an introduction to the dis[illegible]vironment and how it can be changed. [illegible] provide a stimulus to creative thoug[illegible] in [illegible]assroom and in the field.

B. Other Land Studies

1. WHY MAKE LAND SURVEYS?

Surveys [illegible] methods of finding information about land [illegible] it is like, how it has been used, and how it [illegible] used.

A classic[illegible] of survey is that of locating property line[illegible] description. Three different types of sys[illegible] used throughout the United States—one for [illegible] of the Ohio River, one for Texas, and [illegible] Township/Range method. The latter system locates land by Township (measured north and south of a reference lattitude "Baseline") and by Range (measured east and west of a reference longitude called a "Principal Meridian"). This system uses 39 different sets of Baselines and Principal Meridians for about three-fourths of the 48 states, and five sets of Baselines and Principal Meridians in the State of Alaska. Figure 19 shows the baselines and principal meridans for the United States. An application of this is shown in Figure 2, which shows [illegible] range and township boundaries in the Bear Creek dam area. Additional information on this subject can be obtained from the local Bureau of Land Management.

In urban areas, surveys are [illegible] traffic [illegible]ties to determine the routes that [illegible] most heavily travelled. The most common [illegible] place pressure tubes across the roads to count the number of times vehicles [illegible] over them. Other traffic surveys are conducted by observers at strategic locations. Traffic surveys of this type can count the number of vehicles by type—private cars, delivery trucks, buses, ambulances, etc. while the pressure tubes count only wh[illegible].

Sometimes it is necessary to determine who the people using the roads are, where they live, and where they are going. Public transport system planners need information to develop the most useful passenger routes. In surveys of this type samplings are made of the traffic at specific times; vehicles are flagged down, and a few simple, well chosen questions are asked of the driver and passengers. Because it is important that the people questioned should be delayed only a few seconds, the questions must be carefully planned, and the questioner should be able to record the answers on a report form prepared in advance.

Rural land surveys are conducted for many reasons:

There are parts of the State of California where agriculture survives through intensive irrigation. Farmers using irrigation water are required to pay for the water according to the amount used. The method used is to assign an irrigation tax based on the type and acreage of crop to be grown. Some crops need little water; some need a lot. Figure 20 is a Skylab photo of agricultural land adjacent to the Salton Sea in Southern California. It clearly shows the pattern of fields in the area.

The irrigation authorities in California discovered that some farmers were paying taxes based on one crop but were growing crops that required higher taxes. A system of aircraft surveys was introduced to identify crops in photographs of the area.

The technique of making these crop surveys relies on the "spectral signature" of the crops. If a number of fields with different crops are photographed at the same time with cameras sensitive to

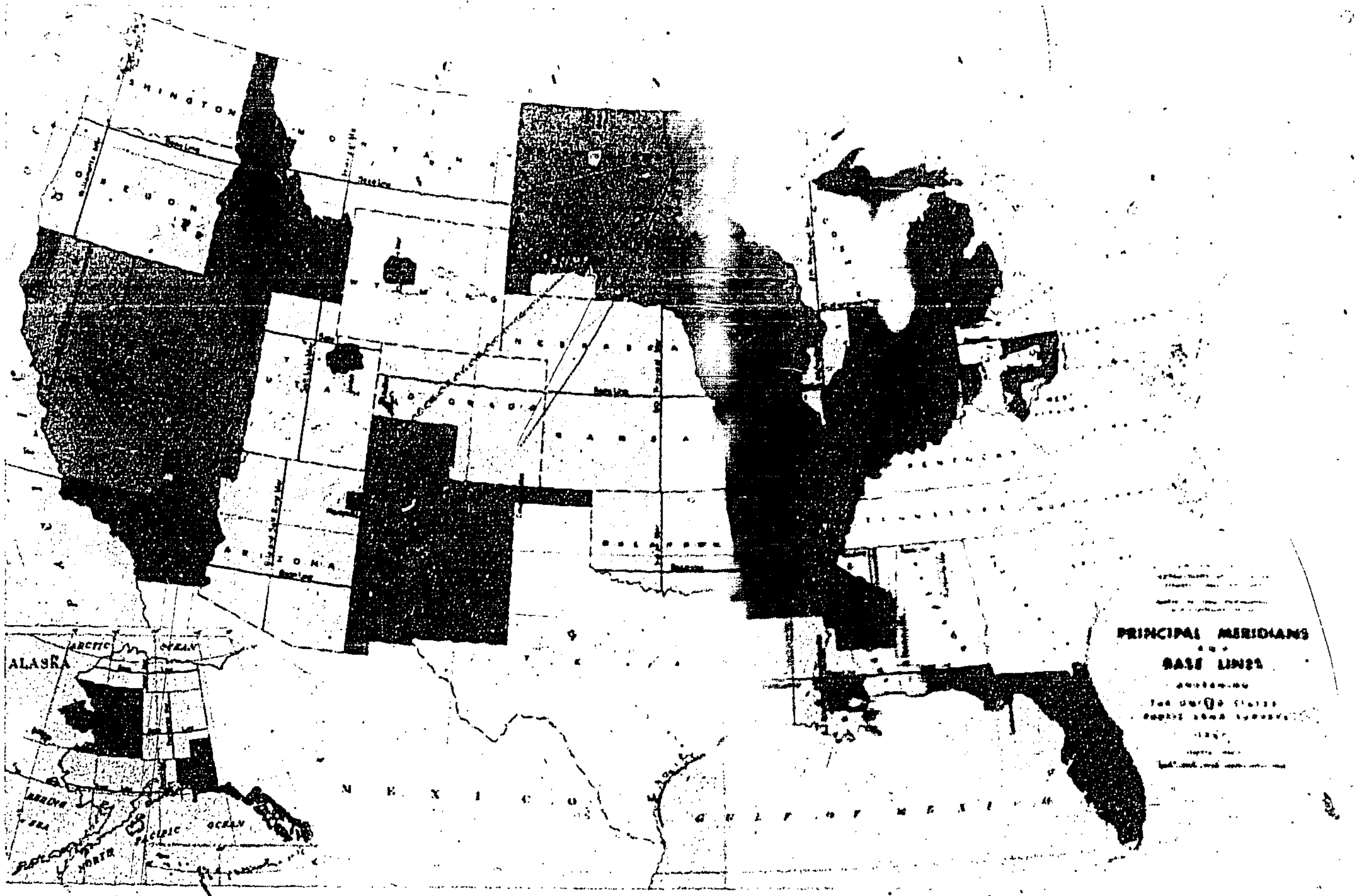


Figure 19 Principal Meridians and Baselines in U.S.

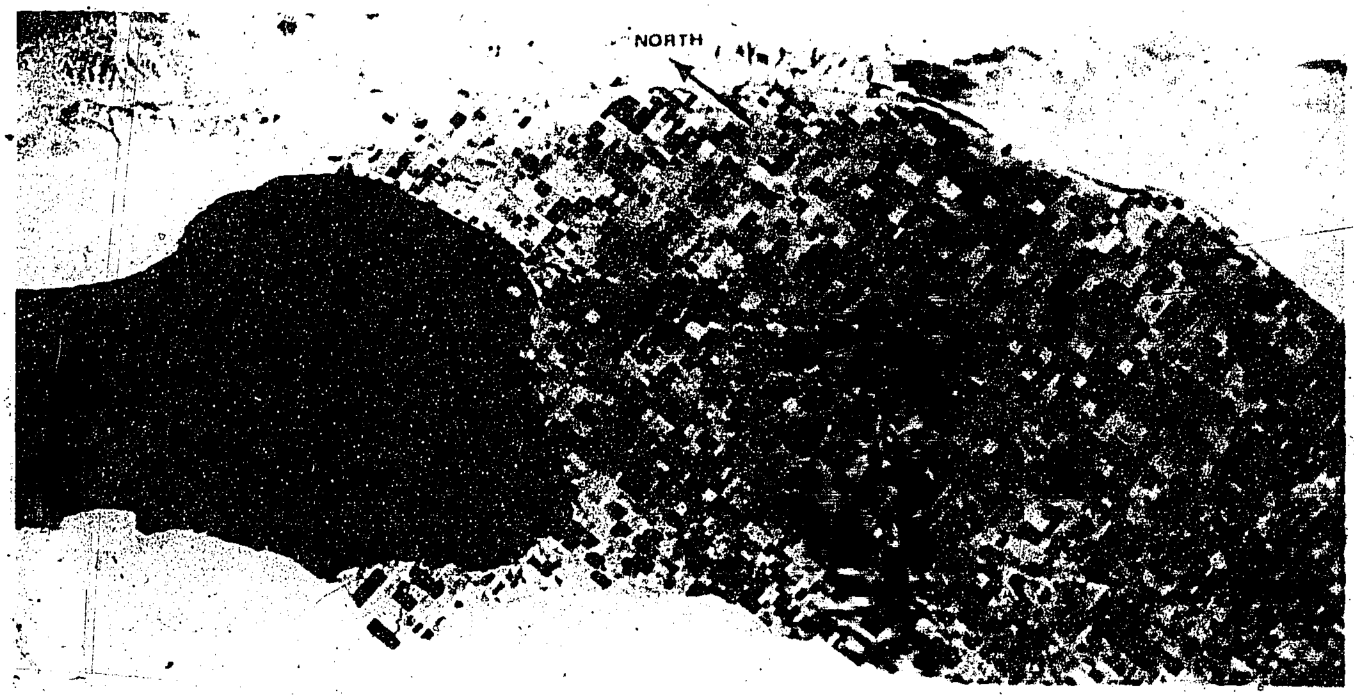


Figure 20 Skylab Photo of Salton Sea Area, Southern California (June 15, 1973)

different wavelengths in the visible and infrared wavebands, the various crops will have different appearances in the photographs. The surveyor only needs to have positive identification of one field bearing each crop to identify all the fields in the photographs. This technique is described in more detail in *Observing Earth From Skylab*, a companion volume in this series.

In the California grape country, raisins are produced by spreading the grapes on kraft paper sheets on the ground between the rows of vines. Airborne photographic surveys were made to determine how many acres of the vineyards were "laid to raisins." The photographic team developed an experimental program to determine the combination of photographic films and filters that gave the clearest spectral signature of the raisin drying areas. Then by comparing the quantity of grapes on the ground with the quantity on the trees in a few sample areas, a statistical survey was made daily of the entire area. In this way, a balance was maintained in the harvesting of the grapes for raisins, for fortification of wines, or for the table.

2. SURVEY OBJECTIVES

Before any survey can begin, it is necessary to identify the subject and the reasons for the survey—in other words, to identify the objectives. The number of survey topics that can be addressed by students is limitless. In this section, a few examples of survey topics with suggested objectives are presented.

One topic could be to determine the distribution of recreational land in a city relative to where the users live. The objectives of this type of survey could be:

1) To relate the distribution of recreational facilities to population distribution;
2) To develop an understanding of the factors that govern the location of recreational facilities;
3) To relate the recreational facilities to the complete ecosystem, i.e., the effect the facilities have on wildlife, plants, etc. or the importance of the wildlife on recreational activities in the facility.

Another topic could be a rural survey to estimate the percentages of different crops in an area. Some objectives of this kind of survey could be:

1) To e[illegible] the role of the agricultural industry in the [illegible] ecosystem and man's place in it:
2) To locate the fields of farmland in the area and to identify what crop was planted in each field;
3) To define the number of acres of each crop in the area:
4) To define dryland farmland and irrigated farmland. (For example, in Figure 21 the difference in appearance between dryland farms and irrigated farms is quite clear. The fields along the river valley at the lower edge of the picture are irrigated. The fields in the middle of the frame are dryland farms.);
5) To estimate the yield of the crops in the area;
6) To coordinate with the local farm bureau to determine the accuracy of the survey.

Other survey topics for students include:

1) The distribution of industries in the local area;
2) The environmental effects of industries in the local area;
3) Local transportation patterns;
4) Factors influencing the location of industry in a rural area;
5) Trends in residential growth;
6) Factors influencing preservation of wildlife in the area;
7) Application of unused land for agriculture;
8) Environment and pu[illegible] of range land;
9) The role of the forest in our natural environment.

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Another topic could be a rural survey to estimate the acreages of different crops in an area. Some objectives of this kind of survey could be:

1) To e[illegible] the role of the agricultural industry in the [illegible] ecosystem and man's place in it;
2) To locate the fields of farmland in the area and to identify what crop was planted in each field;
3) To define the number of acres of each crop in the area;
4) To define dryland farmland and irrigated farmland. (For example, in Figure 21 the difference in appearance between dryland farms and irrigated farms is quite clear. The fields along the river valley at the lower edge of the picture are irrigated. The fields in the middle of the frame are dryland farms.);
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6) To coordinate with the local farm bureau to determine the accuracy of the survey.

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6) Factors influencing preservation of wildlife in the area;
7) Application of unused land for agriculture;
8) Environment and pu[illegible] of range land;
9) The role of the forest in our natural environment.

IV. Types of Data for Land Use Studies

After a student survey has been selected and the objectives are clearly defined, the next step is to apply the available data. In almost all surveys, maps are required.

In general, two types of maps are mandatory—U.S. Geological Survey Maps and aerial photographs. For surveys to be conducted within the boundary of a city, a current "gas station" city map will add information. For larger surveys, a current "gas station" state map may also be helpful. Sometimes, special survey maps, such as Corps of Engineers plans or Bureau of Reclamation plans, are necessary.

U.S. Geological Survey maps are available from any regional federal center or from some sporting goods stores. The address of the nearest federal center can be obtained from the telephone directory listing entitled "United States Government." More details on what to order and what to expect are given in Section A of this chapter.

Other types of data include direct observations of features recorded in photographs or in notebooks; measurements made in the field by means of surveyors tools such as measuring tapes, levels, and transits; or data obtained by "remote sensors."

In this publication, the term "remote sensor" is applied to systems that record information from above the ground by instruments in aircraft or in spacecraft, i.e., the camera, an altimeter, or a spectrometer. These data are available as photographic images or as electronic information on magnetic tape.

Three general types of vehicles have been used to obtain remotely sensed data gathered from above the surface of the Earth—by aircraft, by earth resources satellites, and by NASA's Skylab spacecraft. The Space Shuttle, scheduled for launch in the late 1970's, will also obtain remote sensor data.

Aerial photographs of all areas of the United States are available in several different forms. Aerial photographs have been taken from altitudes of 12,000 to 25,000 feet of areas from about 4.5 miles square to 9 miles square respectively. The classical application of data obtained by aircraft is for map-making. The information is generally obtained from photographs that are used to update existing maps, to make new maps of unmapped areas, and to provide accurate contour information through analysis of stereo photographs (see *Why Survey From Space*, NASA Facts NF-57/1-75).

Aerial photographs are available from the U.S. Geological Survey Photo-Mapping Service, the U.S. Department of Agriculture, NASA and from the National Oceanic and Atmospheric Administration.

Remote sensor information is provided by ERTS-1, the first Earth Resources Technology Satellite, that was launched by NASA in July 1972 and is still providing information to the ground.

ERTS-1 orbits the Earth at an altitude of about 920 kilometers (570 miles) in an orbit that passes close to the North and South Poles. This was the first of a series of satellites with the primary purpose of demonstrating the usefulness of remote sensor data in the study of surface conditions of the Earth. This unmanned satellite completes one complete cycle of scanning the Earth's surface every 18 days. Information obtained by instruments scanning a 185-kilometer (115-mile) square area is transmitted to the ground electronically and converted to photographic images in four different wavebands: two in the visible light frequency and two in infrared. Figure 21 is an example of a photograph obtained from this satellite.

When the second satellite in this series was launched in January 197[illegible], the program name was changed to LANDSAT. ERTS-1 became LANDSAT 1 and the new satellite is LANDSAT 2, which has a design life of two years. A third LANDSAT launch is planned for 1977.

Remotely sensed data were obtained from Skylab in three manned missions from May 1973, to February 1974. Earth resource data were obtained as photographs and as electronically produced images. Some areas were photographed at the same time by two camera systems. One was a combination of cameras that produced photographs in six different wavebands—three in the visible and three in infrared—all obtained at exactly the same time. Figure [illegible] was obtained by one of these cameras on June [illegible], 1973. The other was a high resolution camera that obtained photographs in either the visible or infrared wavelengths. Electronic data were obtained for altimeter applications, for determining surface brightness temperature, and for recording the reflected radiance of the Earth's surface in many different wavebands. *Observing Earth From Skylab* (NF-56/1-75) contains more information on these instruments and the data they obtained.

A. Where to Obtain Remotely Sensed Data

The following paragraphs give detailed information on the types of data available from different sources and show how to obtain it.

1. EARTH RESOURCES OBSERVATION SYSTEM (EROS)

Earth resource data can be obtained by writing to the EROS Data Center, a division of the Department of the Interior. The address is:

EROS
Data Management Center
Sioux Falls, South Dakota 57190

The EROS Data Center will assist in locating imagery and photography to suit the particular needs of the user. The center's computerized storage and retrieval system is based on geographical coordinates (latitude and longitude), the date and time of day the photographs were obtained, and the scale of the photographs.

The requestor may provide the center with the latitude and longitude of a point of interest or may define an area by giving latitude and longitude of a maximum of eight perimeter points. On receipt of a request the center staff will locate the area of interest and will prepare a listing of photographs from which the requestor can make the final selection.

EROS stocks Skylab photographs as well as LANDSAT (ERTS) photographs. The Skylab spacecraft operated at about half the altitude of LANDSAT. Consequently Skylab photographs contain more detail than LANDSAT.

If you elect to use Skylab photographs in your study, it is possible to help EROS speed up your order by quoting the specific photograph numbers of the scene you need. You can write to the following address for help.

Lyndon B. Johnson Space Center
Research Data Facility
Mail Code TF-8
Houston, Texas

Include the names of prominent features in the area. City names, rivers, and mountains should be included as well as latitude and longitude. Research Data Facility personnel will check through their catalogs and provide you with photograph identification numbers that you can then send to EROS to obtain the copies you need.

At the time of writing the prices of EROS photographs are:

ERTS/LANDSAT

Paper Print	Scale	Black & White	Color	Area of Photograph
70 mm. square	1:3,369,000	$1.25	— —	149 mi sq
9x9	1:1,000,000	$1.25	$ 7.00	140 mi sq
18x18 in.	1: 500,000	$3.50	$15.00	140 mi sq
36x36 in.	1: 250,000	$9.00	$25.00	140 mi sq
Film transparencies are available at two to three times the above cost.				

SKYLAB

Image Size	Print Price	Black & White Transparency	Scale	Area of Photograph
2.2 in. sq		$2.00	1:2,850,000	100 mi sq
6.4 in. sq	$ 2.00	— —	1:1,000,000	100 mi sq
12.8 in. sq	$ 5.00	— —	1: 250,000	100 mi sq
25.6 in. sq	$12.00	— —	1: 250,000	100 mi sq

Color reproductions cost about three times as much as black and white. For more details write to EROS at Sioux Falls, South Dakota.

Another outlet for EROS services is located in Bay St. Louis, Mississippi. At the National Space Technology Laboratories, anyone can obtain a wide variety of Earth resources information and order photographs by writing to the following address:

National Space Technology Laboratories
Bay St. Louis, Mississippi 37520

2. U.S. GEOLOGICAL SURVEY

U.S. Geological Survey (USGS) maps are available from any regional Federal Center and from certain commercial stores such as sporting goods stores. The nearest address should be listed in the telephone book under "United States Government—U.S. Geological Survey."

The most common USGS maps are of an area 7½ minutes square or 15 minutes square—that is, 7½ or 15 minutes of latitude and 7½ or 15 minutes of longitude. The scales of these maps are 1:24,000 and 1:62,500 respectively. Both are sold for 75 cents each at the time of writing.

Other maps are available. Check with the USGS office for more details.

3. SKYLAB EARTH RESOURCES DATA CATALOG.

The *Skylab Earth Resources Data Catalog* (GPO-3300-00586), prepared by NASA, provides a complete index of Skylab earth resources photographs and other data, plus direction on how copies can be obtained. It also provides a discipline-by-discipline review of possible uses of the Skylab photographs and data with appropriate illustrations. It is intended as a basic reference work, or tool, for farmers, scientists, engineers, students, mineral developers, or anybody else who has a specific need to obtain, interpret, and use remotely sensed information.

The catalog is divided into six major subject areas:

1) Land resource management—This term encompasses familiar issues of public policy related to such matters as population growth, economic development, land use, depletion of natural resources, urban planning, transportation, and environmental impact. To meet dynamic mapping and monitoring requirements, satellite data are currently being used by seven states (Alabama, Alaska, Arizona, California, Iowa, New York, and Ohio) and three interstate planning agencies in the Midwest, New England, and the Middle Atlantic regions.

2) Water resources—Skylab and other space data are well suited to: exploring for new sources of water; making inventory of existing water supplies in lakes, reservoirs, rivers, and snowfields; and assessing water quality in terms of turbidity, sedimentation, and temperature (by thermal scanning). Depths of shallow bodies of water can also be estimated with some precision. Space observation can establish the area of a watershed and facilitate study of stream channels in relation to an entire drainage system, runoff patterns, and possibility of flooding. River ice, crucial to transportation and flood prediction in some parts of the country, can be watched. Coastal lands, estuaries, and wet-lands—with their ecological as well as economic significance—can be delineated for analysis.

3) Marine resources—From seeking to establish patterns of movement of schools of fish to measuring degrees of roughness of the open sea, Skylab data have increased our knowledge of the world's oceans and helped point to operational marine satellite systems. Better weather forecasts and charts of ocean currents and ice conditions are expected as direct results. To measure oceanic roughness or sea state, a matter of vast practical importance to shippers, Skylab successfully tested a combination of instruments (radar scatterometer, microwave radiometer, and altimeter) that provided ocean-wide readings starting at small-scale roughness. Channels, shallow areas, river discharges of sediment, and other features of waterways often show up better from space than by any other means.

4) Geology and mineral resources—Obviously, space photography and data acquisition are made to order for geologic investigators in every facet of their work from theory to actual mineral prospecting. In exploring for minerals and hydrocarbons, the cost per mile of space coverage is lower than for any other method. Major mineral exploration organizations have been working with Skylab and LANDSAT 1 data while incorporating use of space data in plans for the future. Space sensing, it is pointed out, should be seen as one basic step in the overall prospecting program. After reviewing satellite data, mineral exploration target maps can be constructed with a rating system to indicate the relative likelihood of deposits in each target area. Decisions on further exploration—such as aircraft remote sensing, seismic profiling, geochemical analysis, or field testing—can then be made with a far greater chance of success.

5) Agriculture, forest, and range resources—Survey of the world's rice crops and battling Black Hills beetles are only the beginning in these fields. Potential space applications are enormous: crop and timber inventories, yield estimates, comparative analyses of crops, detection of diseases or insect infestations of vegetation, reconnaissance for potential logging operations, location and mapping of forest and range fire damage, determination of animal-sustaining capacity of range forage, and multiple use planning for forest and range lands. Skylab and LANDSAT 1 data and experience have made major contributions, and now are pointing the way to further hardware and techniques.

6) Environment—In a broad sense, all Skylab effort deals with man's environment. The data also proved particularly useful regarding specific environmental problems. Sources of water and air pollution often can be located and the spread of contaminants traced for long distances in a single photograph. Looking ahead, Skylab demonstrates the advantages of an Earth resources package, including both high resolution cameras and electronic sensors, complementing each other's capabilities to perform a four-part environmental mission in space: detection, determination of source and extent, direction of aircraft surveys and ground measurements, and monitoring changes.

The *Skylab Earth Resources Data Catalog* is obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Price $12.50). The book number is GPO-3300-00586.

4. AGRICULTURAL STABILIZATION AND CONSERVATION SERVICE (ASCS)

Three different types of Earth resource data are available from the U.S. Department of Agriculture ASCS—ERTS/LANDSAT data, Skylab data, and aerial photography.

The ERTS/LANDSAT and Skylab data can be ordered from ASCS in a similar manner and similar cost as from EROS. The aerial photographs can be ordered by state and county, and by symbol, roll, and exposure number as listed in the state ASCS office. These photographs can be ordered from either the Eastern or Western ASCS offices. The addresses are listed below:

Eastern Aerial Photography Laboratory
ASCS - USDA
45 South French Broad Avenue
Ashville, North Carolina 28801

Western Aerial Photography Laboratory
ASCS - USDA
2505 Parley's Way
Salt Lake City, Utah 84109

If the state ASCS office is not convenient, either laboratory above will assist in identifying the numbers of the desired photographs. Typical costs of the photographs are:

Size of Prints	Approximate Scale	Cost of Paper Prints	Cost of Film Positives
9½x9½ in.	1:20,000 (1 in. = 1667 ft)	$ 2.00	$3.00
12x12 in.	1:15,840 (1 in. = 1320 ft)	$ 4.00	$4.50
17x17 in.	1:12,000 (1 in. = 1000 ft)	$ 5.00	$5.50
24x24 in.	1:7920 (1 in. = 660 ft)	$ 6.00	$7.50
38x38 in.	1:4800 (1 in. = 400 ft)	$12.00	$6.00

5. FOREST SERVICE

The Forest Service, a division of the U.S. Department of Agriculture can provide aerial photographs of numerous locations in the United States. Black and white, or color prints can be obtained of scenes photographed in visible light or infrared wavelengths. The prints are in a range of scales, predominantly 1:15,840 and 1:80,000.

Requests should be sent to the Regional Forester in your area. The address should be listed in the telephone book under "United States Government—U.S. Department of Agriculture." Alternatively you can write to: The Forest Service, U.S. Department of Agriculture, Washington, D.C. 20250.

B. How to Use Data

The multidiscipline study plan described earlier in this publication outlines the use of data for a study of a flood-control dam. A different type of study, such as a rural survey with the objectives of studying agricultural land use, would require that the data be used somewhat differently.

A rural study requires the same kind of data: a gas station map, aerial photographs, multispectral space photographs, and USGS maps.

First, the user would study the area of concern on each of the above data. Each set of data would then be related to each other to obtain a thorough understanding of the area of the survey. The gas station map will present the area in a large scale and in a format familiar to the user. It would generally orient the area in relation to streams, lakes, cities, highways, and railroads. The aerial photographs reveal the study area in a scale so the user can recognize all major features—buildings, fields, structures, rivers, vegetation, etc. The aerial photographs can be obtained in approximately the same scale as the USGS maps that define geological features: Space photographs are valuable in this type of study because they show the watershed areas, streams, valleys, and general land formations in a large area. Multispectral photographs from aircraft or spacecraft can be used for crop identification and detection of crop disease.

After the user is familiar with the data collected and has combined the essential features on a single layout, a field trip should be made to the study area to compare actual conditions to those indicated on the maps and photographs and ensure that the layout is up to date. To identify the crops that were in each field at the time the multispectral pictures were obtained, the user must identify at least one field of each crop in the area. This will make it possible to establish the "spectral signature" of that crop as derived from the multispectral pictures and then to identify every like crop in the area by merely analyzing the multispectral photographs taken during that same growing season. Refer to *Observing Earth from Skylab*, NF-56/1-75, and the Skylab Earth Resources Data Catalog for more information regarding the interpretation of multispectral photographs. The technique consists of comparing the gray tones in the photographs with a graduated gray scale, such as is marketed by Kodak, and recording the set of tonal values for each field. All fields with the same combination of tonal values (spectral signature) should have the same crop in the same state of growth.

To determine the total area planted to each crop in the scene, the user can measure the area of all the fields with the same "spectral signature." Also, by similar analysis of multispectral photographs of the same scene taken throughout the growing season, the relative health of the plants can be determined, thereby allowing the user to estimate the yields of the crops.

High resolution and infrared photographs can be used to locate irrigation ditches and to differentiate between the irrigated and dry-land farming areas.

After the spectral signatures have been established for the entire area, a field trip should be taken to fields not visited previously to verify the accuracy of the survey. The final results should be coordinated with the local farm bureau office where these types of data are gratefully received. Here, the user can get an appreciation of the reasons for rural surveys.

Appendix

How Land Is Used

This appendix has been prepared to enable educators to help students understand the interactions between the community, the environment, and the land. Suggestions are included for classroom activities or discussion themes to stimulate creative thoughts by the educators.

Cities, highways, and industry take up about 3% of the total land area in the United States. About 60% of the land is used for agriculture and livestock. The remaining 37% comprise government land and reservations.

Land prices vary tremendously based on location and potential use. A square foot of land may cost $200 in a metropolitan area and less than a tenth of a cent for some livestock pastureland. To a large extent, the price of land determines what it will be used for—where to route highways or power lines, where to locate a factory, and where to build permanent or recreational homes. There are other considerations involved in the use of land. Sites of historical or religious interest may be preserved against development regardless of cost. More effective use of land becomes increasingly important as population grows and technology advances.

URBAN LAND USE

Land in a metropolitan area is used for the following purposes: commercial use, housing, recreation, utilities, and transportation.

Commercial Use

Commercial land uses range from the small merchant's store on Main Street to the large old industrial plant on the fringe of the downtown area or the new industrial area in the suburbs. Each has its role in the economy of the community. The business use of land is based on a number of economic factors and can be summed up by the concept that the income from the business, in addition to paying salaries and profits, must support the cost of owning and maintaining the land on which it is situated.

Different types of businesses have different land use requirements. The basic requirements for a jewelry merchant are a display area for his wares and a small storage area for his inventory. His merchandise is characteristically small in size but high in value; his entire inventory is not bulky.

A doctor's needs are different—a waiting area and a number of private consultation rooms are the principal requirements. Space for storage for the doctor is also a very minor consideration.

The large factory is a different case. Storage requirements almost equal the area devoted to manufacturing. Transportation is an important element in determining the location of a factory. Employees must be able to travel to and from their work. If adequate public transportation is not available or used, parking area must be provided. Delivery of raw materials to the factory must be possible by road or rail, and delivery of finished products must also be possible. Ask the student to list the special transportation requirements of the following factories.

A factory that makes automobiles.

A factory that makes ships.

A factory that makes airplanes.

A factory that makes potato chips.

Have the student list some other businesses that have their own unique land use requirements.

Housing

Residences must be made available for all levels of income and require a considerable amount of land area. Zoning of residential areas must be seriously considered because families with the same income place different emphasis on their living conditions. A family in the high income bracket may prefer a beautiful large home with open space, while another will prefer a plush city apartment with no maintenance worries. Certainly these types of dwellings cannot be permitted to be randomly built throughout residential areas because the objectives of both groups would be defeated. In the middle or low income brackets, one family may place emphasis on a late model car and another family with similar income will prefer to drive an older model and spend the resulting savings to upgrade their residence. "A man's home is his castle" regardless of the type it is. Whether large or small, housing costs represent the largest part of most family budgets. For these reasons, all metropolitan areas provide for varying property sizes as well as home sizes.

Request your students to list some areas in their community that are zoned for apartments and some areas that are zoned for one-family residences. Also, have them list other categories of zoning besides housing areas.

Waterfront Apartment Towers, Boston, Massachusetts

Recreation

Recreational areas are established where people can enjoy their leisure time. Lakes, parks and playgrounds provide for family enjoyment. Athletic fields are provided to encourage people of all ages to participate in some form of athletics to maintain good health in the community. One of the largest uses of land for organized recreational purposes is for golf courses.

As the standard work week is reduced, people have more time to use recreational areas, and because there is less manual labor required by most jobs, people need more recreation. Here, again, the population increase and the technology advancement directly influence the need for these areas.

Because recreation also includes watching athletic activities, spectator space must be provided at athletic fields, race tracks, etc. Making a list of athletic activities existing in your local area will help to identify the ones most likely to attract spectators and those which are least likely.

Utilities

Land must be provided in or near cities for utility services that are necessary for society to function. Gas, oil, and coal are extracted from the earth and are used to generate electricity. Power generating stations are large facilities in which the energy in gas, oil, or nuclear fuel is converted into electrical power. Characteristically, power generating stations are located in or near the cities so they are close to the users of the power they generate. Gas and oil-powered generating plants, or power stations, need fuel supply systems. Coal-fired power stations need coal storage areas in addition to supply lines.

Regardless of whether oil wells are located in the area, most cities of significant size in the United States contain oil refineries. An interesting class activity would be to talk to local oil refinery officials to discover why this is so.

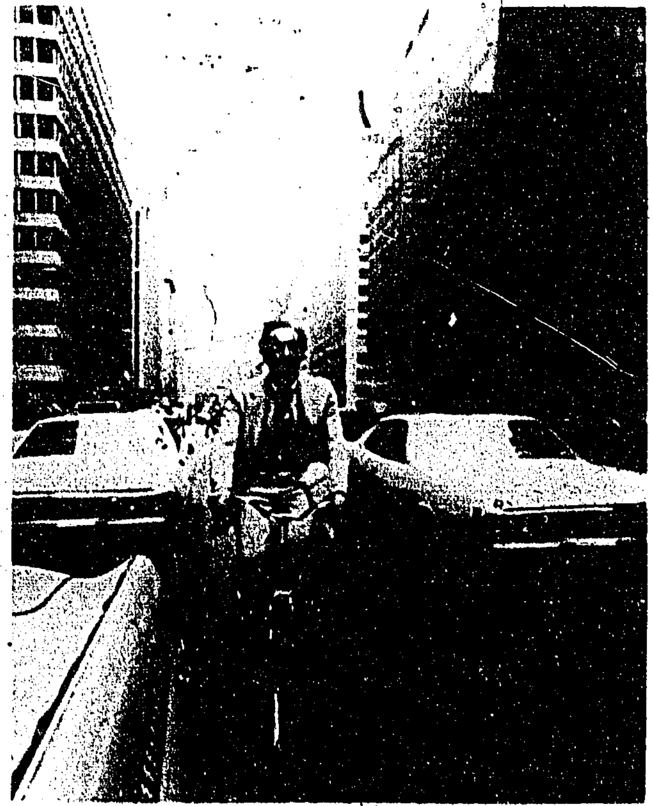
Water supply is another utility essential to the community. Water supplies are drawn from underground sources or from water that has drained into the river valleys and collected in reservoirs. These reservoirs may be many miles from the cities. Purification and pumping stations are usually located very close to the cities. This minimizes the possibility of contaminating the water by pumping it through long supply pipes after it has been purified.

At the other end of the utility spectrum are waste disposal systems for sewage and trash. These systems have their unique land use requirements, and also require rigorous environment protection efforts. Have your students list some environmental restrictions that must be imposed on the location of waste disposal systems.

Transportation

Transportation is a vital part of our society and has a wide variety of land use needs. Roads and railroads are necessary to link communities. They are used within the communities to move people and merchandise and to provide services.

A familiar urban feature is the parking lot for the vehicles that use the roads within and between communities. Ask your students to give the railroad equivalent of these areas.



Urban Transportation in Manhattan

Raw materials for energy production require transportation systems. Oil production requires ocean terminals where fuel is pumped into or out of tankers. In January 1975, President Ford signed a bill supporting the development of deep water harbors in the United States for use by giant oil tankers. Ask the class how deep these harbors must be to accommodate the very large oil tankers.

The location of new airports and the expansion of existing ones has another set of land use considerations. Aside from obvious problems of large amounts of land required, there are other factors to consider, such as safety and noise pollution.

RURAL LAND USE

Land in rural areas has a variety of uses including: agriculture, industry, energy production, transportation, forestry, recreation, and environmental protection.

Agriculture

Throughout the world the agricultural uses of land are the same: raising livestock and producing crops. But that is where the similarities end. The techniques of raising livestock vary widely. In India cattle are considered sacred and are permitted to go where they wish without control; there is no attempt to convert cattle to food. The Masai Tribe in Kenya, Africa, graze their cattle on very sparse vegetation but do not slaughter them for the meat. Instead, they use the blood of the animals for food.

In Denmark, where the yield of food per hectare (2.471 acres) is possibly the highest in the world, cattle are grazed wherever grass grows. In the United States, cattle are grazed first on the open range and then fattened in feed lots where maximum special food and minimum physical exertion of the animals produces tasty beef for the table.

Egg production in the United States as well as parts of Europe has become highly mechanized. Chickens used in mechanized egg production never see the light of day. Chicks are hatched in incu-

Example of the Combination of Sea and Land Transportation (Prepacked containers transported on ships are loaded on trucks for direct overland delivery.)

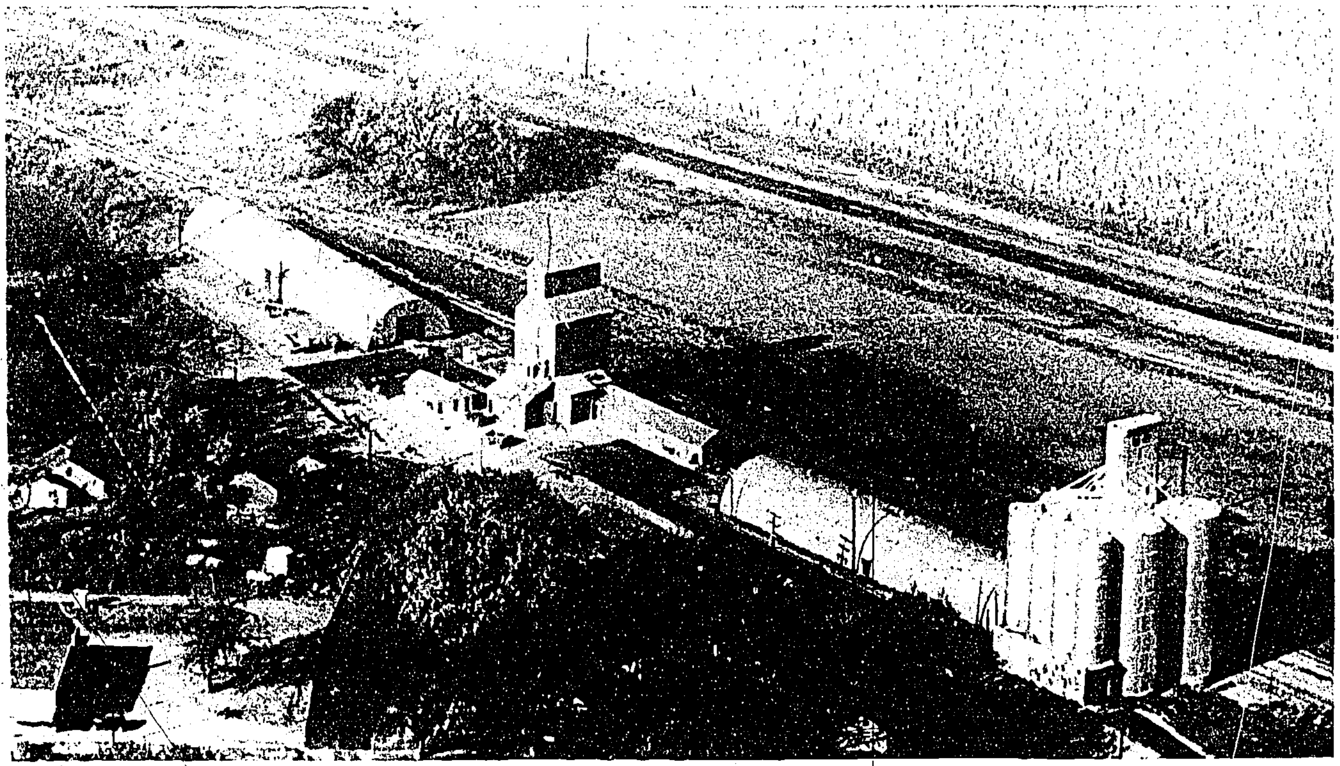
bators and raised in brooder houses. An incubator maintains the temperature and humidity better than a mother hen and produces higher hatch success. The brooder provides the young chicks with the ultimate in living conditions for the first few weeks of their lives. Adult chickens then spend the rest of their productive lives in cages. Food and water are provided automatically. Illumination of the building is artificial and is controlled automatically. Eggs are collected, checked, graded, cleaned, and packaged automatically (for more detailed information, see the *National Geographic Magazine*, February 1970).

Similar levels of mechanization are possible in the production of milk and milk products. Ask your students to identify some of the machines used in milk production.

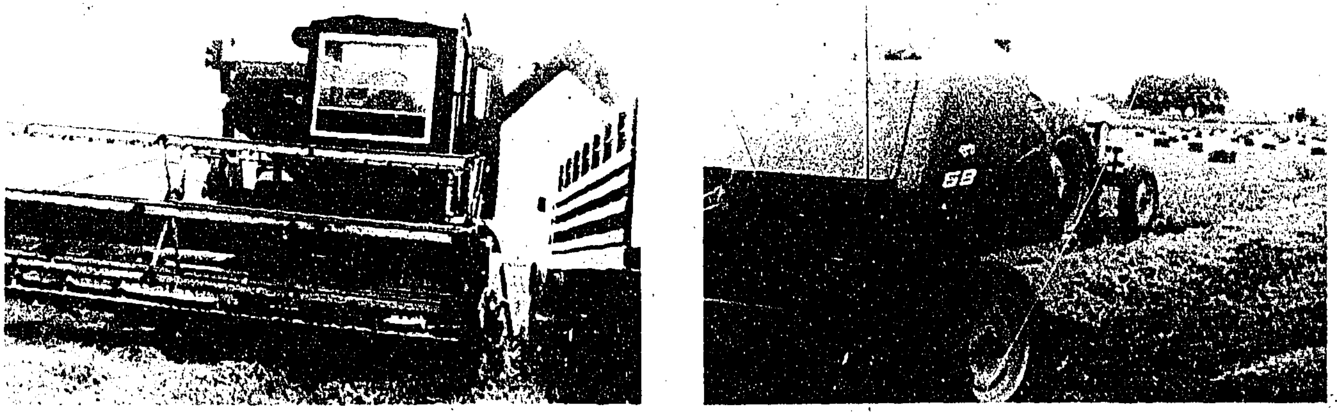
Similar variety exists in the area of crop production. There are still parts of the world where crops are grown on land that is cultivated in the slash and burn manner. The trees and brush on the land are cut down and burned, and crops are planted on the soil that has been "enriched" by the ash. When the soil is depleted, another area of forest is cut and burned.

In some areas in Southeast Asia, rice is grown on terraced fields that follow the contours of all but the steepest hillsides so that very little available land is wasted.

Crop production in the United States varies from the small truck garden where vegetables are grown for sale at roadside stands, to the vast, highly mechanized, wheat farms of the midwest where plowing, planting, fertilizing, protecting against pests, and harvesting are all performed by machines (again see *National Geographic Magazine*, February 1970).



Cooperative Storage of Farm Products in Danbury, Nebraska



a. Combining Wheat

b. Baling Hay

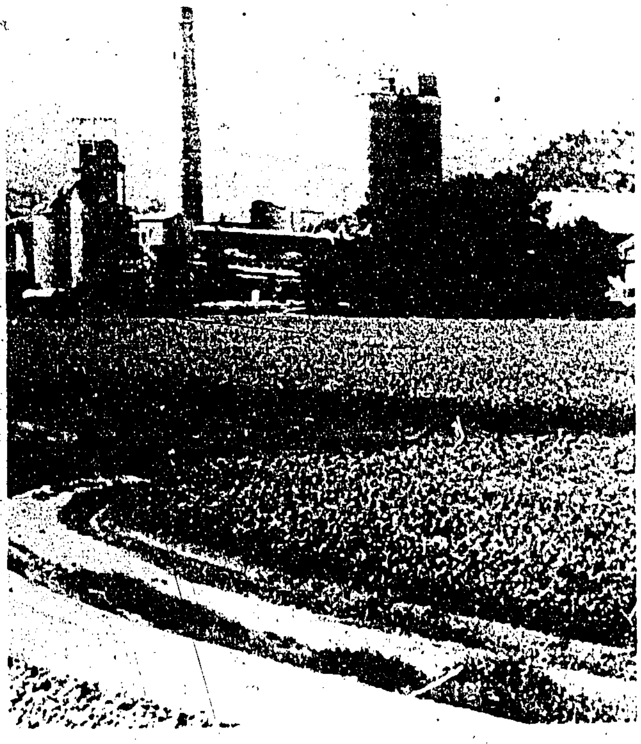
Agricultural Land Use in Nebraska

With the continually increasing world population, the need for food production is of paramount importance. Too many people are underfed. On a world-wide basis, the land used for food production should be used in the most efficient way possible, and more land should be put into use for this purpose. Wherever possible, the richest farmlands should be preserved for the production of food and should not be used for highways, cities, and industry. Ask your students to identify some of the famine areas on a world map. Also, have them plot the annual rainfall for those areas during the periods of famine and see if there is any correlation.

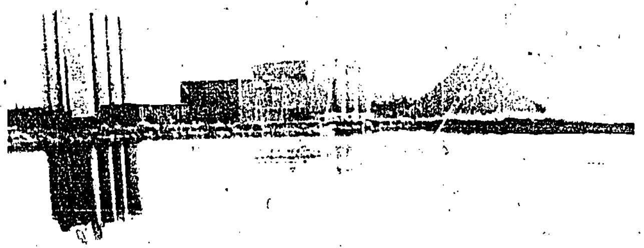
Industry

Not all industry is located in cities or even in their suburbs. Many industries are located in the country. For the most part, these are the plants that mine or process raw materials. Cement factories are usually located near the sources of stone from which the cement is made. Other industries that extract minerals from the ground and process them for future use are similarly located. Can your students identify any examples of these? In which state is the Bingham Canyon Mine located? What mineral is extracted?

Some industries are located in rural areas for safety reasons. An example of this type of industry is one that produces hazardous products such as explosives or toxic materials such as radioactive isotopes. Other nonhazardous industries are located in the country for no other reason than the desire to be in attractive surroundings. Have your students list some local industries that are located in the country and ask them to give reasons for that location.



Cement Factory near Lyons, Colorado



Workers Fishing on Their Lunch Break Near Lyons, Colorado, Cement Factory

Energy

The sources of energy are frequently located away from the centers of population. Coal may be obtained either from deep underground mines or dug out of seams that have been exposed in what is called open-face or strip-mining operations. While the older deep mines are located in urban areas, because the towns have developed around the mines, the open-face activities are located in open country.

Deep mines require a number of specialized facilities including buildings to house the machinery that raises the coal and the workers to the surface, coal sorting machinery, railroad car loading docks, and areas in which to dump waste products. Open-face mining operations can dump the waste products back into the trench from which the coal is removed.

Ask the class to discuss a recent environmental issue related to open-face coal mining.

Facilities for extracting oil or natural gas from the ground are similarly disposed. Some are in urban areas, but the majority are located in rural areas. In fact, some are located miles off shore. The land-based oil wells, of greater interest than offshore facilities in this discussion, require pumping machinery, storage tanks, and the equipment required to transfer the oil to other forms of transportation such as ships, railroad tank cars, tanker trucks, or pipelines.

Electrical power is produced in facilities located outside of, or quite remote from, the cities that are the major users of that power. Hydroelectric power stations must be located close to reservoirs. High dams hold back river water until an adequate and constant head of water can be achieved to drive turbo-generators. A field trip to a hydroelectric power station near your school would be a very interesting activity. Power station personnel are usually proud to have an opportunity to describe their facility and the important features of the process.

Grand Coulee Hydroelectric Power Dam on the Columbia River

Nuclear powered generating stations are usually located outside cities for different reasons. There has been much discussion recently on the environmental hazards that may be associated with these facilities. The students can be asked to list these potential hazards.

A similar environmental discussion has developed around a coal-fired electrical power station in the Four Corners area. Where is the Four Corners area and why is it so named? Why is a power station there? What area does it provide with electrical power?

Transportation

Roads, railroads, electrical power lines, and pipelines for oil, gas, and other commodities are required across the country. Roads and railroads generally follow the most direct routes that provide easy grades and maximum safety. They would not be located in areas that are subjected to severe flooding after each rain storm. Similarly traffic routes across mountains attempt to use low altitude passes instead of high altitude passes. Have the students give the reasons for this.

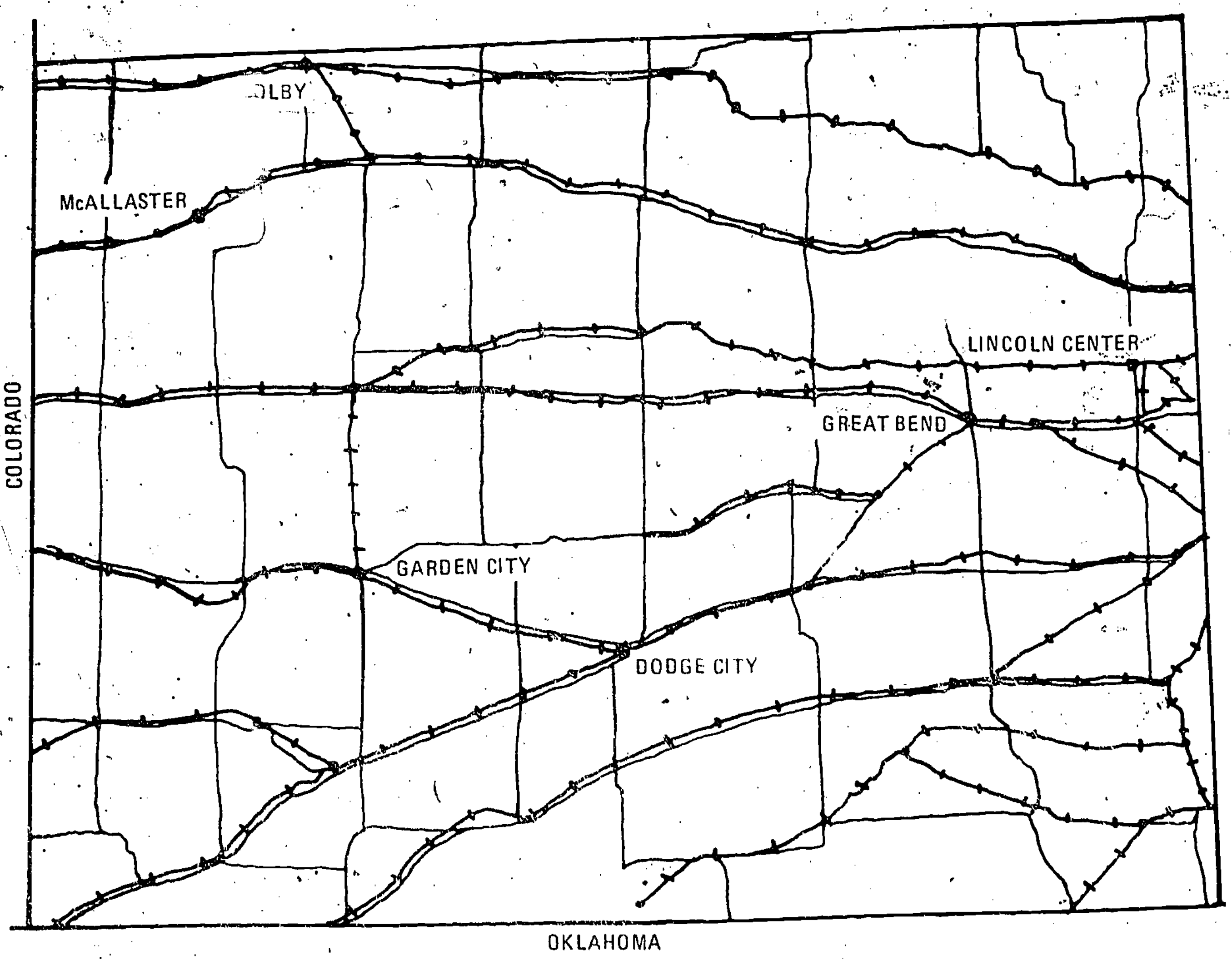
The requirements for road and railroad building are very similar. The main difference is that roads can use somewhat steeper grades and smaller radius bends. Can your students explain this?

The development of the railroads in the late 19th century played a major role in the history of the nation. The map shows a portion of Kansas. Note that the major railroad routes run in relatively straight lines, that numerous communities are located along them, and that they are paralleled by highways. Have your students explain why this is so. Which came first—the towns, the railroads, or the highways?

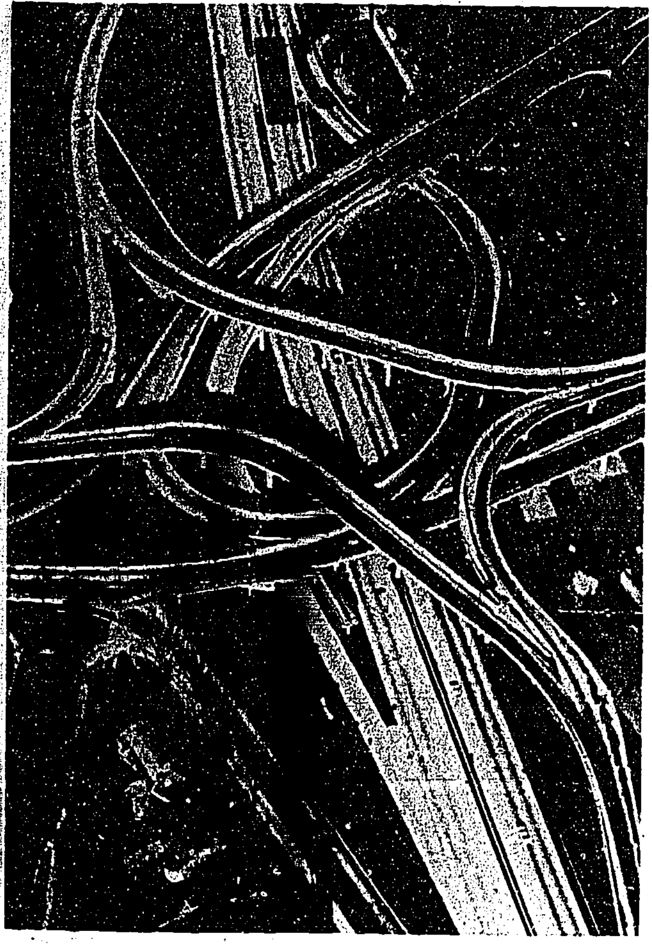
Overland transportation of gas and oil is provided by cross-country pipelines, railroad tank cars, and tank trucks on the highways. A network of pipelines criss-crosses the entire country. A new major pipeline is now being constructed after some years of argument over the environmental effects. Can your students give the name and location of this pipeline?

Many commodities are transmitted across the country through pipes. Mixtures of solids and liquids can be pumped hundreds of miles through pipelines. The "Big Inch" (24 inches diameter) and the "Little Big Inch" (20 inches diameter) are examples of this. During World War II, the government constructed these pipelines under emergency conditions to meet the demands of war. They originally carried crude oil from Longview, Texas, to New Jersey. After the emergency they were sold to private industry. The "Big Inch" still carries crude oil while the "Little Big Inch" has been converted for transportation of petroleum products.

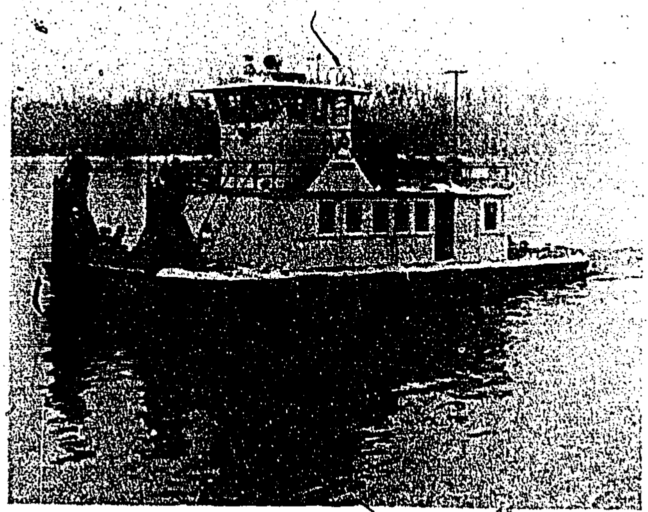
Electrical power is "transported" across the country by high voltage transmission lines. The *Smithsonian Magazine* states that there are now some 1200 miles of powerlines transmitting electricity at 765,000 volts, and that voltages as high as 2,000,000 are being considered. An interesting, and to some a disturbing, feature is that the electric field around these lines is so strong that a fluorescent light bulb will light up without power connections even when held as much as 50 feet away from the powerline. Ask your students to locate the local main power transmission lines and give the voltage. A visit to the local public service company or a visit by one of the public service engineers will be very informative.



Map of the Southwest Corner of Kansas Indicating the Development of Towns, Highways, and Railroads



Typical Freeway Intersection



Rivers such as the Mississippi are used as transportation routes. This is a boat designed especially for pushing barges.

Forestry

Forests cover vast areas of the nation. These vary from the predominantly hardwood forests of the eastern states to the predominantly softwood forests of the western states. The hardwoods include oak, ash, maple, and walnut; the softwoods are the pines, firs, and redwoods. Both types of woods are used extensively by man. Ask the students how each type of wood is used.

In addition to providing a source of raw materials, forests play a vital role in the natural environment of the country. For many years, we have been urged to prevent forest fires that can endanger the lives of wild animals, the lives and property of people who live nearby, and the lives of the men who fight fires. Can the class list the dangers resulting from forest fires? Now we are told that naturally started fires in certain National Parks are being allowed to burn themselves out. Can the students give the reason for this apparently conflicting approach?

Recreation

The recreational uses of the land are many. They range from the arduous athletic sports of skiing, water skiing, surfing, and mountain climbing, to the more contemplative activities of fishing and enjoying beautiful scenery.

Recreational activities are generally seasonal. Skiing obviously requires snow while water skiing and surfing generally require warm weather. Hunting seasons are governed by the breeding cycles of the game as is fishing to a lesser degree.

Water sports such as boating, both power and sail, and water skiing are encouraged in the majority of inland water areas such as natural and man made lakes. Hunting takes place in all states although the nature of the game pursued may vary from state to state. Ask the class to list the types of game hunted locally, and to identify the seasons related to each type of game.

These Sand Dunes in Colorado are Dedicated to Recreational Activities

Environmental Protection

Environmental protection or conservation is being discussed with much greater frequency and interest in recent years. The objective is to preserve the natural or artificial conditions of the many features of the countryside.

Conservation of the forest areas preserves the beauty of the trees and the natural habitat of the wild life in the area. It helps retain the top soil in place; destruction of forests exposes the top soil to erosion by natural and artificial forces, which in turn causes pollution of waterways that drain these areas. Suggest that the students relate this condition to the discussion of forest fires on page 23.

Conservation of agricultural land helps maintain the quality and productivity of farmlands. Conservation of rivers and other bodies of water maintains the quantities and quality of water for our needs.

The targets and methods of environmental protection are continually being expanded as new threats are identified. Some of these threats are associated with industry—the ruining of the countryside with unrestored open-face mines and the pollution of rivers by effluents from industrial facilities. Vast areas of agricultural lands were almost destroyed in the early part of this century as a result of cultivation practices that did not protect the delicate balance of soil and natural moisture unique to that area. Have the students show the area most affected and the most apparent results.

Regretably, many recreational activities result in damage to the natural order of things. Forest fires can be started by careless people who discard matches or glass bottles or leave campfires burning. Erosion of hillsides results from careless use of recreational vehicles such as trail bikes, snow mobiles, and all-terrain vehicles. Spectacularly beautiful scenery is spoiled by carelessly discarded litter.

Each of us must show concern for the needs of each part of the countryside we visit so that we can preserve it for nature and for future visitors.

The foregoing paragraphs are but a brief summary of the many uses of land and have been included to stimulate thought, discussion, and possible evaluation of land applications near your school.

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TEAROUT SHEET

Figure 1 Aerial Photo of Bear Creek Dam Site

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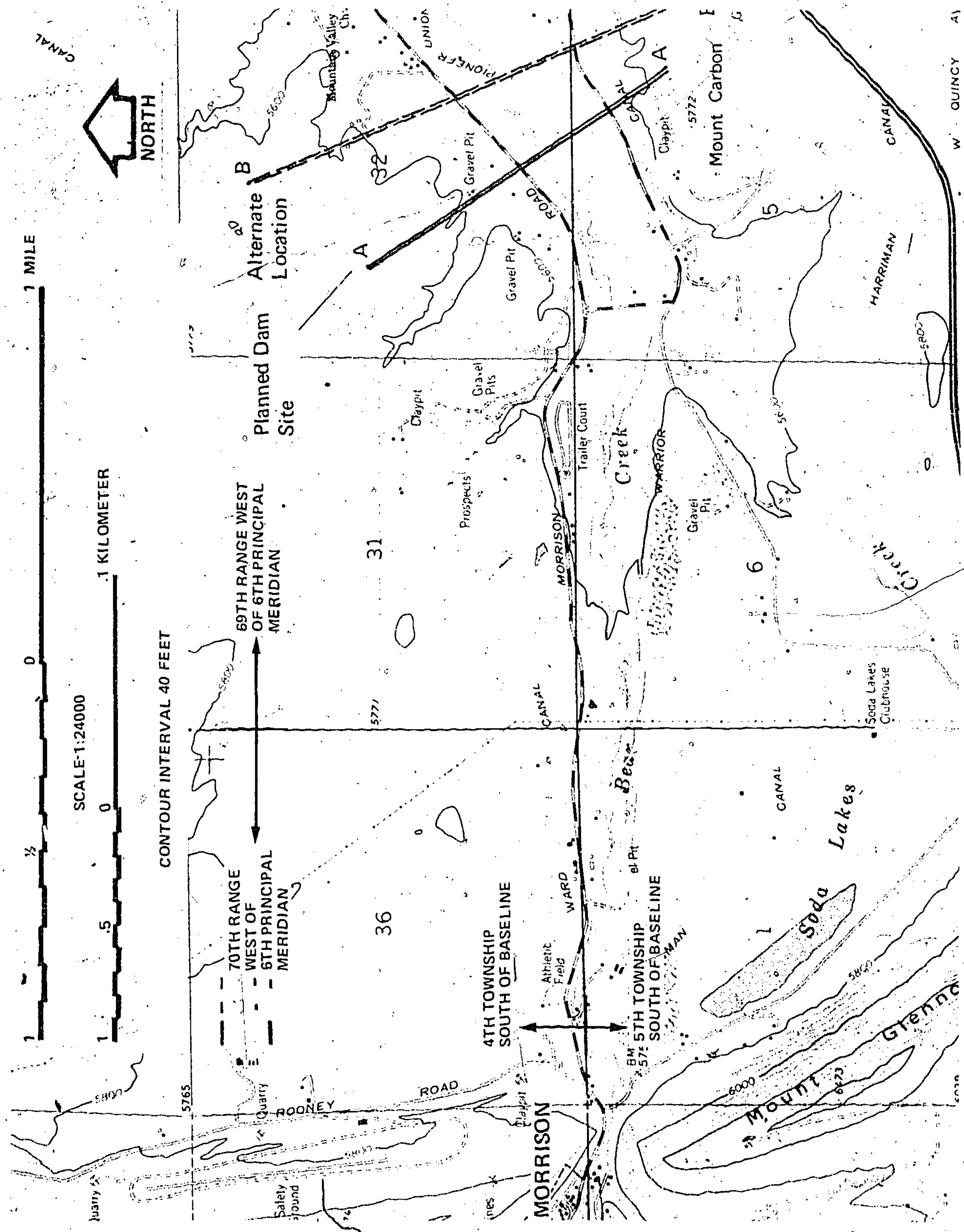

Figure 2 USGS Map of Bear Creek Dam Site

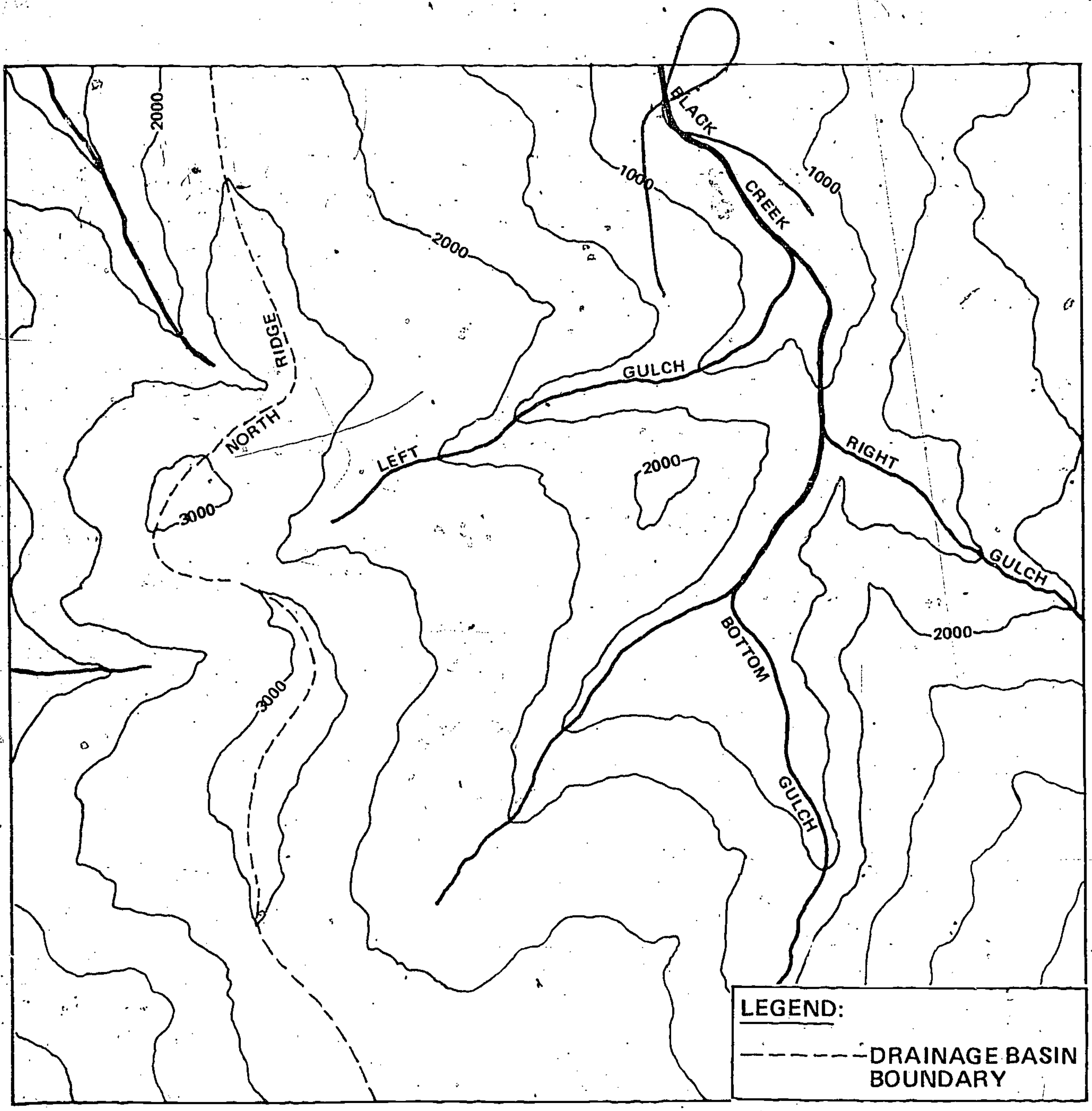

Figure 3 Schematic of Drainage Systems

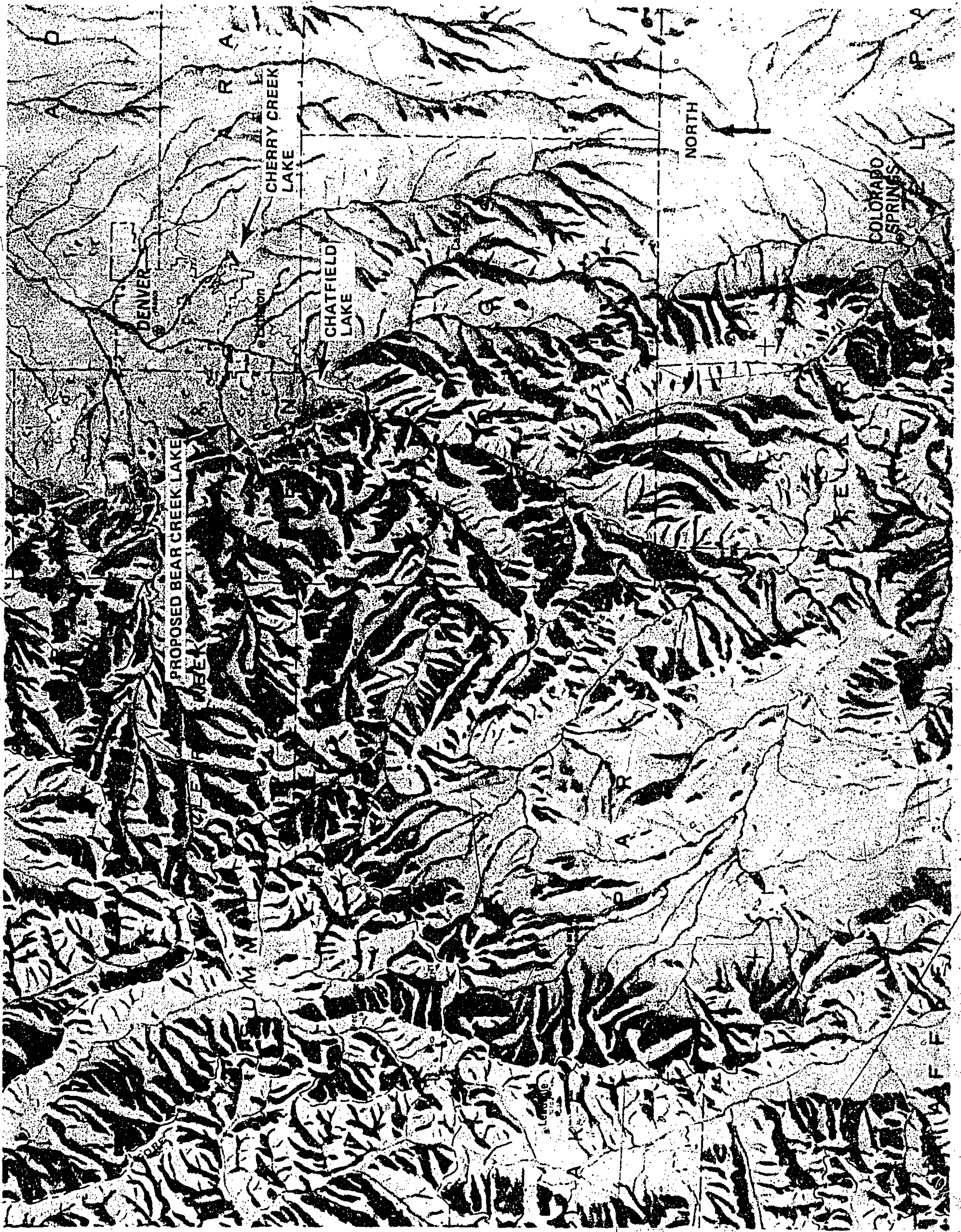

Figure 4 USGS Relief Map of Central Colorado

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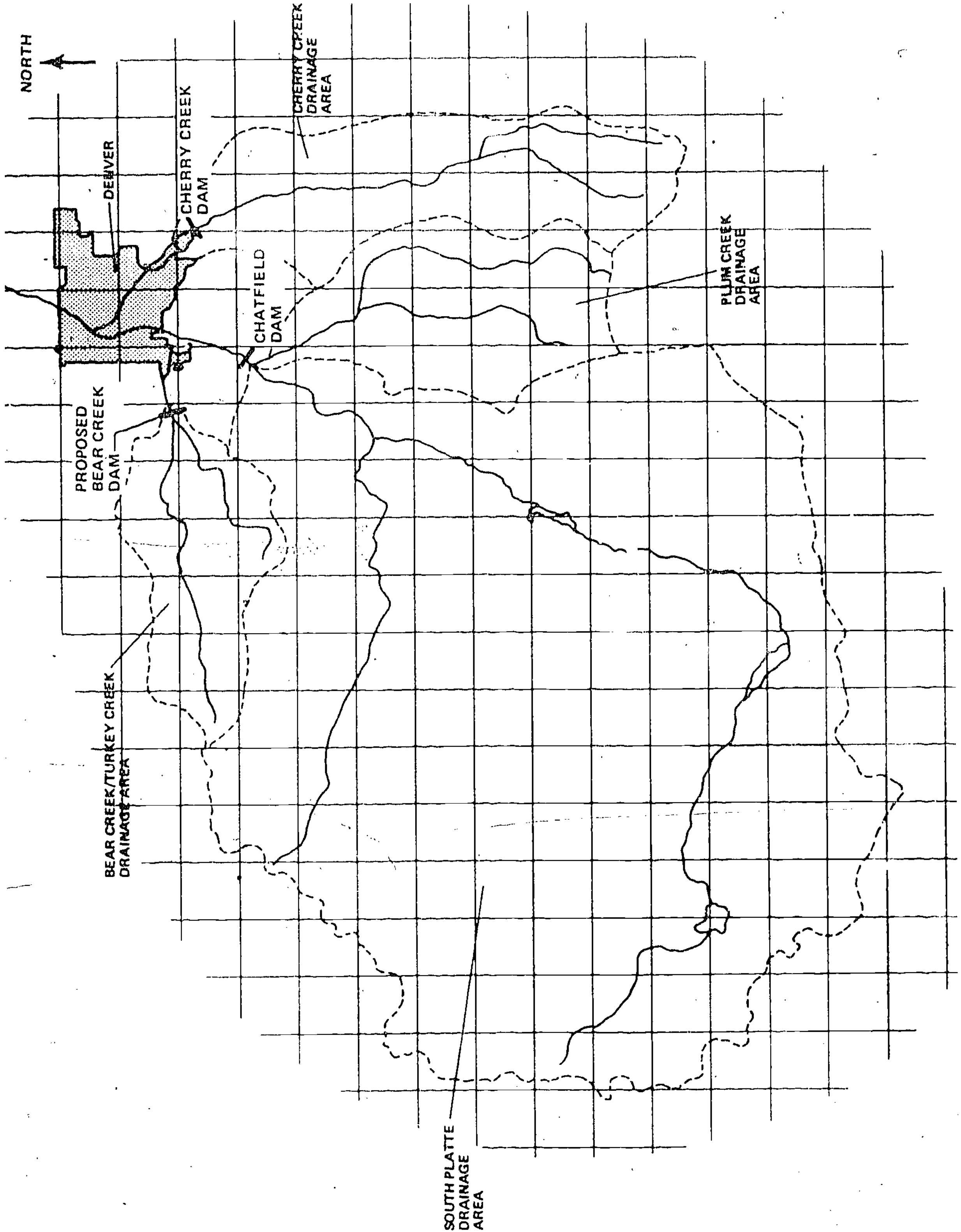

Figure 6 Watershed Areas Draining into Denver

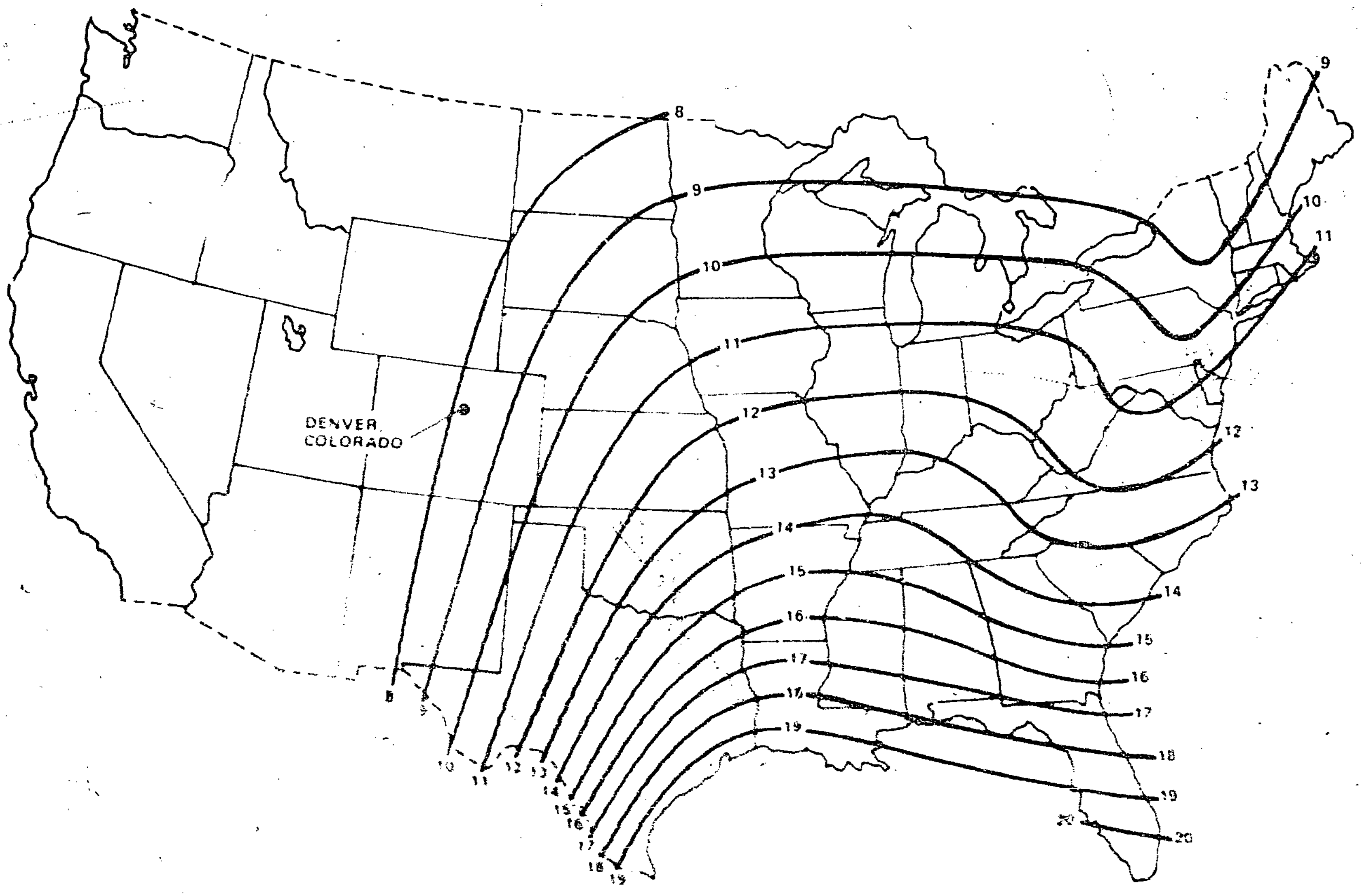

Figure 7 Index Rainfall Rate [illegible] Continental United States

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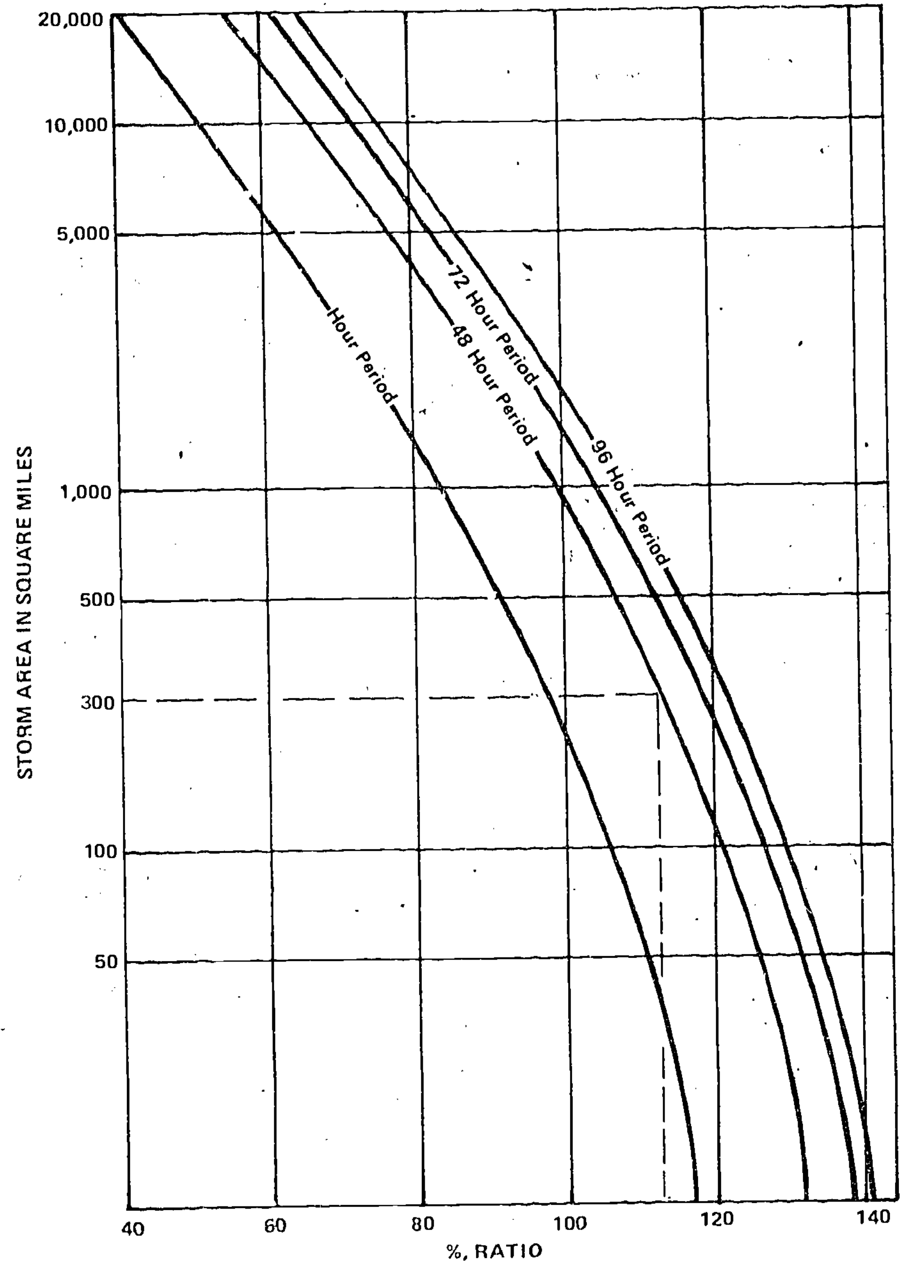

Figure 8 Index Rainfall Ratio

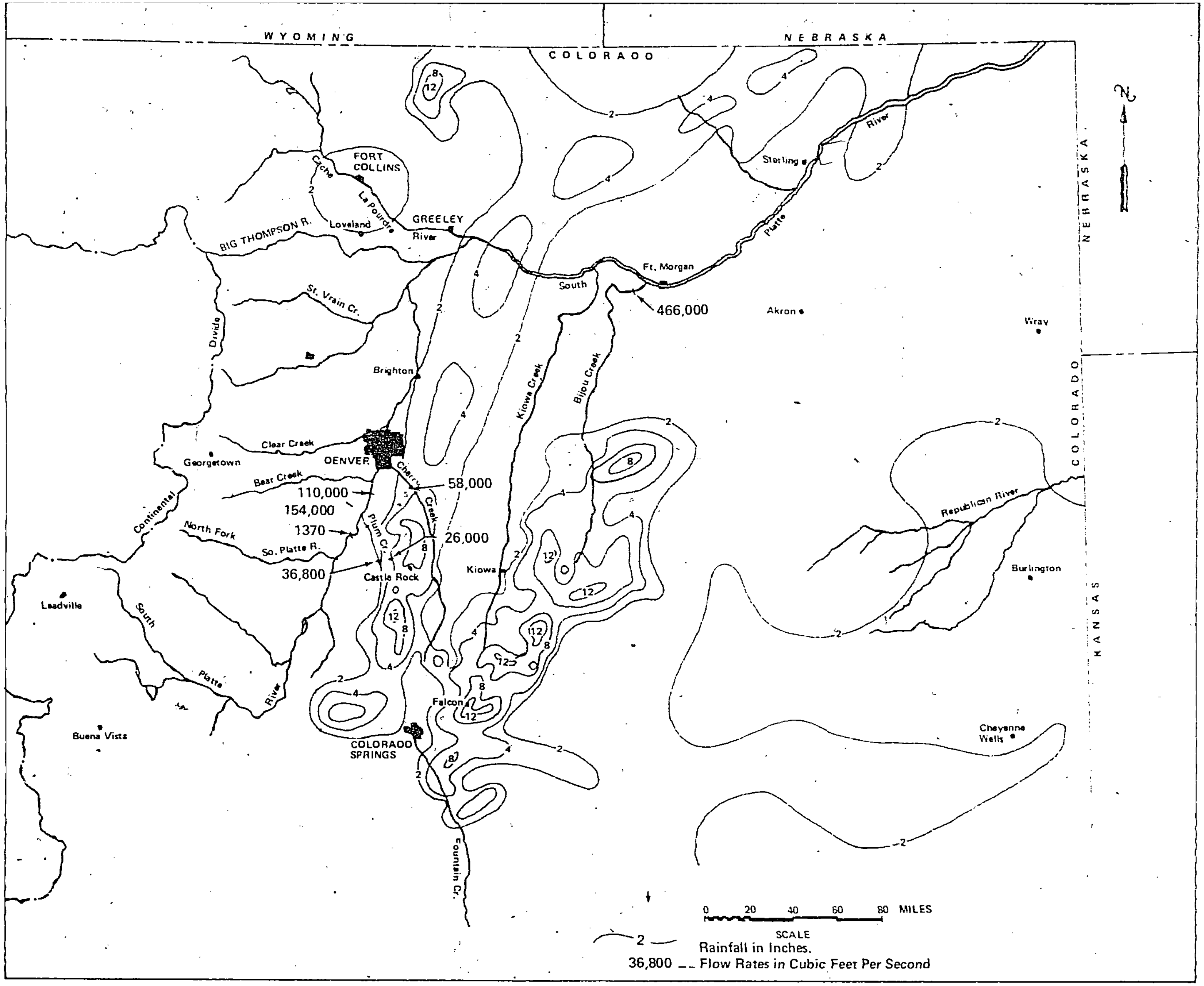

Figure 9 Rainfall Depths and River Flow Rates, June 1965 Flood

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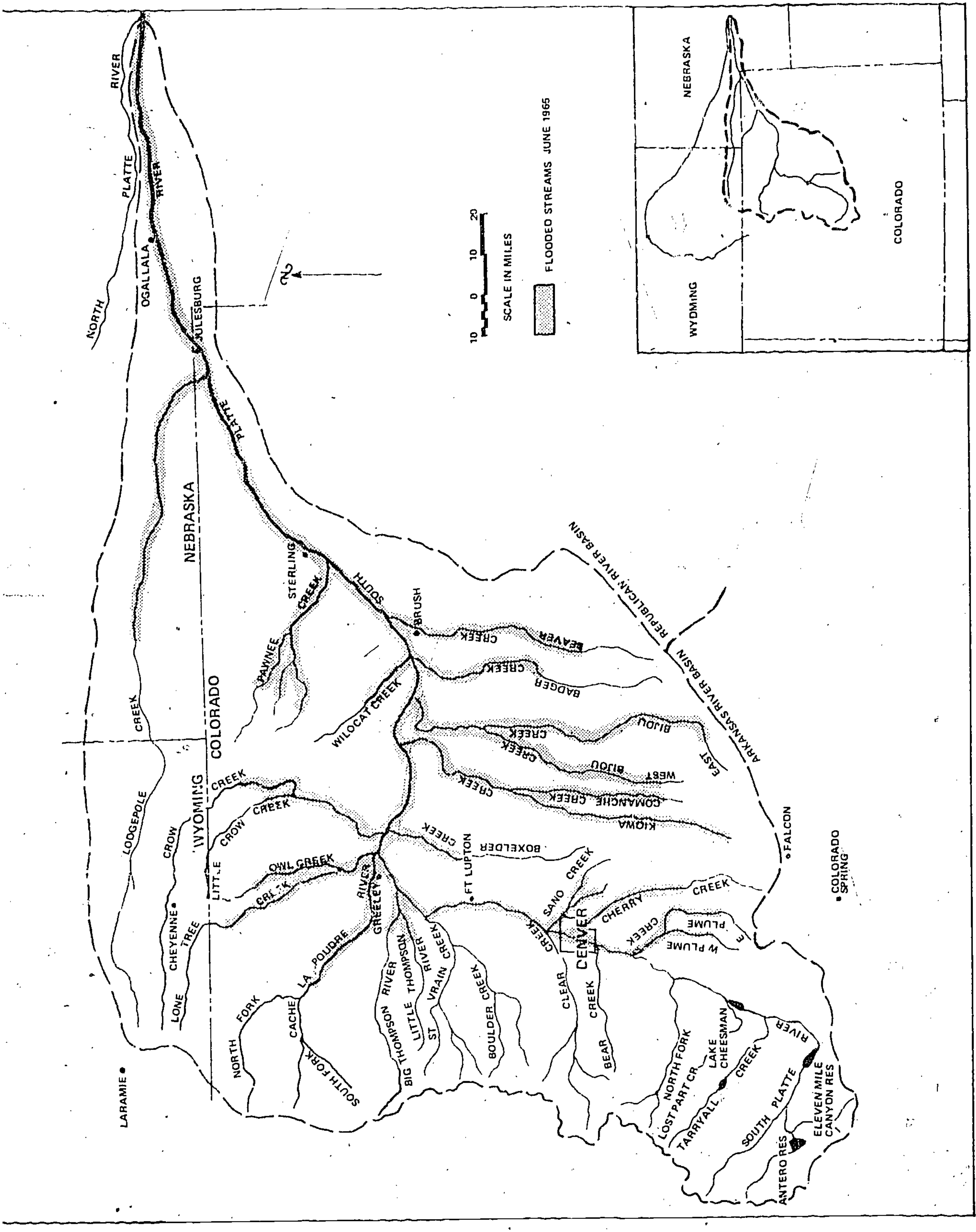

Figure 10 Rivers Draining into South Platte

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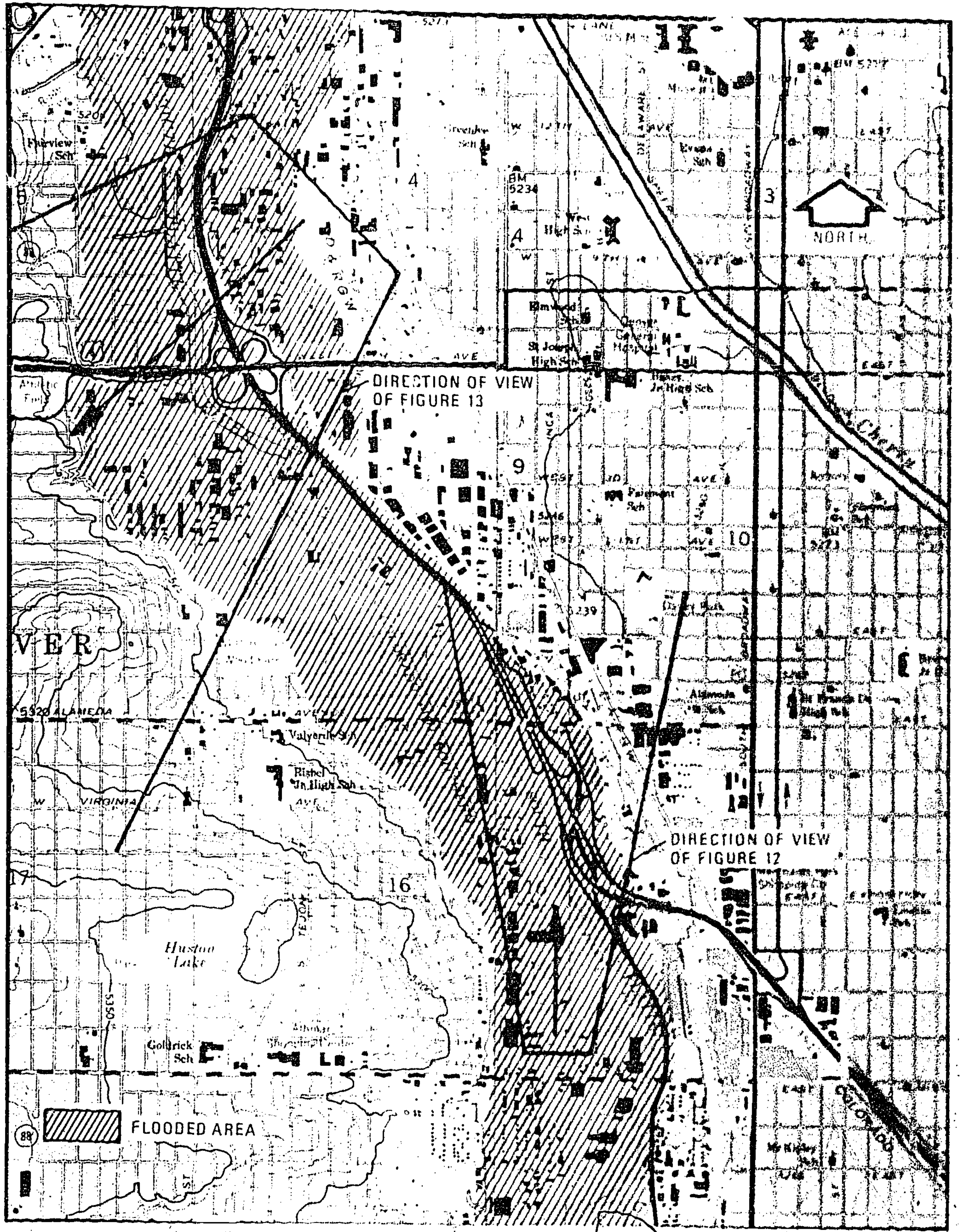

Figure 11 - Portion of South Platte Valley in Denver

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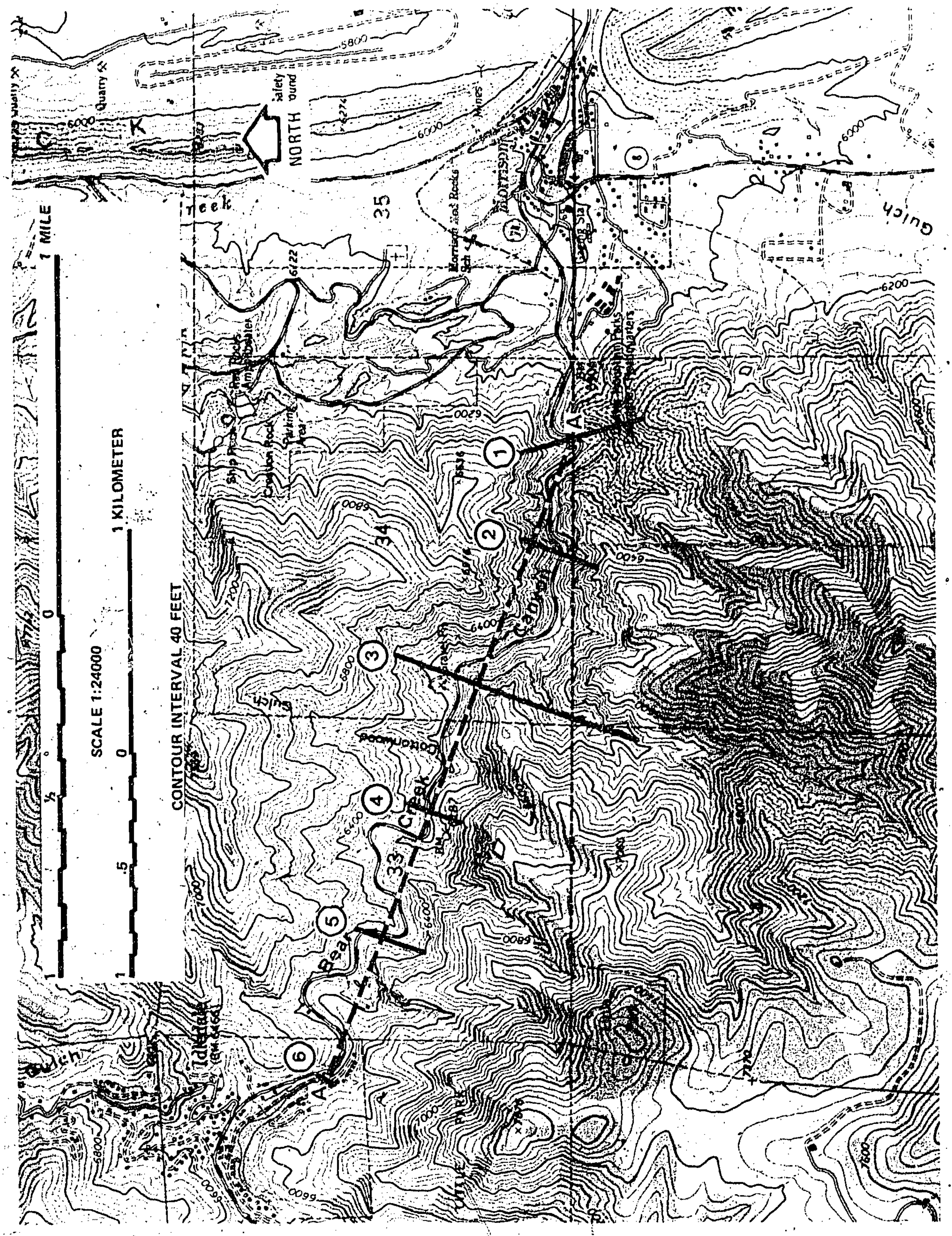

Figure 15 Alternate Upstream Bear Creek Dam Location

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