The GOVERNOR'S CONFERENCE

ON

ENVIRONMENTAL GEOLOGY

SPECIAL PUBLICATION NO. 1

COLORADO GEOLOGICAL SURVEY

DEPARTMENT OF NATURAL RESOURCES

John W. Rold, *Director*

ARRANGED BY

ASSOCIATION OF
ENGINEERING GEOLOGISTS
Denver Section

AMERICAN INSTITUTE OF
PROFESSIONAL GEOLOGISTS
Colorado Section

DENVER, COLORADO, APRIL 30 - MAY 1-2, 1969

The GOVERNOR'S CONFERENCE

ON

ENVIRONMENTAL GEOLOGY

SPECIAL PUBLICATION NO. 1

COLORADO GEOLOGICAL SURVEY

DEPARTMENT OF NATURAL RESOURCES

John W. Rold, *Director*

DOI: https://doi.org/10.58783/cgs.sp01.ynhy2030

ARRANGED BY

ASSOCIATION OF
ENGINEERING GEOLOGISTS
Denver Section

AMERICAN INSTITUTE OF
PROFESSIONAL GEOLOGISTS
Colorado Section

DENVER, COLORADO, APRIL 30 - MAY 1-2, 1969

TABLE OF CONTENTS

The following papers were also presented at the Conference but were not submitted for publication:

STATE OF COLORADO

JOHN A. LOVE
Governor

JOHN W. ROLD
Director

COLORADO GEOLOGICAL SURVEY
254 COLUMBINE BUILDING — 1845 SHERMAN STREET
DENVER, COLORADO 80203
PHONE 892-2611

LETTER OF TRANSMITTAL

Colorado Geological Survey
Special Publication #1

The Honorable John A. Love
Governor of Colorado

When the Colorado Geological Survey was re-established on February 1, 1969 exactly three months prior to the Governor's Conference on Environmental Geology, the detailed legislative charges included:

> "Determine areas of geologic hazard that could affect the safety of or economic loss to the citizens of Colorado,"
>
> "Evaluate the physical features of Colorado with reference to present and potential human and animal use,"
>
> "Assist, consult with and advise existing state and local governmental agencies on geologic problems."

These charges summarized a specific agency mission in environmental geology, and could actually have served as guidelines for much of the Conference.

Each of the papers presented here contributes to a better understanding of specific environmental problems now being faced, not only in Colorado, but wherever geologic processes or conditions affect man's present or planned activities. Study of the principles and examples portrayed here will provide valuable insight into an interdisciplinary approach toward the solution of these problems. The Colorado Geological Survey, therefore, presents with pride the proceedings of this Conference as its Special Publication No. 1.

COLORADO GEOLOGICAL SURVEY

John W. Rold

John W. Rold
Director and State Geologist

FOREWORD

The Colorado Governor's Conference on Environmental Geology was conceived, organized, and presented as a public service. The conference was arranged by the Association of Engineering Geologists (Denver Section) and the American Institute of Professional Geologists (Colorado Section), under the sponsorship of Governor John A. Love. Although pertinent mainly to the State, it was intended as a contribution to a broader understanding of the importance of environmental geology throughout the nation. The conference was really aimed at non-geological professions, the practices of which are greatly affected by geologic conditions. The intent and aim of the conference was realized. This was evidenced by the wide geographic distribution of registrants from Alaska to the east coast, and from as far away as Guam. Non-geologic professions represented included engineers, architects, lawyers, and planners, all of whom constituted 36 percent of the registrants.

Perhaps some of the strong interest shown in the conference resulted from the one-day field trip on the second day of activities. This provided an opportunity, particularly for non-geologists, to observe geologic conditions being changed to suit man's environmental needs. The trip also prepared the registrants for the third day's technical papers, making for a better dialogue between non-geologists and geologists.

The deep concern today over the environment is felt in every part of our nation and in much of the world. The professions represented in this conference have an obligation to see that concern with the environment goes beyond a now-popular word used to throw fear in the heart of the polluter, and to generate public funds for environmental studies. We must not lose sight of geology and how it affects man's total environmental adjustment while we attempt to dissipate smog and clean our waters. This is our obligation, not just to our professions, but to the general public.

Governor Love represented the public as a whole when he stated, "There is a great and growing interest and concern about our general environment, --- about the quality of life now and in the future." He further stated, "The concern to maintain the quality of our environment is increasingly more difficult of accomplishment by virtue of the fact, this is a time of increasing demand for raw materials, for more energy, when the production of goods grows at an ever increasing rate, and at a time when population growth is termed an explosion." It is therefore fitting that this group of papers be one of the first publications of the recently re-established Colorado Geological Survey.

The problems are great, and the challenges are exciting. We hope that the conference was fruitful for those attending it. Our thanks are extended to all who participated in the program and who contributed papers in this publication, which we hope will be helpful to its readers. Also thanks are extended to members of both organizations who contributed so much time and effort to committee work. Special thanks are extended to the Editorial and Publications Committee who undertook to produce this volume for the Colorado State Geological Survey.

The Committee

COLORADO GOVERNOR'S CONFERENCE

ON ENVIRONMENTAL GEOLOGY

COMMITTEE

GENERAL CHAIRMAN	John B. Ivey (AEG-AIPG)
VICE GENERAL CHAIRMAN	Richard W. Lemke (AEG-AIPG)
COORDINATING COMMITTEE	Robert M. Lindvall (AEG-AIPG)
OPERATING COMMITTEES	
TECHNICAL PROGRAM	Willard G. Owens (AEG)
FIELD TRIP	David T. Snow (AEG)
REGISTRATION	James T. Morgan (AIPG)
HOTELS AND HOUSING	Robert M. Valentine (AEG)
SERVICE COMMITTEES	
FINANCE	Howard E. Simpson (AEG-AIPG)
PRINTING AND PUBLICATION	William W. Whitley (AIPG)
TECHNICAL SERVICES	John O. Maberry (AEG)
PUBLICITY	John Dolloff (AIPG)
CONSULTANT TO ALL COMMITTEES	David M. Evans (AIPG)

EDITORIAL AND PUBLICATION COMMITTEE

William I. Gardner, Chairman
G. William DePuy
Charles E. Hall
Willard G. Owens
William W. Whitley

WELCOMING ADDRESS

John A. Love, Governor of Colorado

Thank you very much and good morning. I am pleased to be with you, albeit briefly. The reason I am going to have to leave is the fact that I am deeply involved in my immediate environment, my legislature which is still in session. To my knowledge, this Conference on Environmental Geology is a first, certainly for the State of Colorado.

I am pleased to see this large turnout, gathered here to consider our environment and its involvement with geology, a discipline that I know has much to offer in our approach to the many problems we face and must resolve. I think this meeting and this large turnout indicates and reaffirms what is becoming apparent to us here and to the public at large, that there is a great and growing interest and concern about our general environment, our total environment, about the quality of life now and in the future. We know too, that there is concern about some of the things that have happened in the past and are happening now to the detriment of some very important aspects of our environment.

Many of us hadn't heard the word "ecology" until fairly recently. It's growing familiarity in our everyday language is indicative of the transformation in our thinking and the deep concern for our environment that is pulling together many disciplines to contribute their special knowledge needed to achieve the wisest and most beneficial uses of our natural heritage. And by the wisest and best, I don't think it necessarily means digging up the country or leveling it off or erecting great structures upon the land; open space itself can be a great asset to our environment by providing light, a vista, a quieter spot for some restful moments in our dominantly urban life.

I think the concern to maintain the quality of our environment is increasingly more difficult of accomplishment by virtue of the fact this is a time of increasing demand for raw materials, for more energy; when the production of goods grows at an ever increasing rate; and at a time when population growth is termed an explosion. I was startled to hear the other day, although this may be familiar to you, that in the United States of America — not one of the fastest growing societies numerically — that by the year 2000 A.D., just 31 years from now, there will be an additional 100 million people in this country. The population explosion underlines the problems involved in maintaining the best values in the environment and yet providing what we consider life's necessities in our affluent society.

I think about the times I've been to Hawaii and have found more people on the Island of Oahu. Each time in the past 8, 10, or 12 years the papers have been full of some zoning fight; for instance about Diamond Head or another beauty spot where one group of people seek to protect natural values against the pressure of population. It also seems true, unfortunately perhaps, try as hard as they may, and I am sure it is most worthwhile to try, that if enough people are added to that Island it will be difficult if not impossible to establish all the protection that some seek.

So I am delighted that this meeting is being held and gratified particularly that you have gathered here in the great State of Colorado. Our State has bountiful natural environmental resources to preserve and to protect against deterioration, but it also means that as we develop and utilize these resources, we must not exclude the rights of all to enjoy the wisest and best use of our environment. In this framework, I know that Geology has much to offer in a common effort with the other disciplines represented here today to achieve these goals.

I hope that you will have a most productive conference. To those of you from out of State — welcome — and to all of you, have a great conference. Thank you very much.

DEFINITION OF ENVIRONMENTAL GEOLOGY AND PURPOSE OF THE CONFERENCE

JOHN B. IVEY

Doeringsfeld, Amuedo and Ivey, Denver, Colorado

The purpose of the Colorado Governor's Conference on Environmental Geology is to communicate directly with planners. For our consideration, "planner" includes people in many fields, often working as team members on projects of major public significance. City, county, state and regional planners, architects, engineers, constructors, bankers, insurors, lawyers, conservationists, politicians, government officials, geologists and others are all included in this group. If any major interest is not included, ours is a sin of omission and not of commission.

According to John C. Frye, Director of Illinois Geological Survey, (personal communication) the term, "environmental geology" was coined by a member of the Illinois Geological Survey, James E. Hackett, in 1964. Hackett pointed out the need for multiple uses of land, particularly in urban areas, and the necessity to be informed on the geology of an area as a basis for comprehensive urban planning. Geological studies prior to Hackett's time had been made in different areas and professional geologists and others had recognized man's need for knowledge of his geological environment. Many geologists were contributing to these needs on the Federal and state levels, and in the private sector.

The population explosion is upon us in Colorado, the rest of the nation, and in the world as a whole. The need to plan well in advance of future growth has never been more apparent. It is with the planners that geologists must establish meaningful contact at every level to achieve the greatest benefits from our environment by an orderly and safe development. Ultimately, this contact reaches to the public, the most important consideration in the entire picture.

Definition of Environmental Geology

Likely each of us has his own idea of environmental geology. These ideas obviously will not all be the same, and the need for a definition of the term, "environmental geology" is apparent. Webster (New Collegiate Dictionary, 1959 ed.) defines environment as, "that which environs; surroundings, specifically, the aggregate of all external conditions and influences affecting the life and development of an organism--." In the same volume, geology is defined as, "The science which treats of the history of the earth and its life, especially as recorded in the rocks." Thus, we can take the essence of the two definitions, and combine them to define environmental geology as, "The total of all geological conditions, and influences affecting the life and development of man." Other animals upon which man is dependent should be included, but for practical use we will speak mainly in terms of man himself.

From this definition it is obvious that mining, petroleum, engineering, urban, groundwater, and many other types of geologists practice environmental geology at one time or another. These are fields in which the principles and techniques of geological science are applied to satisfy the everyday needs of man. It is easily shown that the geological conditions and influences which affect the life and development of man must be considered mainly in practice and not in theory. For this reason, environmental geology is applied geology.

Man is in perpetual competition with his environment, seeking to change it to better suit his own needs and purposes. This competition has produced remarkable advances in construction equipment and methods. If, however, this is considered progress, attention must be given also to set-backs. Each development of mechanical technology has increased man's potential to create geologic hazards. The success of man's adjustment is usually proportional to his knowledge of natural conditions and processes. When he knows reasonably well what the natural conditions are, his projects are usually successful. When he does not know what the natural conditions are, he usually is doomed to some degree of failure. It is the role of a whole group of geologic disciplines to prevent creation of these hazards and to counsel and effect the wisest use of our geological environment. This is environmental geology.

To help prepare this paper, a form letter was sent to each state geologist in the 48 states now having geological surveys. Replies were received from 63 percent of the surveys polled. The letter essentially asked four questions. One, does your geological survey designate anyone as an environmental geologist? Two, about what percentage of your total survey effort is devoted to man's adjustment to his geological environment? Three, does your survey have a special series of publications to report this effort? Four, has your survey defined environmental geology? The response to this letter was good. The data collected will be of real interest to planners as it shows at least part of the effort being made in an area of interest to all phases of planning.

Sixteen of the state surveys replying indicated a specific division set aside for studies of the geological environment, or that staff geologists with or without the title, "environmental geologist" are working on problems related to man's adjustment to his environment. Twenty of the surveys indicated that some of their work was devoted to effort in the field of man's adjustment to his geological environment. The amount of this effort compared to total budget varied from five to more than 50 percent in most of the groups, with most ranging from 20 to 30 percent. Twelve indicated that they had publications specifically related to environmental geology and two of these noted that their publications were under the heading of engineering geology. The Colorado Geological Survey was reactivated recently and it is sufficient to say here that this agency will have a strong commitment in environmental geology because of its charge by the legislature.

The most interesting response from all state surveys was relative to the definition of environmental geology. Practically all indicated a definition, or some parameters defining the scope of environmental geology had been established. A few indicated that they were actively working on a definition for their efforts in this field. Only six responded that no definition had been formulated and, at least by implication, that no work was being done or contemplated on such a definition. It is obvious that most of the states replying have developed some general idea of what environmental geology means in their efforts to provide useful data. Some tend to restrict the subject to engineering and urban geology. Three of the surveys noted that all of their geologists work on environmental geology problems at various times. Two surveys used the term, "people geology" in reference to the subject.

Many geologists consider "environmental geology" a catch-all term. The one field of geology which embraces more aspects of this subject than all others is engineering geology. The California Division of Geology has a section devoted to the study of geologic hazards. In the past the efforts of this group had been referred to as the "urban mapping program". Ian Campbell, state geologist of California, indicated (personal communication) dissatisfaction with both terms and with the term "environmental geology", and expressed the hope that a suitable term would be forthcoming. Kemble Widmer, state geologist of New Jersey, expressed (personal communication) an opinion that the geological profession would be better off if we had only "geologists" instead of so many specialists. Other surveys, such as ones in Alabama, Illinois, Kansas, and Texas have strong commitments in the field of environmental geology and recognize the term outright, or at least in a "de facto" way.

These diverse opinions are not mentioned to expose disagreement among geologists but to show that we as a profession have an awareness among ourselves as to how we can serve the planners' needs. It is noteworthy that in spite of disagreement as to the exact usage of the term, all but six of the surveys replying are consciously and in varying degrees making efforts to define the field of activity.

Likely, many have heard and used the term, "geologic hazards" and many may equate this term with environmental geology. In this regard, early in the planning stage it was decided that this conference would emphasize solutions to problems, as well as the hazards themselves.

It is true that certain hazards are the most dramatic manifestations of what nature, and man, can do to unbalance conditions of near equilibrium. If there is prior awareness of the hazard it may be mitigated through adequate planning. On the other hand, ignorance of the geologic situation and lacking proper planning, the works of man can produce geologic hazards where none existed before.

The broadened concept of man's regard for his geologic environment is reflected in a recent action of the American Institute of Professional Geologists in renaming its Geologic Hazards Committee, the Committee on Man's Geologic Environment. Environmental geology, because it must include solutions to problems, cannot be considered only in terms of geologic hazards.

The United States Geological Survey, through its Branch of Engineering Geology, has studied and is studying many problems of environmental geology. The state universities of Kansas and Texas have demonstrated their commitment by establishing programs leading to higher degrees in environmental geology. Colorado State University is now working on the curriculum requirements for a doctoral degree in the subject. It is likely that many other schools are doing similar work. Last and surely not least, many consulting geologists are devoting an increasingly large amount of their efforts to the subject.

As a result of this activity one does not have to be a profound and deep thinker to conclude that within a few years the difficulty in defining the term, "environmental geologist" will have been resolved for the profession.

Many geologists are involved in environmental considerations for engineering works. Considerably fewer geologists are involved in long-term planning. This latter condition should be changed. The situation has caused some planners to proceed with projects without the benefit of geological advice, or to obtain advice only after some type of failure has commenced or is imminent.

Recent history shows many examples of the planners' need for geology. Slope failures, dam failures, urban development where mineral resources become unavailable to further extraction, development over mined-out areas, ground-water pollution, and many other examples could be stated.

The need for well directed planning can be demonstrated in suburban areas as well as in the cities. In many areas the mortgage investment is already too high for owners to economically change geologic conditions which affect their mortgaged improvements. In many other areas to which man is being attracted, it is not too late to plan for what should be. It is difficult to imagine a more irate person than the real estate developer or investor who has been told that property for which he has paid dearly is not as salable as he thought because of some geologic problem of which he had been unaware. Perhaps a worse situation yet would be the case of a public official who had spent public funds without the proper advice as to natural conditions.

Recently, the State Supreme Court of California held a lending institution responsible for not seeing that the developer to whom it had made a construction loan had adequate advice on the soil conditions in the area where he was building homes (Western Construction, April, 1969, p. 14). Although this was a complicated matter having to do with the relations of the lender and borrower, it is clear that a precedent of this kind has the broadest implications not only for bankers and other sources of construction money, but for all phases of planning.

Almost daily our news media report on the more dramatic and destructive natural conditions such as earthquakes, landslides, and floods. The effects of these conditions are often truly horrible to contemplate, as we in Colorado recall the destructive Platte River flood of 1965. Less dramatic and not so well publicized, but very important to the persons affected, are the more subtle effects of natural conditions — leaky basements, slowly shifting soils, lowering ground-water tables, and many others. All natural hazards cannot be averted or even predicted, but much can be done to reduce their effects. A great step forward would be for communities to "zone out" areas subject to known or reasonably possible hazards. You will read of much that is being done in Colorado and other areas in the following papers.

A great deal of geological information is already available and more is gathered daily in our state largely through efforts of the U. S. Geological Survey. On February 1, 1969, the Colorado Geological Survey was re-established. It will collect more data which can be interpreted, modified, and added to for the planners' uses. An increasing number of consulting geologists are becoming involved in direct studies of environmental geology, using data already in the public domain, supplemented by their own findings. The available data is of no value if it goes unused. It is the geologist's role to express himself in terms which can be understood by the planner. The simple fact is that there is still a communication gap between the planner and the geologist. In most cases the party supplying information to be used by another, should speak in the terms of the user. So, geologists, when writing or speaking for planners, must use terms that can be understood by them.

Although geological counsel should be available at any time to the planner, there are three general times during which it is most important. First, in the feasibility stage of a project when general information is needed. Second, in the design stage when the geologist will be called upon to work closely with other disciplines active in earth problems. (Soils mechanics, rock mechanics, hydrology, mining engineering, and many others.) Third, in the construction phase where the unexpected always seems to appear and the geologist must take into account new evidence not available in earlier studies.

A variety of natural hazards were referred to earlier. Naturally, the planner and the geologist want to either control or avoid actually or potentially hazardous areas or limit them to non-critical uses. Control is not always technically or economically feasible, and avoidance is not always possible because of established urban and industrial growth patterns. In such cases the planner needs first to know of the potential hazard, and second, know within what limits he can plan around it. Economic limits must be established to determine the extent to which potential hazards can be controlled.

One of the best rules-of-thumb to follow is to utilize the natural landscape wherever feasible. This should not be mistaken for extreme conservationism. This is stated merely to remind us not to disturb any more of nature's balance than is necessary. When we alter natural slopes or grades, we must be sure that the new, artificial condition will be stable enough so that we are not creating an unwanted hazard. When a dam is constructed, we must be assured that it will have the maximum economic and aesthetic effect without creating downstream problems. When waste is disposed of on or near the surface, or deep within the earth, we must protect present and future ground-water users. In the development of one subdivision lot, we must assure that neighboring lots will not be adversely affected. The list of situations is practically endless because the variety of natural conditions which can be expected is virtually unlimited.

All of us, planners and geologists, must work against the inertia of the status quo — "if it has worked for years, why change it now? — why rock the boat?" Certainly there are situations where adherence to the status quo is advisable and desirable. Mainly, though, the planner is being called upon to revise his concepts and to be more creative and bold in his design. The geologist, too, because of increasing technology is constantly gaining more data which can be useful to the planner. The advances of both disciplines should be used to the common advantage of the public, which ultimately will pay the bills for both.

The planner naturally will be interested in what geologists outside of government are doing about environmental geology. You are aware of the interest displayed by the various state geological surveys, by the U.S. Geological Survey, many universities and colleges, and many consulting geologists are specializing to an increasing degree in environmental studies.

Purpose of the Conference

At an early planning meeting for this conference the purpose was set forth as follows, "-- to lay groundwork for planners, governmental agencies, contractors, architects and engineers to make optimum use of geology in the planning and construction of facilities to be used by man." Later meetings established the need to reach out to the other disciplines and to include all aspects of planning. In arranging the technical program for this conference, emphasis was placed on natural resources use and conservation, planning policies, urban development, highway engineering, dams, reservoirs and tunnels, waste disposal, water pollution, legislation and legal concern, and urban flood control. In fact, geologists attending this conference should be exposed to as much learning as the planners.

The purpose of this conference can be summed up best by John C. Frye's words in the March, 1969, issue of "The Professional Geologist" (p. 6) where he states, "If geologists are to become significantly involved in environmental applications, the first lessons they must learn are the basic principles of communication." I can certainly agree with this statement, as geologists generally have been subject to a prodigious amount of professional inbreeding. Frye goes on to say, "Unfortunately, in the area of environmental applications we are dealing with planners, administrators, and elected public officials, and to an important degree with the general public. These groups have no intention of learning the specialized terminology of our science, and if we expect them to use geologic data it is up to us to put our information and conclusions in a form they can readily understand. It is also up to us to let them know, in a straight-forward way, that we have geologic data that are vital for the future of society."

This statement sets forth very well what we as geologists must do to make our science useful in man's adjustment of his geological environment. Geologists have been self-critical on this subject for some time to the extent that we might paraphrase on a well known saying about the weather, "everybody talks about environmental geology in Colorado, but no one does anything about it." It is the intention here to reverse the paraphrase, and do something about making environmental geology a better known subject to all charged with the responsibility to provide man with an environment which is livable, pleasant, and productive.

Conclusion

Colorado is a great and rich state today. More important, we have a state with even greater potential than has been demonstrated by historical fact. The future potential of our state, its communities and its economics rests with those who must plan its development. The lessons of the past must be used so that our natural wealth is developed in a manner compatible with our social well-being. This is more critical today than ever before because the size of our state is shrinking. We are growing closer together with each super highway and each subdivision that is built. The wise and coordinated approach to the use of the geological environment for our good will bear interest payable to this state at rates which our banking laws would consider usurious.

THE ROLE OF ENGINEERING GEOLOGY IN URBAN PLANNING

JAMES E. SLOSSON

James E. Slosson and Associates, Sherman, California

Engineering geology has become a very useful and necessary science in the establishment of safe, economical, and meaningful urban development. Geologic data made available during the original real estate appraisal allows for a more realistic estimate of the natural environs and their effects upon land value and estimated development costs. Possibly even more important at the present time is an evaluation of the effect of a development upon the environment and, in particular, what factors should be considered in design to allow the retention of ecological preserves while still creating a safe and economical project.

A complete analytical geological study prior to the design of a master plan, tract map, dam site, highway, etc., will not only avoid the possibility of an unsafe and/or unstable condition, but in almost every situation it will aid in the creation of the most economical and efficient construction criteria. As an example, the Saint Francis Dam would not have been designed as it was if a thorough geologic analysis had been made. The loss of hundreds of lives in addition to a monetary loss of over ten million dollars in the catastrophe could have been avoided. This failure was probably one of the most important individual events to stimulate recognition for the need for the relatively new specialty in geology referred to as engineering geology.

Engineering geology has been defined as the application of geologic data, techniques, and principles to the study of the geologic environment and its effect on the planning, design, construction, operation, and maintenance of engineering projects. The geologic environment includes the origin and stability of the natural topography, the properties of rock and soil materials, and the occurrence, effect, and flow patterns of surface and subsurface water. The engineering geologist must have a general knowledge of civil engineering and practical experience from which to make judgments. His duty is to protect public welfare and safety and to provide data to the architect, design engineer, and developer which will facilitate safe and economic development. Public welfare and safety are easily explained and understood. The function of the engineering geologist in design and construction of urban development projects, however, needs greater exposure to public view.

Southern California suffered considerable damage during the torrential rainfall of 1969 and provided a complete test of newly developed techniques and procedures in the field of engineering geology. An in-depth analysis of the statistics of damage and slope failures within the City of Los Angeles from this most recent storm was performed by the City of Los Angeles Department of Building and Safety. The results from this study show that the practical and efficient use of engineering geology, teamed with excellent engineering control procedures (via codes and supervision), can and will produce safe and economical urban developments. These statistics show that almost $6,500,000 damage was done to some 1400 sites. Further analysis indicated the basic data shown on Table I.

A review of Table I clearly and accurately demonstrates that adequate in-depth engineering geology studies teamed with capable soils and design engineering will produce safe, stable, and economically feasible urban projects. The most notable data are found in the column related to the predictable percentage of failures

Pre-1952	1952-1962	1963 to Present
No grading code, no soils engineering, no engineering geology	Semi-adequate grading code, soils engineering required, very limited geology but no status and no responsibility	New modern grading codes; soils engineering and engineering geology required during design; soils engineering and engineering geology required during construction; Design Engineer, Soils Engineer, and Engineering Geologist all assume legal responsibility.
Approx. 10,000 sites constructed	Approx. 27,000 sites constructed	Approx. 11,000 sites constructed
Approx. $3,300,000 damage	Approx. $2,767,000 damage	Approx. $182,400 damage *
Approx. 1040 sites damaged	Approx. 350 sites damaged	Approx. 17 sites damaged
An average of $330 per site for the total number produced $3,300,000 / Sites 10,000	An average of $100 per site for the total produced $2,767,000 / Sites 27,000	An average of $7.00 per site for the total produced $80,000 / Sites 11,000
Predictable failure percentage: 10.4% 1040 damaged / 10,000 total sites	Predictable failure percentage: 1.3% 350 damaged / 37,000 total sites	Predictable failure percentage: .15% 17 damaged / 11,000 total sites

* Over $100,000 of the $182,000 was incurred on projects where grading was in operation and no residences were involved, thus less than $80,000 occurred on sites constructed since 1963.

** It should be noted that the storms of 1952, 1957-1958, 1962, 1965, and 1969 all produced similar total losses associated with similar destructive storms.

TABLE I

(major and minor) for the three time periods. For those sites developed prior to 1952 and where no engineering geology or soils engineering was required, the percentage failure is slightly above 10%. For that time period when soils engineering with very limited geology was required, the percentage dropped to approximately 1.3%. For the present period where both competent soils engineering and engineering geology are required and where these professions are required by law to certify their work, the predictable percent failure has dropped to a low of .15% (approximately one-tenth of a percent).

Again, as it has been illustrated in our space program, when science and engineering work together as a team, the problems of safety and accuracy can be solved. Engineering geology has proven its value and its exactness as a science.

I am sure that the 1969 storms were covered in the press and on television in your immediate areas. As previously stated, the immediate or actual damage to private property in the City of Los Angeles was a little over $6,000,000. After a total accounting, it probably will be well in excess of $10,000,000. One of the interesting things is that in 1952 when the first code was enacted, I was a typical college professor and took a group of students to the hills to show them a grading operation. I believe it was one of the first attempts to use applied geology in an introductory class in geology. While on the site, I made the error of explaining to the class that the contractor was doing the job wrong and that the hill would probably fall down. The next day I was put on legal notice by the developer that I should no longer make such reference, but luckily for me, before they could take further action, the rains came along and the hill fell down. In the recent (1969) storm, of the over $6,000,000 of damage which occurred, 53% of that damage was attributed to those sites and houses that were constructed prior to the first code (1952) and 44-1/2% between the first code and the enactment of the 1963 code.

These figures bring us down to only a few percent — as computed, approximately only 2-1/2% of all the damage occurred on projects which were under the 1963 code. In other words, the performance of projects completed from 1963 to the present time was very good and at least 2.4% of the 2.5% was attributed to projects under construction; all of us know that when you're grading during the winter season you are susceptible to damage. Summarily, the actual damage to houses and other structures built under the present code was less than 1/5 of 1% or .15% with the actual monetary figure for damage to structures being $5,000. In any storm, in St. Louis, in Chicago, or even the student riots there will be more damage than this — in fact the Administration Building at the college where I teach was partially burned accounting for $20,000 damage from just one Molotov cocktail — so I think we can say that the public is well protected.

At one time there was great fear that this new code (1963) was too restrictive and would bring about cessation of building and grading in the Los Angeles area; this was not true because even with the construction recession of 1965-1969, work proceeded and new houses are still being built. The 1963 code for the City of Los Angeles was somewhat the model for Chapter 70 of the Uniform Building Code. I might point out that the codes in both the City and County of Los Angeles are much more rigid than Chapter 70 which, in itself, is an attempt to cover the entire nation in a loose manner rather than a code for local complex areas.

I think it is a case in point that urban development can be designed safely and that engineering geology — when well utilized and in association with a good team of engineers, planners, and the governmental agencies where all are involved and where all have equal status — produces projects that will be safe. In southern California we, as geologists, are equal partners on projects with the design engineer and the soils engineer. By code, the geologist, soils engineer, and design engineer must supervise the construction of graded sites and at the completion of grading certify that the work was done in compliance with the codes and good engineering practices.

This policy is becoming a real issue because we, as geologists (as well as the soils engineers and design engineers), are now responsible in the eyes of the law and there are probably a few million dollars worth of law suits pending in California on failures that have occurred on some of the older projects where possibly there may have been errors or omissions because of the lack of adequate geology and/or soils engineering. In fact, in a recent case a geologist accepted a fee of $25.00 to look at a house for a pre-escrow evaluation or to see if the site was safe. The geologist took a quick look and said that it looked acceptable. It happened to be one of those built under the early codes and was damaged in the recent storms. The house was worth about $150,000 and the geologist is now being sued for $150,000.

Here we have a situation where the insurance company will not insure for landslide damage to property, but when you do professional work you legally accept the professional responsibility and possibly provide de facto insurance policies. I think this is something you should all be aware of and give consideration to, because the consultants who do the soils engineering, geology, and design engineering, by the code(s) may be accepting more responsibility than they are aware of.

The planners and design engineers should also be made to realize that they theoretically accept responsibility so beware of those who do not know what they are doing — be sure you choose a well-qualified geologist — one who understands engineering geology and one who has some background in engineering. If you do not, you may be responsible, also, for not obtaining qualified consultants.

In another legal case in southern California where there was severe damage to many houses, the lending agency was cited and they picked up the tab for a large sum for the loss. According to the courts, they really were the only entity that was fully aware of the capability of the consultants and, therefore, the jury found them guilty. So, again, beware but also understand that if it is properly done it will be safe; be aware that development can be done safely and economically as well as efficiently.

The engineers, architects, and governmental agencies are now becoming fully aware of the need for engineering geology.

Our chief problem right now, I think, is convincing those people in the news media as well as those people in the lay situation that engineered projects can be safely constructed. We are only too aware of the scare tactics and also the misinformation presented in some cases by the press. A good example would be the great earthquake hoax of this year (1969). Many people in California and other areas along the Pacific Coast were essentially in a state of shock as a result of the news references about the "Great Earthquake" and the impending calamity of California falling into the Pacific Ocean. People fled to the Rocky Mountains and elsewhere to avoid the disaster. While references were made to the earthquake of 1556 in Shenshi, China, where over 800,000 people were reportedly killed, no reference was made to the type of structures that people were living in at that time. They were essentially adobe brick or masonry block with no mortar and with timber and sod roofs. Even a moderate magnitude quake would destroy this type of structure and kill all occupants. In contrast, however, the performance of modern structures was seldom, if ever, discussed during this period of new hysteria. It would be similar to discussing the probability of a polio outbreak or even the plague sweeping across the United States without making reference to modern medicine and only using reference material related to events occurring 50 to 1000 years ago.

Possibly we have failed in not making the news media and the public aware of cause and effect and the modern scientific and engineering methods of understanding and designing. In a recent lecture which I presented at the college, I pointed out how possibly the public is often afraid because they do not understand. I used as an example the estimated fatality factor for deaths attributed to earthquakes in the United States as compared to auto accidents and especially fatalities associated with small foreign cars. During the last 200 years, approximately 1500 individuals have been killed by earthquakes and causes associated with earthquakes whereas there are approximately 50,000 to 60,000 killed each year in auto accidents and approximately 15,000 per year of these fatalities in small foreign automobiles. Thus, in a little over one month more people are killed in small foreign automobiles than have been killed in the last 200 years in earthquakes.

Still another example relating the improvement of science and engineering could be made comparing the Saint Francis Dam and the Baldwin Hills Dam failures. In the one instance we can consider the Baldwin Hills Dam where the geologic environment was well understood and where fair use of these data was implemented and in the other instance (the Saint Francis Dam) where there was no geologic input provided or accepted. Both suffered failure; the Saint Francis Dam failed very soon after construction. In fact, as I remember the sequence, it was started in approximately 1925, finished about 1927, filled by 1928, and collapsed in 1928. The Saint Francis Dam was constructed upon poor quality bedrock with an equally poor total geologic environment. To further complicate things in this poor environmental area, the decision was to construct a concrete gravity dam. The resulting failure caused approximately 500 deaths and millions of dollars of damage in what was then a rural agricultural area.

The Baldwin Hills Dam was built in an area of known seismic activity and subsidence and was designed to compensate for these environmental limitations. The design was one of an earthen dam holding or retaining an asphalt membrane. Realizing the seismic and subsidence potential, the reservoir area was provided with an elaborate subdrain system in addition to a drainage device for the reservoir which could theoretically drain the reservoir in approximately one day. The disaster associated with the Baldwin Hills Dam can be attributed to mechanical complications related to the drainage devices. Even with these complications, however, a densely populated urban area was evacuated and only five lives were lost. These lives could have been saved had the victims followed police rescue directions. Thus, modern methods again prove that safety can be achieved by comparing 500 fatalities in a rural area to five in a densely populated urban area. It should also be interjected that an adequate water supply is essential for our existence.

We now, more than ever, need larger quantities near the populated areas. Inadequate supplies can allow fire to ravage an area; inadequate supplies can allow health problems to develop. In other words, we need these facilities; the challenge and the responsibility is to strive for perfection in both the safety and appearance.

Possibly reference to and elaboration on the material presented earlier will assist you in evaluating the value of properly used engineering geology data compiled by competent engineering geologists. I hope that the growing pains and evolutionary processes that we all went through in Los Angeles for the period following World War II to the present can be synonymous to an academic learning experience to you. There is no need for the other areas which have or will have the burden of an expanding population to go through or repeat all of the learning steps. The benefit of education is to gather knowledge to learn, shall we say, by reviewing what others have done before using this knowledge to proceed forward — using the experiences, data, and knowledge of others to develop newer and better techniques.

In the early development of Los Angeles, the good and more easily accessible sites were utilized for housing. After World War II, people moved to sunny southern California by the thousands. To provide housing, areas which had previously been by-passed, used for agriculture, or that were located in inaccessible mountainous regions were developed. In these mountainous regions, the building sites were graded without the benefit of professional engineering supervision and with total ignorance of the geologic environment, its effect upon grading, and the effects of grading upon the geology.

The winter rains of 1952, however, quickly pointed out the folly of this method of development as significant damage from landslides, mudflow, erosion, and flooding occurred. Damage from this winter storm was assessed as being in the millions of dollars to private homes in the City of Los Angeles, along with similar damage occurring in other developed portions of California.

As a result of this damage, the City of Los Angeles created the first municipal grading code. This code was essentially keyed to procedures utilized by the California Division of Highways and other governmental agencies. This code proved to be inadequate as it required only very limited engineering supervision and problems related to geology were still not recognized.

In 1957, there was another period of high intensity rainfall and again losses estimated at millions of dollars occurred. Realizing that the initial codes and procedures were inadequate, the City Council and the Mayor of the City of Los Angeles appointed a special "Geologic Hazards Committee" to review the causes and effects and to make recommendations for the improvement of the codes and techniques. From this study, the codes were improved and geological reports were required for proposed grading projects. However, the supervision, the requirements, and the limitations as to who could submit reports and what their contents should be was inadequate. Geologists with no experience in civil engineering were submitting reports and generally these reports were totally irrelevant with regard to the project(s) and the proposed grading.

The rains of 1962 which caused an estimated $7,500,000 damage quickly indicated these shortcomings. Again, a learning experience and again evolution and from this developed the modern City of Los Angeles Code which was put into effect in 1963. This code has proven its effectiveness as pointed out earlier and possibly the two most significant changes were:

1. Only qualified engineering geologists could submit reports (now licensed and certified by the State of California as "Engineering Geologist"). These engineering geologists now must have a minimum of five (5) years experience in this specialty of geology and must have a knowledge of civil engineering and construction procedures.
2. The design engineer, engineering geologist, and soils (or foundation) engineer shall provide supervision during construction and on completion must submit a report certifying the work and/or project.

In other words, qualified professionals are required by code to accept responsibility for the performance and safety of the project(s) with which they are associated.

A project that I have been working on recently is one where the new techniques have been used. A team of consultants representing all of the disciplines associated with urban planning and development was brought together to produce a safe and effective, economic, and aesthetically appealing project. This team of consultants included engineering geologists, soils engineers, design engineers, architects, landscape architects, economists, traffic engineers, hydraulic engineers, and others. The team went through the conception of the master planning and in almost every situation geology, because it was the analysis of the natural environment, preceded the other disciplines.

This project, which is one of the most recent created under modern technology, is referred to as Palisades Highlands and is being developed by Land Resources Corporation. It is located in the Santa Monica Mountains of Los Angeles and comprises virtually the last large undeveloped area in the City of Los Angeles. It also comprises an area with unique and exciting development potential — a potential which can unquestionably be maximized by development under a comprehensive master plan.

Because of its location and natural features, the site enjoys many unequalled assets. It lies between the Pacific Ocean, the San Fernando Valley, and downtown Los Angeles with easy access to all sections of the region by existing and proposed freeways. The neighboring residential districts are the exclusive areas of Brentwood, Bel Air, Westwood, Pacific Palisades, and the San Fernando Valley. Elevations in the property range from 500 feet to 2000 feet above sea level. This combines with its location to provide magnificent views of the ocean, the city, and the surrounding mountain ranges. The climate is mild and smog-free, with summer temperatures averaging 15° cooler than the San Fernando Valley and 8° cooler than downtown Los Angeles.

Formal approval has been granted by the City of Los Angeles for a master plan for development to include land uses, residential densities, road locations, and community facilities. The planning, engineering, and geological studies which have been completed, and the approval of a master development plan by the City of Los Angeles all provide significant assets of the project.

Fortunately, the project manager had experience in other areas of somewhat similar nature and decided that geology should precede all design work. This was rather unique in 1965 when we first became involved. We found, from experience, that when the engineer knows what the problems are, he is very happy to design in accordance with good engineering. However, if he designs prior to the geologic investigation and is advised later that he has a problem — possibly an unstable slope as an example — he has a tendence to resist because he feels that geologists are telling him that he has made an error, when in reality his only error was that he did not understant the environment. Therefore, if we can tell the design engineer ahead of time what the problems are, then I am sure in almost every case he will prepare a good design, because this is just what he has been trained to do, but without information he just cannot do it. Most engineers have had possibly one class in geology and probably the instructor taught it very academically. As students, the engineers were very bored and probably got the "B" that they needed and shrugged their shoulders.

The first planning stage in this program was to initiate comprehensive geological engineering studies for some 2100 acres of the total ownership. The rugged mountainous terrain of Palisades Highlands, like the balance of the Santa Monica Mountains which separate the Los Angeles Basin from the San Fernando Valley, is characteristically an area of complicated geologic structure. Because of the geologic complexities and because of the problems that they presented in development costs, construction practices, and safety, it was determined that a thorough geological study on the property must be a prerequisite to detailed land planning.

The first phase of this geologic investigation was initiated with field mapping, aerial analysis, and limited subsurface exploration. These findings were presented weekly in meetings with the team of planners, architects, engineers, etc. Determinations were made as to the feasibility of development and that general approach to development for each of the smaller areas of the property. A team effort among the consultants was initiated to determine the corrective measures needed to stabilize the geologic conditions and to determine the most appropriate and economical land use approach and development practices for each of the areas. An important step in this process was a series of analyses conducted by the engineers to determine the comparative efficiencies of varying quantities of earthwork to correct geologic instability versus the varying yields of developable land.

From this point detailed or second phase geologic studies were initiated and planning and engineering proceeded as a team effort with close coordination on refined geologic findings. Extensive planning analyses were made of land use, density, development approach, traffic circulation and road requirements, flood protections, storm drainage, and utility service. Similarly, extensive studies were conducted of the recreational potential of the property, the preservation of open space, and the preservation of the unique natural environment of the property. Studies in construction methods and techniques were undertaken specifically to minimize extensive cuts and fills.

The study showed that there were some natural origin landslides in the area of the proposed project. After an in-depth analysis of these slides, it was determined that most of them could be locked in place or retained by proper design. Those of you who have a background in geology know that many landslides exist or occur because streams cut into the slopes and expose rocks which dip or are tilted in an adverse condition. This is generally referred to as undercutting of the bedding planes by natural forces. If we were to calculate the number of landslides in a geographic area, we would find that more are caused by nature than by man. This should also be understood by the news media and the general public.

We can take an area such as this and with corrective grading convert it back into a region which is essentially safe. At this time in the development of the urban plan, the engineers and architects can proceed with their design.

Another interesting portion of the study indicates that the beautiful park-like canyon areas could be preserved or retained as they could have a dual function of flood control and park and recreation areas. These areas were retained as natural flow channels and a 20-acre region within the canyon would be converted into a flood retention reservoir and a recreation lake.

The major canyons in a hilly area are generally filled with engineered fill; however, in this case, the oak and sycamore lined canyon will be preserved. These regions make excellent parks compared to upper shope regions where slope gradients range from 20° to 40°. Often these more hilly regions are rattlesnake infested and covered with sage brush.

Some of the rugged cliff areas and regions of interesting geologic and/or natural appearance were programmed to be retained wherever possible. Thus, approximately 50% of the area will be retained as park-open space-green belt and the remaining 50% utilized for housing.

The next step was further analysis of some of the canyons and bounding slopes which were felt to be unstable in their present condition. These canyons with unstable slopes are programmed to be filled to the point where safety is achieved. Some of the high ridges will be removed to eliminate geologic hazards and the dirt produced will be used to fill canyons. The corrective grading design produced by this method was designed so that both the fill and the cut will be graded at a 15% or less slope. This we feel is the maximum gradient that the engineers and architects could work with and still come up with a usable plan. This converted the total area back to a safe and stable region and from it more finite design commenced. One of the engineers associated with the project went through an analysis to see how much yardage had to be moved to come out with an economical development that provided the safety required, and it came out somewhere between 15 and 18 million cubic yards to make the area not only safe but also economically feasible. With this method of development, we were also able to eliminate the extremely high cut and fill which scars many areas. This area will actually result in a region of subdued topography rather than the typical "rice paddy" appearance.

Another part of the study was to look at the adjacent natural slopes to see which could be used without creating hazards or adversely affecting the green belts. Those which have zero to 20% slope gradients can be used without difficulty; 20% to 30% have some potential; and those over 30% are undesirable. We also completed a rippability analysis which turned out to be very valuable because we were able to determine that some rock material could be graded at normal costs while other would be more difficult and somewhat more costly while some would require ripping and some blasting or blasting all the way through. It was determined that we should avoid the difficult areas which would cost $1.00 to $1.50 a cubic yard or more to move. Fortunately, these difficult areas were where rugged rocks existed that could be blended into the park land. Most of the earth material that is to be graded will be of the lower cost factor and thus the economics of the project were established. The design engineer was able to predict what the cost of grading would be ahead of time and predict which earth materials would be easiest to move and when and how to move it. All of the grading design has been pre-programmed so that it is known that there will be no problems as far as drainage, geology, soils, and that the project can be developed.

All of the aforementioned details have provided the such-sought-after master plan approach which provides for stability and safety while retaining at least 50% of the natural terrain establishing an aesthetically appealing project to the benefit of all.

* * * * * * * *

"Engineering as a profession is not limited alone to the merely scientific aspects but covers the entire realm of adaptation of all natural laws to the benefit of mankind. Such thoughts are ever-present in the mind of the truly dedicated engineer, who must of necessity be deeply religious. At many times nature can play strange tricks and we must watch our every move to avoid the many pitfalls."

* * * * * * * *

"The rockies present factors perplexing to the best of those in the engineering profession. The uncommon outcrops, geological upheavals and subsidences, and miscellaneous occurrences too numerous to mention which took place eons of time past may result in unknown reactions on the steep sided slopes and adjacent valleys. Any new cuts or construction made in this geological jumble may set forth reactions later which might have telling effects upon man-made construction."

* * * * * * * *

The above quotations, from a report written by a prominent engineer the day after the failure of a dam spillway he had designed, express the concern for and the frustration created by the unknown and often uninvestigated effects of geology on the engineer's works.

URBAN GROWTH AND ENVIRONMENTAL GEOLOGY

PAUL L. HILPMAN

Chief, Environmental Geology, Kansas State Geological Survey

Earlier this spring I observed a neighbor planting trees and shrubs around his newly constructed home and I was dismayed to note that he clearly intended to plant two young maple trees within six feet of his house. When I inquired if he had thought about the problems to be faced when the trees matured, his response was "I don't plan to live here long enough to worry about such matters."

I think an analogy exists between my neighbor's "planning" and some of the land-use planning taking place today, for it is certainly not difficult to find examples of shortsighted thinking in the design of our modern metropolitan centers. The main difference between my neighbor and the urban planner is that the latter makes land-use decisions on a grander scale. Largely because science has done more to forestall death than control birth, our modern cities are subject both to tremendous population pressures and an ever-increasing population longevity. Our national indifference to, and ignorance of, the long-term effects of natural processes is clearly costing the United States billions of dollars each year.

In spite of claims to the contrary, urbanites are characterized by a high degree of conformity. They work together, play together, panic together, and befoul the environment together, and herein lies the real challenge of those concerned with planning for the future needs of man and his cities. Consider the old example of troops parading across a suspension bridge in precise cadence. The synchronized step of a group of men in unison with threaten the stability of the structure, yet another group of the same size, but characterized by less conformity, can pass safely over the span. In similar fashion, widespread "togetherness" in metropolitan centers produces peak demands that threaten the stability of the overall urban structure. Rapid weather changes create serious fuel and power shortages, holidays precipitate congestion of transportation systems, and willing acceptance of the "one-way container" by nearly everyone has produced a waste-disposal crisis. The point to be emphasized here is that activities in our urban sectors, whether wise or imprudent, have reached staggering proportions, and if we are to avoid problems of the same magnitude, shortsighted planning for urban growth cannot be tolerated in the future.

In Table I, essential urban activities are listed that are of vital concern to the environmental geologist, because he can contribute substantially to the solution of problems related to these activities. Because this paper is specifically concerned with urban growth, I will confine my comments as much as possible to two activities closely related to urban growth-mineral resource extraction and waste disposal. Much like a living organism, cities consume resources as they grow, and in doing so, they create wastes that must be eliminated. If either of these activities is thwarted, the well-being of the city rapidly deteriorates.

What are our resource needs and what are the critical problems to be solved in this realm? Data from the U.S. Bureau of Mines reveal that 150,000,000 tons of metal are needed annually in the United States and that 1.6 billion tons of fuel are consumed each year as well. Neither of these resources is renewable, but no crisis exists as yet because both have such a sufficiently high unit-value that they can be extracted economically from a wide variety of deposits and at great distances from markets. In contrast, major problems exist today in regard to construction materials (sand,

URBAN ACTIVITIES STRONGLY DEPENDENT UPON ENVIRONMENTAL FACTORS

Waste disposal: solids, liquids, gases	Design and construction of foundations
Transportation: land (surface and subsurface), water, air	Extraction of mineral resources
Flood control	Open-space and recreation
Water supply: surface, subsurface	Underground utility networks
	Land reclamation and urban renewal

Table I

gravel, crushed stone, asbestos, gypsum) that have relatively low unit-values and are commercially valuable only if extracted in proximity to market. The average value of sand and gravel used in construction is $1.00 per ton. A common "rule of thumb" for transportation costs is $0.25 for the first mile and $0.05 for each additional mile. Clearly, hauls of more than 16 miles raise the cost of transportation above the value of the resource. Accordingly, reserves of construction aggregates must be developed close to or within metropolitan areas if sand, gravel, and limestone are to be extracted economically. Unfortunately, pits, quarries, and mines are by their very nature undesirable in urban areas because of the noise, dust, blast vibration, and traffic generated. Social, economic, and environmental forces accompanying urbanization have effectively curtailed this type of resource extraction in almost every metropolitan area in the United States, with an accompanying loss of potentially valuable resources. If such waste is to be prevented in the future, sound planning based on resource inventories must be instituted at the local level.

Let us now shift our attention to the second urban growth parameter — waste disposal. In our present society, characterized by planned obsolescence and one-way containers, each of us produces approximately 1500 pounds of solid waste per year — equal to a volume of approximately 3.3 cubic yards. It has been estimated that after ten more years have passed, the total volume of solid waste produced in the Chicago metropolitan area during one year will be approximately equal to the total volume of soil and rock excavated during the construction of the Panama Canal. If such vast quantities of waste cannot be disposed of rapidly and adequately, even our most modern cities will suffer crisis conditions in a matter of a few days, as did New York City a few years ago. New York's crisis, however, was brought on by a labor strike and was not an environmental problem per se. It is highly likely, however that if present trends continue, many major cities will be faced with similar crises due to lack of adequate disposal sites to bury their waste.

The national cry for quality in the environment is putting pressure on continued use of the common dump — our cheapest disposal method, costing approximately $0.75 per ton. Alternatives to the dump are: sanitary landfilling at $1.50 per ton; incinerating at $4.00 per ton; and grinding and mulching at $7.00 per ton. Unfortunately, none of these alternatives remove the need for a nearby burial site for the waste residue. Much like pit and quarry operations associated with mineral-resource extraction, our waste-disposal sites are subject to social and economic pressures, for few people want to live or work near the area.

A comparison of mineral-resource extraction activities and waste-disposal operations reveals some interesting similarities. Both activities depress land values in their immediate vicinity, and both activities involve the handling of materials of little or no unit value. In addition, both activities create nuisance factors such as traffic, dust, litter, and noise.

Further comparison of these two activities reveals significant differences. Resource extraction commonly produces an unused excavation, whereas waste-disposal activities require some form of excavation for burial of refuse. Vehicles transporting mineral resources to market carry their loads to the city and return empty. In contrast, waste-disposal vehicles carry their loads from the city and return empty.

In recent years planners have taken a careful look at both of these activities in an attempt to develop efficient multiple-land-use techniques. In several states, trucks and rail cars are being tested that can transport construction aggregates to the city and carry solid waste on the return run. The double use of resource-extraction sites as waste-disposal sites has proved successful in several major metropolitan areas and the practice is receiving wider recognition. By way of example, the site of the Denver Coliseum was a sand-and-gravel pit prior to being used as a land-fill during the late 1950's. By 1962 the Coliseum and adjacent parking areas were completed, representing at least a third stage of land-use. Commonly, recreational uses are particularly well suited to this type of multiple-land-use practice. Through carefully planned placement of the refuse and cover material, a variety of topographic forms can be constructed, enhancing the area for such activities as golf, hiking, horseback riding, and even skiing.

It should be emphasized that use of mineral-resource excavations as waste-disposal sites is not the only alternative in achieving multiple-land-use benefits for growing cities. Throughout the Midwest, strip pits and quarries have been flooded and developed into attractive hunting and fishing areas. In the metropolitan Kansas City area, underground limestone mines are successfully used for a variety of purposes after extraction ceases. More than one-seventh of all warehouse space in Kansas City is located in underground mines. In addition to warehouse space (some of which is used for cold storage) Kansas City mines also house a wire-fabricating factory, several offices, and a plant that manufactures precision instruments. Through proper design, such subsurface excavations permit the development of underground facilities coexisting with surface use by residential, commercial, and industrial interests. This coexistence is economically important because it permits maximum growth of the surface tax base. Approximately 30 percent of the area of our cities is devoted to transportation uses that do not generate taxes. Where feasible, thru-way and city bypass routes placed underground also yield economic advantages if the bedrock excavated is marketable.

Clearly, the benefits of multiple land-use techniques cannot be realized without an orderly planning program. The geologist must first inventory the area, identifying all potential resources that might be pre-empted by urban encroachment. The planner must then institute a multiple land-use program that will facilitate utilization of such resources at the appropriate times. Through zoning regulations, the local government must insure that the resource areas are adequately protected from imprudent and premature development. Finally, the engineer is charged with the responsibility of putting the plan into operation, such that each successive activity is carried on in a way that the ultimately desired land-use can be achieved. Long-range planning for urban growth is very much a team responsibility and the geologist's role is played in the inventory phase.

Thus far, resource extraction has been largely related to multiple land-use. Now let us focus on a resource related to hazards — namely, water. When controlled and of high quality, water is the lifeblood of home and industry. In contrast, when uncontrolled and polluted, it is a threat to both life and property. In the large, undeveloped areas of the Midwest, 85 percent of the annual precipitation is lost through evapo-transpiration, 10 percent constitutes surface runoff, and 5 percent enters ground-water systems. As urban areas expand into the rural periphery, previously permeable farm land becomes "roofed over" with impermeable roadways, parking lots, and buildings, and hydrologic relationships are drastically altered during this process. In the extreme situation, such as the central business district, more than 90 percent of the rainfall becomes runoff. Obviously, man-made urban drainage systems (storm sewers) must be designed to handle peak discharges far in excess of those occurring prior to urban development. It follows therefore, that storm-sewer design limits must vary directly with the maximum urban density expected and that drainage basins are fundamental planning units to be assessed by the geologist in his environmental inventory. Unlike natural drainage courses, storm-sewer systems generally are completely enclosed with a fixed discharge capacity. A common error in urban planning occurs when early storm-sewer installations built in lower reaches of a

FACTORS USED IN MAKING GEOLOGIC MAPS FOR PLANNING

Elevation	Hardness and rippability
Slope	Soil types
Surface water	Ground-water
Bedrock geology and structure	Natural resources
Soil-mantle thickness	Drainage basin factors
Faults, joints, and other rock defects	Land use
	Vegetation
	Precipitation

Table II

basin are inadequate to handle runoff from late development of the upper reaches of the basin. And, storm waters back up into basements and streets in lowland areas. Through more careful evaluation of geologic and engineering data, such commonplace planning errors can be eliminated.

Why then, are geologic data so seldom used by urban planners? I think if we are honest with ourselves, we will recognize that the geologist commonly presents his findings in a style and language unintelligible to those outside his discipline. However technically competent a geologic inventory of the environment may be, it must be meaningfully related to the planner, engineer, architect, and developer, in such a manner that they can synthesize it into a workable design for managing the environment. For example, deposits of natural resources cannot be protected by zoning unless, initially, the geologist clearly calls attention to the fact that they are present. Similarly, hazardous conditions can not be avoided unless the geologist indicates that danger exists.

In Table II some of the most important physical factors that can be used in making geologic land-use maps are shown. Significantly, the list does not include classic geologic parameters such as geologic age, environment of deposition, index fossils, and the like, for they have little direct bearing on the problems of the planner. Maps showing the areal distribution of quantitative differences measured for each factor in Table II offer a useful means of presenting selected information applicable to a given land-use activity. The planner, in turn, can then directly synthesize the information for the generation of suitability maps, upon which planning decisions are ultimately based.

In the final analysis, environmental geology is concerned with the communication between geologists and those who rely on environmental data in their decision-making processes. It is not a sub-field of geology, but is more a perspective possessed by geologists who recognize a high relevance between geology and contemporary society. The classic aims of our discipline are as important today as in the past, but applied endeavors must not be subordinated to restrictive concern toward unravelling earth history.

THE COLORADO GEOLOGICAL SURVEY'S ROLE IN ENVIRONMENTAL GEOLOGY

JOHN W. ROLD

Director, Colorado Geological Survey

The past year, we've all come to realize that the actions and the fate of many prominent politicians as well as many of the policies of our nation have been determined by opinion polls. An informal poll in the three and a half months since I was appointed Director of the Colorado Geological Survey shows that 83.6 percent of the people I've talked with have asked the question: "What's the new survey going to do?" Realizing that this question is always related to one's own area of interest, and knowing that you're interested in environmental geology or you wouldn't be here, I'm impelled to tell you how I visualize the Colorado Geological Survey's role in the realm of environmental geology.

When we talk about geologic hazards or the dangerous aspects of environmental geology, we must realize that they result directly from the conflict between the habitat of our exploding population and natural geologic processes. A few simple examples should prove this point, and indicate to some degree the scope of Colorado's geologic hazards. The numerous minor landslides — past, present and potential — on the flanks of North and South Table Mountain, some of which will be inspected on the conference field trip, result from natural geologic processes. They would normally rate only minimal geological curiosity. Now, however, our expanding metropolitan population is crying for the beautiful view building sites which this area possesses. The mere presence of people and buildings in the area creates a potential hazard. The natural geologic processes can be accelerated greatly by roads, building construction and the change in drainage pattern caused by man's activities. Man's natural activity and presence here transforms natural geological processes into potential geologic hazards. Although most sites in the area are geologically stable, they also may suffer financial damage from the publicity which will result from those houses which, due to inadequate geologic investigation, will be built in unstable areas.

Let's look at a reverse situation. The famous Slumgullion Slide near Lake City is well-known to geologists simply as a typical example of a major landslide. Had there been a thriving tourist community in the valley of the Lake Fork at the time of the slide, it would have ranked high on the list of so-called natural disasters. Now this dormant slide causes only minor problems for the narrow road which traverses it several times on the way up Slumgullion Pass. If, however, someone tries to put a 4-lane superhighway across Slumgullion Pass, the cuts and fills necessary for such a road would create a geologic hazard. This same reasoning applies to the many slides and potential slides on U.S. Highways 6 and 40 in Clear Creek Canyon, along Straight Creek and over Vail Pass.

Baldwin Hills Dam in California was in reality just a small tank with a capacity of only 896 acre-feet of water. Yet, man's placement of this structure in a heavily populated, dynamic geologic environment created a monstrous geologic hazard. Only a few inches of slump faulting ruptured the dam's asphalt membrane and 30 to 50 million dollars in damages resulted. Had the dam broken at 2:30 in the morning instead of 2:30 in the afternoon, the death toll would have been over 5,000 instead of 5.

Over the years, domestic, municipal

and industrial wastes have been disposed with total disregard of the geologic environment. It's impossible to calculate this practice's overall present and future pollution effect on our precious ground water. The total cost will be felt not only by our own generation, but represents a crime "to be visited on our children's children." In one well-publicized case at the Rocky Mountain Arsenal, thoughtless construction in permeable sandy soils of evaporation pits for chemical wastes ruined domestic and irrigation wells many miles away. Nearly a decade after the practice was stopped, many of these wells are still reported to be unfit even for irrigation.

My point is that man must adjust his activities and habitat to the geological processes and environment. It's difficult from a physical standpoint, and usually economically impossible, for man to adjust the geologic processes to his environment and activities. Simply ignoring geologic factors, as has been done so many times in the past, results in a terrible waste of money and can result in loss of life as well as property.

The foregoing portrays the causes of and the scope of the problems facing us. The way geology is often used to remedy this reminds me of a situation during my youth. When I was a boy on a ranch, we always treated our own sick livestock. My dad never felt he could afford to call the veterinarian out from town until he was certain that none of our home remedies were working, and that the cow was going to die unless he called in some professional help. Obviously, the veterinarian was seldom able to save the animal and perform much of a service to us. He could, however, nearly always tell us why the cow died. A striking analogy exists with geology. If you need more than just a post mortem, geology should be called in before the problem becomes a crisis.

Geology can also be likened to the medical profession. If a person discovers a lump under his arm, he'll consult his family doctor. The general practitioner examines the lump. Depending on his diagnosis and the seriousness of the lump, he may treat it himself or call in a surgeon to perform an operation. The surgeon then consults with a pathologist to determine the nature of the tumor. A cancer specialist might be called in for consultation, and to supervise the final treatment. We all realize the necessity of, and are conditioned to, the expenses involved in this type of approach to even minor medical problems.

The geological science is as varied, diverse and specialized as medicine. Yet, many people feel that any geologist should be able to look at a problem such as a potential landside, a fault zone in a tunnel, or an area of bentonitic clays, and quickly prescribe a simple, cheap, foolproof remedy.

Certainly, at present, the Colorado Geological Survey must assume the role of the medical general practitioner. We must work with the public, attempting to evaluate the seriousness of the problem and helping to find experts who can provide the means of hopefully avoiding or, at last resort, remedying geologic problems.

Fortunately for this state, the Colorado Geological Survey's jurisdiction in environmental geologic problems is clearly stated. HB 1282 which recently recreated the Colorado Geological Survey contains eight specific charges or duties. Three of these deal specifically with environmental geology, i.e., the relationship of man and his activities to geologic processes and the geologic environment. These three charges are:

1. "To assist, consult with and advise existing state and local government agencies on geologic problems."
2. "To evaluate the physical features of Colorado with reference to present and potential human and animal use."
3. "To determine areas of natural geologic hazards that could affect the safety of or economic loss to the citizens of Colorado."

Obviously, over 30 percent of the Colorado Geological Survey's assigned duties relate directly to man's relationship to his geological environment.

We are currently attempting to hire an Engineering Geologist. Obviously, to many of you, demands for this highly specialized field within the science of geology are skyrocketing as the general public awakens to the valuable contribution that geology can make in solving human environmental problems. Colorado is no different in this respect from the rest of the nation. Although the state survived for some 43 years with a geological survey, the unfulfilled demand for geologic service to the state is tremendous. Much of this pent-up demand lies in the realm of engineering or environmental geology. Hiring an expert in this specialty will help to serve this critical need.

Some of the particular environmental

geologic projects planned are:

Landslides

We need to specifically map in detail and publicize present landslides and potential landslide hazards. This should be done not only in metropolitan Denver where a small but excellent start has been made by the U.S. Geological Survey, but in every urban and high land use area of the state.

Swelling Clays

I don't yet know the total extent of research on the geologic relationship of swelling clays. Certainly, many of the state's swelling clay problems can be directly related to specific geologic units which, therefore, could be geologically mapped and predicted before the foundations crack and the highways heave. Even if we could only predict broad areas where extensive auguring and soil testing were required, and other areas where only a minimum of testing were required, we'd be performing a vital service to the public.

Land Use

Someday sufficient geological knowledge will be available that it can be specifically applied to each and every major zoning problem. Considerable geologic and mineral resource data is readily available but often ignored in land use decisions. Even now, geological advice and counsel could be utilized in developing wise solutions for many zoning or land use problems.

Mine Subsidence

Urban development is beginning to move into areas of possible subsidence over mined out coal areas north and northwest of Denver. In areas around Marshall, subsidence has and is taking place. Conversely, subsidence is unlikely over much of the area where mines operated at several hundred feet and competent rock occurs between the mine and the surface. Between these two extremes of known present subsidence and probable stability, several thousand acres of otherwise prime development land face a moderate to high risk of future subsidence. Although specific data is available on each mine, it's never been compiled and studied in light of possible future subsidence. I wonder how many people are buying home sites, and how many people are investing in lands, without even knowing mines exist below the surface, let alone considering the possibility of future subsidence.

Colorado's recent history is replete with examples of inadequate use of geologic data: leaking dams, foundation problems from swelling clays, landslides endangering or destroying roads and buildings, water pollution, improper land use, and tunneling problems. Fortunately, these have not yet resulted in loss of life but, unfortunately, they have and will cost the taxpayers literally millions of dollars. In nearly every instance, geologic knowledge and data was readily available or could have been secured with a minimum of effort. This knowledge could have predicted and, likewise, planned for preventing, minimizing or avoiding the problem. Investigating these fiascos would be fun, and would result in reams of publicity for the Survey. Future success is our paramount aim, and no one ever won a race "by beating a dead horse." Achieving future cooperation will be difficult enough without opening old wounds and dwelling on past inadequacies. These problems will be studied, but only with the viewpoint of using these cases to enable us to diagnose and avoid similar problems in the future.

Geologists always like to fall back on the principle of uniformitarianism. That is: "The past is the key to the future." Applying this to the brief 3-month history of the fledgling Survey, we can see some clues as to future activities. So far, I've worked on dam sites, geologic effects and controls of the Rulison nuclear detonation, landslides (both highway and residential), water pollution problems, guidelines for waste disposal wells, roads, and site selection for a solid waste disposal project. This type of general activity will continue. As our population explodes, urban centers grow over less desirable sites, and as society's demand for mineral resources intensifies, our challenge will expand. We must grow to meet this challenge.

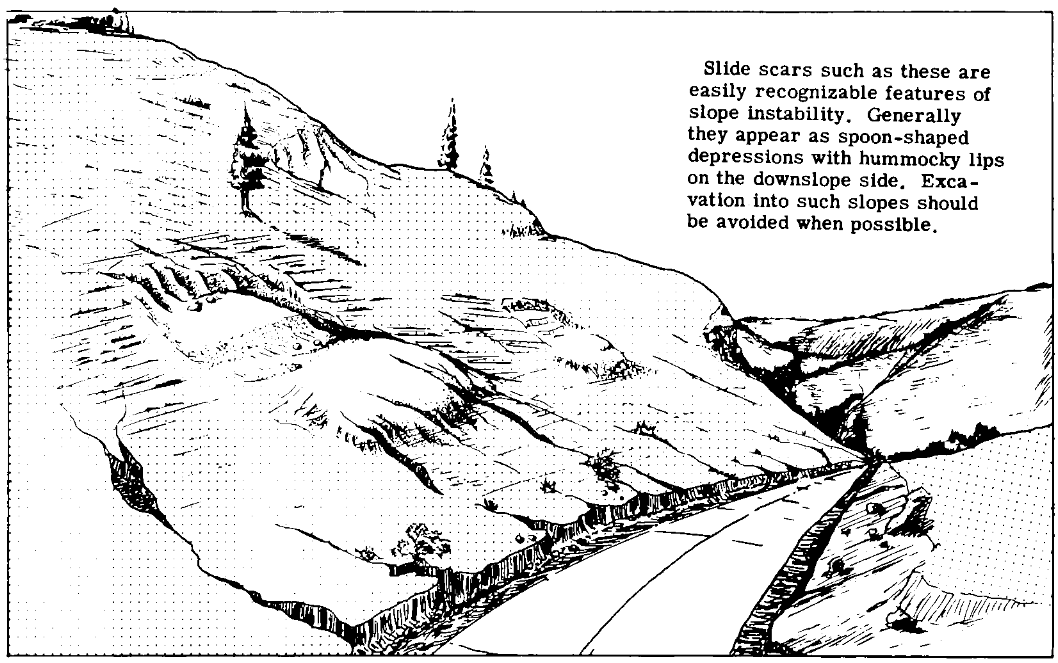
In summary, I visualize the future role of the Colorado Geological Survey as:

1. Educate the public to the value of and the need for geology in many walks of everyday life. Hopefully, this conference is contributing toward that goal.
2. Develop a broad background of basic geologic data which can immediately

be applied to environmental problems.

3. Point out specific geologic problems before they become crises. All geologic hazards do not have to become geologic disasters.
4. Bring the people or the agencies experiencing geologic problems together with parties capable of deriving the solutions. Smaller problems will entail consulting geologists; broader scale or long-range problems would require the U. S. Geological Survey, universities or research foundations. Many agencies with recurring geologic problems can be aided in setting up specialized competent geologic staffs of their own.

Hopefully, in the future, we will have the geologic knowledge and develop the confidence of the government agencies, industry and the public to the point where geologic advice will be sought routinely during the early site feasibility studies of any highway, dam, tunnel, large construction facility or urban development anywhere in the state.



Landslide Scars

From: Landslide Investigations
Field Handbook
by
Arthur B. Cleaves
U. S. Bureau of Public Roads
1961

CITY, COUNTY AND STATE PLANNING POLICIES

JAMES N. MILES

Colorado State Planning Director

In the introduction to a recent book entitled "The Year 2000" by Herman Kahn and Anthony Wiener are the following words:

> "Most theories of social change -- and these were derived principally from the nineteenth century -- have dealt with impersonal processes -- theories of evolution, immanence, cycles and the like. What is distinctive about the middle of the twentieth century is the deliberate intervention of human instruments, principally government, to control change for specified ends. With the growth of modern communication and transportation, we are more quickly aware of the linked consequences of change, and the need to anticpate these and to plan for them from the community to the national level. But the recognition of the need for planning involves an added dimension as well -- the nature of time. The rebuilding of American cities, for example, involves a thirty-five year cycle. The expansion of medical services, as another example, involves fifteen-year planning -- the time it takes for a young man to enter college and complete his medical board exams. In fact, especially in a post-industrial society, where human capital is the scarcest resource, planning necessarily involves long-run commitments and, with equal necessity, it requires long-run forecasting."

For the moment, let me restate a portion of this for emphasis: "What is distinctive about the middle of the twentieth century is the deliberate intervention of human instruments, principally government, to control change for specified ends." Do we in fact control change for specified ends? Is there deliberate intervention? Is government an instrument of this intervention? If we can answer these questions with "yes," then we must accord the emergence of planning some role in this act of control.

Contemporary planning in the public sector began more than seventy-five years ago in response to pressures of intense urbanization placed on the country's major cities. At that time, it was felt that the panacea to urban blight and decay was good physical design. The proper design, location and scale of major structures, circulation systems, parks and open space, and other physical features of the city, it was propounded, would serve adequately to foster an improved urban environment. This we called the city beautiful movement.

Following World War II and the lessons learned in the great depression, it became increasingly apparent that social factors, in addition to physical design, must be addressed if the character of man's environment were to improve. Initially, in 1949, housing was given prime emphasis as a determinant in the quality of the human habitat. However, as time passed and as experience was gained, many social-oriented conditions were addressed. Spearheaded by the federal government, planning began to encompass such human resource areas as education, health and welfare, in addition to protection, safety and defense. Natural resources, such as air, water and mineral wealth, as well as natural fauna and flora plus scenic and geologic features became subjects of more intense planning, preservation, and conservation efforts. Economic resources also came under more intense scrutiny, as agricultural, industrial and commercial growth was associated with the development of social and physical conditions. As the basis for all these efforts, governments at all levels became more fully aware of the increased requirements not only to provide new and improved services, but to effectively manage all resources available, to improve man's place in his environment.

With recognition of the many factors associated with man's environment, and the complex interactions which mark the application of these factors, federal, state and local governments mounted planning processes which built from, and were responsive to, the relationships between these functional issues. The intense growth of problems associated with urbanization and the fragmentation of planning, management and service responsibilities inherent in our federal system, however, clearly pointed out two areas where additional action was necessary. First, various levels of government, and particularly state and local government, must define their respective responsibilities for planning, managing and administering government services and controls. Only in this way can duplication of effort be minimized — can gaps in government responsibility be filled — and can a coordinated and efficient effort toward meeting public needs be established between the state, its regions, metropolitan areas and localities.

Second, regular and continuing channels of communication between state and local government must be established. Only through such channels can major problems, opportunities and desires be identified — can the planning programs of the state and its localities be developed to properly meet public needs — and can action be taken which is not only responsive to identified needs, but is so structured that the greatest thrust may be generated.

To identify planning policy in Colorado government is a very elusive assignment. Responsibility for the development of policy is highly fractured among levels of government and also within the institutions of each level. The problem is further complicated by the fact that a great deal of policy formulation occurs outside the realm of the state and its various subdivisions, both from the standpoint of the federal government, and also from the private sector. Conflict of policy is often the rule because the staggering myriad of agency responsibility makes coordination extremely difficult. A contemporary example could be made of the reported invasion into Colorado of the Dutch Elm Disease. One agency issues an order that all infected trees must be burned or buried with a two-foot cover of dirt. As you might expect, burning being the simpler act, this will probably be the major solution to the problem. This, however, runs counter to another agency's prohibition of burning, issued to control air pollution. An unending parade of such conflicts exist. Areas where there is an absence of policy could be covered by noting who sets policy for highways, health, water development, sewers, welfare, housing, conservation, industrial location, and so on.

But what causes the problem? Of course, the answer is urbanization, for it is increasing numbers which swell the city, creating demands for more recreation, highways, airports and shopping centers. It is the urban community which both directly and indirectly is the basis of the problem.

To be concerned about the environment is to be concerned about that community, for it is this institution which looms large in the modern world. The urban community is a complex phenomena of many facets. It may be seen as a governmental system, a socal organism, an economic unit, a collection of people and buildings, or simply as a geographical area. For the political scientist, one set of dimensions seems to predominate; for the sociologist another, and for the planner, the geographer, the economist, the philosopher, the artist and the geologist — still others. What the observer or scholar looks for in the urban community depends largely on his point of vantage, his individual interests and tastes and his objectives. It is the urban community which generates the demands of modern society whether we are talking of the immediate problems of the historical city, or if we are talking of the demands on the total environment.

The establishment of a department of urban development, at the federal level; the intent of the new administration to formulate an urban policy; the creation of urban coalitions; metropolitan councils of government, even a state planning agency in Colorado, all lend emphasis to the growing concern, particularly of government, about man's self developed environment. Any involvement in this concern and attempt to develop policy must recognize, however, that there are differing aspects of this urbanizing situation; that there are unique and distinctive qualities and opportunities for development, particularly in Colorado.

While the nation is in the midst of a continuing and seemingly unending period of urban expansion, it is well to remember that until relatively recent years, the country was predominantly rural. In 1790, only 24 places of 2500 or more population existed, and urban residents made up only one-twentieth of our population. It was 1920 when the urban figure reached 50%. At present, more than 70% is judged to be urban in character, but this massive urban surge has occurred since the depression. While statistics of this type are old-hat to everyone, it does seem worthwhile to restate them and point out that much of the planning potential and its development has been, and is, inhibited by the influence and institutions of this rural background. In Colorado especially, the rural-urban change has great relevance for not only has our community change carried the basic characteristics of the national trend, but it also has the special features of having concentrated the urban population in one area — one major center — while in fact reducing the population of many rural areas below that in the agriculturally oriented past.

To this we need add the awareness that planning policy in Colorado must face a rapidly emerging industrialization; that in Colorado we are dealing with more than the environment of a permanent residential pattern. We also must accommodate the migratory population of tourist and recreationist, who often outnumber the native; we need an awareness that the state suffers from an imbalance in the development which is occurring; and that most of our community structure is not of sufficient strength or size to meaningfully represent a growth base. Add to this the fact that a spreading population tends to a decentralization of the governmental pattern, and we have the background against which the various units of government seek to develop policy and direct development.

Early in the consideration of planning policy, the point needs to be made that it is not a single act of planning, nor is it a single level of planning. A major factor is the need to recognize the problem levels and structure a hierarchy of planning, for whether with existing institutions or with new arrangements, we need to relate planning to the dimensions of time, scale and degree. When the town or city deals with the major street system, it must work at the level of easement size, topping, curb design and traffic control. But it must also relate to the larger system of state and county wherein it has very little input in terms of policy formulation. The state and county on the other hand must also relate to a broader system when key policy is established.

Legislation in this state, while permitting five forms of planning activity, does not recognize, except in very limited ways, the structure of planning. Proposals are developing, however, which may alter this omission in the future. Four levels of planning are permitted under Colorado law: the town or city, the county, special districts, and regions made up of two or more units of local government. It should be pointed out here that while these four levels are established under permissive legislation, all adoptive processes are reserved to the city and the county. Special districts must operate under the approval of the boards of county commissioners, while the regional planning bodies have only the ability to make recommendations back to the city or county planning unit, for recommendation on to the elected officials.

The primary areas in which planning operates to direct development have to do with zoning — the control of land use, subdivision regulations, protection of street rights-of-way and other public sites, public housing, urban renewal, regulation of utilities, and the establishment of special areas. State law provides that any municipality is authorized and empowered to make, adopt, amend, extend, add to, or carry out a municipal plan. Theoretically, this is the basic document of planning policy. Such plan shall show the planning commission's recommendations for the development of:

1. The general location, character and extent of streets, viaducts, subways, bridges, waterways, waterfronts, boulevards, parkways, playgrounds, squares, parks, aviation fields, and other public ways, grounds and open spaces;
2. The location and extent of public utilities and terminals (public and private) operated for water, light, sanitation, transportation, communication, power and other; and
3. Removal, relocation, widening, narrowing, vacating, abandonment, change of use or extension of any of the foregoing ways, grounds, open spaces, buildings property, utility or terminals.

In preparing such plans, it is the purpose of the legislation that the commission shall make careful and comprehensive surveys and studies of present conditions and future growth, with due regard to its relation to neighboring territory. The plan shall be made with the general purpose of guiding a coordinated, adjusted and harmonious development, which will best promote health, safety, morals, order, convenience, prosperity, and general welfare, including promotion of safety from fire, flood waters, and adequate provision for light and air, the promotion of healthful and convenient distribution of population, the promotion of good civic design and arrangement, efficient expenditure of public funds, and the adequate provision of public utilities and other public requirements.

While somewhat more simply stated, the legislation of the county accomplishes much the same purpose. Each board of county commissioners is authorized and empowered to provide for the physical development of the unincorporated territory within the county. In addition to the general clauses cited for the city and the county, legislation includes the consideration of open development areas for conservation, food and water supply, protection of urban development, and flood control.

Special district planning permits areas such as tourist centers to establish a review body under the authority of the county commissioners. This unit is permitted to zone the territory only, and cannot establish other controls. One of the common problems running through planning legislation, and one which bears on the use of the plan for establishing policy, is whether or not to make a plan public. Without discussing the policy of desirable citizen participation, or a strategy for public acceptance, the question is present as to the liability on the part of the city or county if the publicity given to a plan spoils a property sale, interferes with a loan, or causes some other financial loss.

Fundamental to the implementation of the plan is the exercise of the zoning ordinance. This is an area in which Colorado still shares a conservative view, but this is to be expected in keeping with the historical reluctance to permit the adoption of zoning. The courts finally relaxed after the U.S. Supreme Court ruled that zoning was an appropriate use of the police power. From the standpoint of the geologist, more progressive legislation is found in recent enactments related to subdivision control. In the 1967 session of the legislature, the basic law was amended to provide that subdivision regulations may establish criteria for the subdivision of land; earth testing specifications for the determination of possible earth and rock creep, sliding or bentonitic shales, avalanche, or mudflow problems, and other natural hazards — and provide such protective measures in regulation against such hazards — proper arrangement of streets and roads in relation to existing or planned streets or roads; engineering specifications for the construction of streets and roads; maximum street grades; adequate and convenient open spaces for traffic, utilities, access of fire fighting apparatus, civil defense, recreation, sites for schools and educational facilities and related structures, light and air; minimum area for lots; and such other matters as the commission shall deem necessary for the protection of the public interest. Such regulations may control the design of drainage structures; such regulations may provide, among other things, protection of the public interest by establishing criteria for the subdivision of land including engineering specifications for the construction of streets and roads within the subdivision, and to prevent excessive street grades. Such regulations shall control the design of drainage structures so as to prevent uncoordinated drainage patterns.

One unit of the planning hierarchy has not been included to this point; that is the area-wide or regional factor. A major limitation in the legislation of Colorado is the capability to effectively deal with areas containing a number of governmental sub-units. Cities and towns are limited exclusively to the corporate limits in their application of regulations. This means that the county must provide for the extra-territorial controls of the urban center. Historically, the county has been a service unit helping to get people out of the mud, cutting weeds, providing for the less fortunate and providing justice. The county has not been equipped to handle the problems of urban development. It is in the county, however, that a major part of all development is occurring. This is primarily because of the very conservative annexation provisions of Colorado law. The existing regional planning act was passed as an attempt to provide a vehicle for city-county cooperation. As stated earlier, any two or more units of government may enter into an agreement to form a regional commission. The grave limitation in the act is that the regional body has absolutely no authority to implement its planning proposals. Despite these limitations, the regional act has been used to good purpose in several places within the state. The Denver Regional Council of Governments which is based on this law has now developed a very active program of area-wide planning which includes the five counties of Boulder, Adams, Jefferson, Arapahoe and Denver. Because of the well-developed city and county programs in the area, this group is now working on a very progressive study program. Colorado Springs and El Paso County have also adopted this approach, and the Grand Junction and Pueblo areas have very successful regional bodies.

There is a question, however, if this is adequate, or if there may not be an additional level of planning concern which should be considered.

In his book, "The City in History" Lewis Mumford asks: "What is a City? How did it start? What process does it further? What function does it perform? What purpose does it fulfill?" As far as I know, there are no complete answers; no single definition of the city can apply to all its manifestations, or fully describe its nature and role. What is happening today is the creation by technology of a new population unit — not a city, not a village, not a county. What is being created is the metropolis, an economic and social unit which possesses a large population nucleus or center, and which is a mosaic of sub-areas whose inhabitants are highly interdependent on a daily basis in terms of needs, communication and commutation to and from work.

Jean Gottman, a French geographer, makes this statement:

> "We must abandon the city as a tightly settled and organized unit in which people, activities, and riches are crowded into a very small area clearly separated from its non-urban surroundings. Every city in this region spreads out far and wide around its original nucleus; it grows amidst an irregular colloidal mixture of rural and suburban landscapes; it melts on broad fronts with other mixtures, of somewhat similar though different texture, belonging to the suburban neighborhoods of other cities."

This perhaps is the basis for the careful review of planning and its ability to establish comprehensive policy. While retaining, or attempting to retain, an ability for variety in the types of environment we can choose from, logic indicates that we cannot succeed in a meaningful way of controlling the environment as long as it is left to a hundred or more uncoordinated units in an area such as Denver. Perhaps metropolis is a new unit which must be brought into the government structure if elements such as transportation, pollution, recreation, open space are to be accommodated. As we look at new units, we need also to look at new methods, and today many are emerging. Planning is not a mechanical process. Central to it is the problem of choice both for the ends desired and for the allocation of resources. Thus, planning and rationality are one. All this puts us on the threshold of an ancient and persistent human quest — to choose our futures.

A large part of America since the end of World War II has been reshaped by the desire of millions of Americans to own their own homes, on separate plots of ground. A consequence, in part, of the pastoral myths of America's past and the moralistic protestant fear of the "big city." But few persons were aware of the large costs of such a change — the problem of travel time and of roadways; of vast new service needs such as schools, water and police; the sprawling and chaotic growth of townships and the like. Nor was there an effort to sketch the total costs of alternate plans — cluster-type suburban developments, or concentrated high-rise densities with large open spaces. It may well be that even if such alternatives were presented, most Americans would still have chosen the present dispersal of suburbia, but the policy would have gained a clearer idea of the range of problems involved. Hence the heart of future studies is the effort to chart "alternative futures" as the basis for policy choices.

NATURAL RESOURCES: THEIR PROTECTION, UTILIZATION AND CONSERVATION

THOMAS W. TEN EYCK

Executive Director, Colorado Department of Natural Resources

I would like to start out by asking all of you who are NOT geologists, would you please raise your hands? I would like to see if we are outnumbered. Wonderful! I wondered if the dialog were really going to be possible to achieve here. I think we can do it rather well. I would like to set a little bit of a prolog in the comments that I make to you today. Our environment in the early stages of man's recorded history was considered an enemy. The environment was our foe. Man has always struggled against his environment — to overcome it, to adapt himself to it, but generally our environment has been an enemy. It is also interesting to note that most of our greatest advances in the development of civilization came from peoples where the environment was a challenge and a handicap. The tropical and polar region inhabitants generally had less impact on our development.

Our western civilization, and by that I am going to limit it essentially to European and the North American civilizations, is probably the first civilizations that had an interest in what the Governor referred to earlier, "the quality of living." We have for the most part in all of our developments of society and civilization been simply trying to dominate the environment, to extract from it those things we needed with which to live. I believe that today, and perhaps, for the first time, our civilization is able to consider, and is indeed seriously considering, the quality of living and not simply the fact of living itself. We perhaps are the first civilization with the means to consider our harmful effects on our environment. I doubt that very many of those early civilizations gave much attention to the spoils that they were guilty of. In the first place, even if they had a harmful effect on the environment, they were relatively small in number. If a locality became really unsuitable, they simple packed up and moved. If they exhausted one field, they could find another field.

Now, in this period when we are seriously considering our impact on our environment, we should look perhaps at some of the reasons why this is so. The Governor referred to an outstanding authority on population problems, who indicates the population explosion is going to affect the entire United States, when in the next 31 years we will increase our population again by half. I can bring it a little closer to Colorado by reporting that projections for Colorado in 1985, only 16 years away, indicate an increase of population of 74%. This is a greater increase than the United States will have in the next 31 years. The population crisis is one of major factors which makes it necessary for us to consider our impact on our environment.

There is another factor that we need to take into account, another cause that is increasing our impact on the environment. We have a tremendous increase in the expectations of people. Perhaps it is not necessary to go into the reasons as to why this is so. There is no doubt that the developing nations throughout the world are leaping from whatever stage in development which they may be in now, into the present. In most cases, they are leap-frogging many many steps that those of us who are in more advanced societies have taken much time to pass through.

I'll give you one example — I worked in

and spent a little time in Spain, which was one of the most under-developed countries of Europe. Spain has almost by-passed completely the fossil-fuel thermal power stage of electrical energy development. For many years in the early part of this century, Spain had probably the greatest development of its hydro-electric potential of any of the countries in Europe. Then they had a period of eclipse during the civil war and thereafter. They have no significant fossil-fuels for thermal energy sources. They do have some coal, but no oil. Spain is simply by-passing the fossil-fuel generation of power stage, and nearly all of their recent power generation capacity is nuclear.

This same trend, I think, is going to be even more dramatically evident as the countries of Africa and Asia develop. They will skip many of the steps that we took in arriving at where we are now in our development. Some of these rising expectations, which they are going to actually achieve, have been brought about by effects of instant communication. I think if TV has done nothing else, it certainly has raised expectations of many people. They see the possibilities of a good life. They are aware that it exists and they want some of it for themselves.

The rise in our standard of living, particularly in our own country, is also a factor which makes it possible and desireable for us to consider now the quality of our living. Our greater degree of mobility and the greater amount of leisure time that we have both tend to increase our interest in recreational opportunities, and increase our interest in the kind of environment in which we can do this recreational activity. There have been so very many technological advances. Those of you who are planners are particularly aware of the many technological advances in the automotive industry, and the many negative results of these advances. Maybe we would be ahead if we could do away with automobiles, but we haven't really gotten ready for that yet. Other technological advances have been home appliances, and the ladies here may quarrel with these comments, but today they are not the same kinds of slaves to their homes and their home chores as they used to be not too many years ago. They may be the victims of the appliance breakdowns, but they are not bent over the old washtubs. There is more leisure time for other kinds of activities. Some of the ladies in the crowd may disagree, but the woman's role is changing. The woman's life is different, and technological changes are, to a great extent, responsible.

Now, before we consider the implications of all of these pressures and the politics in regard to Natural Resources, I would like to discuss the way I see some of our resources. The geologists certainly don't need to be told that some of our resources, and particularly our mineral resources, are of a non-renewable character. There may be a lot of some of them, but even with iron, there still is only limited amount available on this earth that we live on. There may be a good deal less gold, and perhaps even less than that of uranium. Our mineral resources for the most part are non-renewable; they exist in a limited quantity, and that's all there are. In some cases, there are possibilities of recycling. For example, we can salvage steel and iron, and re-use it, and we should do this as much as we can. But minerals are one kind of resource which require one kind of policy, as compared to some other resources.

Some of our resources are renewable within limits. They may be fixed in quantity but they may be renewable. I think to a degree at least that our land fits in this category. So too, do our forests. We have great natural resources in our forests and these can be renewed. Water is fixed in quantity but it can be re-used, it can be purified. These different kinds of resources call for different kinds of policy and I would like to talk a little with you about these.

The non-renewable resources, such as the minerals, are going to require everything we can do in the way of salvage and re-use. It appears to me that we are still going to have need for them and they will be utilized. Another consideration is that in some instances, we may be able to develop substitutes, preferrably of organic origin. As you are aware, we have in the last few years done a great deal with plastics, which are now used in many applications in place of metals. A combination of these two things, salvage and substitutes, would, I think, be a wise policy for these resources.

Those of you who are involved in mineral exploration and mineral development recognize that those minerals are where they are. If they be in the middle of wilderness areas, and if they have economic value which is more important than other values, if they are vital to our country, someone has the task of deciding if they should be developed. Should the security of our society be at stake, they are going to have to be either developed or substituted for.

With our renewable resources we shall

need to develop other policies. For example, land can be renewable within limits by proper techniques of fertilization, irrigation and drainage. We can perhaps even enhance the utility of our land. In the use of our land for agriculture, we can use more efficient farming methods to develop more crop yields, but this will require significant efforts, both in technology and practice. Our forest resources can be "farmed" on a sustained yield basis. Many of the more advanced forest industry operators are getting better yield and better quality of timber than they did when only harvesting the natural growth that they encountered before.

Our policy problem for the use of land, in my opinion, relates to an effective system of land use planning and the controls to carry out the planning. Such planning and controls as now exist is very limited, both in effectiveness and geographic scope. Perhaps it is unfortunate, but I believe it will have to be applied statewide, rather than only in urban areas. I think this problem is of such importance and difficulty that there is going to be a land use allocation and this is going to call for some very hard decisions. Right now these problems seem to exist or tend to be recognized only in the places where we have urban concentration. Somehow or another we put the question off. But it is going to be a severe problem and some people are going to have to make some decisions about allocations.

There has been a good deal done in our state as recently as yesterday and I hope yet today in connection with water. This very renewable but limited resource is going to require a great deal more re-use. We must give a great deal of thought to our practices and we are going to have to do a much more complete treatment of water. I may not see it, but I predict that the time will not be too far in the future when sewage treatment plant effluent will be put to use again in municipal water systems. It will come, since there isn't any alternative.

Now when I spoke of the mineral resources, I spoke of what I hoped we could agree on as some kind of wise utilization. When I talk of land and water, I think we can call these examples of conservation. We have amounts that are renewable and reuseable and these resources we want to conserve. We have another resource, our air, which is also renewable in the natural resources sense. It will be renewable only so long as we can either depend on the snow and rain to continue to clean our air for us, or so long as we purify it by our own efforts. Before long we may see an overburden on that system.

All of these forms of pollution that we have developed, polluting our air and polluting our water and now polluting whatever areas we use for waste disposal, are attacks upon all our environment and threats to human survival.

One other form of resource that we should consider is our wildlife. This is in most cases a renewable asset or resource. In other cases, it is in real jeopardy of extinction. In some special cases and for some special species we are going to have to follow preservation policies. We may have to set aside an area and say, "In this area we are going to prohibit slaughter of any of these animals or any of these birds or any of this forest", simply to preserve it so that others in future generations will know what it looks like and what it is. We have already eliminated some species of wildlife. This is, at least for me, the most supportable of the preservation series. There are other cases where I think preservation should be taken into account.

I talked a good deal about natural resources but I haven't yet come back to what I tried to set the stage for with my comments about the early history of mankind. I think now we are just beginning to assess our effect on ourselves. When the Governor spoke about ecology, a relatively new word and a relatively new science, he recognized that we are all a part of an immensely complex, interdependent system, and we must become more aware of <u>all</u> the consequences of our actions and policies. This applies not only to government, but to all sectors of our society. We have within the last few years become seriously concerned on a wide scale with ecology and what we are doing to the ecological balance. There is generally a rising and increasing fear for the environment. More than just the geologist, or engineer, architect or government administrator, I think the general public is becoming aware of and significantly concerned about this problem.

Since the environment is physically limited there is need to consider and develop the concept of multiple use. In the earlier comments I made about wise utilization, conservation and preservation, I meant to deal with a specific type of resources but I didn't deal with the total environment. I think that when we begin to consider the total environment we must consider the multiple use approach in the use of our resources. I think it is absolutely essential that some compromise and some general agreement be reached on the environmental impact we are going to have in any type of undertaking. We must find ways to permit the utilization of minerals without spoiling the entire country side. We should continue to harvest our timber, but in such a way that we don't encourage erosion and leave a shambles behind us. We have to change our criteria.

What I hope to do in these comments on our natural resources and the difficulties in developing policies for their utilization, is help set a framework for this conference. I hope that this will help you bring environmental consideration to our resource development and conservation in whatever way you have an impact upon them. In the major questions that this whole group is addressing itself to, I think the geologist can make an important contribution. How those in geology can communicate their expert knowledge in regard to environmental geology to the attention of those others who are involved and concerned in the environmental questions is the whole purpose of this conference. Success in this effort will benefit all of us. I wish you luck!

PLANNING FOR DISPOSAL OF OIL SHALE, CHEMICAL AND MINE WASTES

JOHN W. HAND

Vice President, Cameron Engineers, Denver, Colorado

There is no serious lack of technology available to enable us to exploit natural resources for our use without creating uncontrolled hazards or offending our sensibilities. The fact that this has not always been done has arisen out of our willingness to pay the price under certain conditions or, more likely, out of confusion or controversy as to by whom and how the price should be paid.

Man's drive for economy, spurred by competition, demands that the most concentrated and most easily accessible of nature's raw materials be used first and at least cost. In this way, capital is accumulated in the form of resources and technology which enable succeeding generations to utilize more marginal resources. Thus any burden placed on the mining and processing of minerals beyond that needed to protect the environment from dangerour pollution can become a burden on future generations.

However, we have become so efficient in this period of our evolution that we can afford to go beyond the point of just protecting the environment from dangerous pollution. We can afford to leave the environment in a little better condition than it was before we came upon the scene.

Total planning for the disposal of wastes from the extractive and chemical processing industries is probably infeasible today and may not even be desirable. However, planning for a single industry or an interrelated group of industries should be practical. The developing oil shale industry of Colorado, Utah and Wyoming provides us with a case in point.

I want to define some terms and discuss some of the technology in use today. Then I will discuss what is being done in the brown coal fields of the Federal German Republic and in mine waste disposal by Union Carbide Corporation, particularly in the uranium industry in western Colorado. Finally, I will describe some of the challenges faced by the oil shale industry and suggest some criteria for use in planning for waste disposal by this industry.

A mine or processing plant waste is any substance derived or produced from the operation which has no further economic value at that point in time. Since the disposal of wastes is frequently a costly part of the operation, the mine or plant management is constantly looking for ways to convert wastes to salable by-products or to reuse them in the process, even if such sale or reuse is only on a break-even cost basis.

The solid wastes arising our of mining operations are of two types — the burden or material which must be removed to get to the ore and the tailings, or the unusable material called the gangue, which is separated from the valuable constituent of the ore during milling or processing.

Let's consider the burden first. The quantity of burden removed depends on the mining method selected — whether open pit or underground.

Open pit mining is used when the cost of removing the overburden by utilizing large, efficient equipment is lower than the cost of less efficient underground mining systems. The ores recovered by open pit methods are usually flat lying, bedded deposits rather close to the surface. The amount of burden removed to get to the ore is frequently quite large in relation to the ore but the limit to which you can go in removing overburden is determined by the economics of the situation.

Underground mining results in much lower burden removal — only that required to open shafts and drifts to gain access to the ore. Ores extracted by underground methods are usually those that are deep below the ground surface or that occur in narrow veins.

In contrast to burden removed during mining, which is generally in its natural state except that it has been broken up or loosened by digging, the tailings and other solid processing wastes are usually finely divided and frequently chemically altered. Many of the processing methods are carried out in the wet state so these wastes or tailings are loaded with free water and residual amounts of dissolved acids, bases or salts which might subsequently drain from the tailings pile.

Whatever may be the source of the solid waste, the operator must include the cost of its disposition in the cost of his product so he seeks to dispose of it as near to its source as possible and to place it permanently out of the was the first time it is handled. If he does any more than this, it is because he is motivated by the indirect costs of his acts or by imposed rules and regulations.

The problems in solid waste disposal are: (1) to find a suitable out-of-the-way site to contain it and (2) to stabilize it so that no further problems are created.

Worked out mine areas, when available, are the first choice for disposal sites, particularly for open pit or strip mining operations. Sometimes, the burden or tailings can be disposed of in underground mined to advantage to the operator such as to provide roof support in cut and fill operations or to provide a working floor when mining by a shrinkage stoping method.

A second choice of disposal area is a naturally eroded valley or gully which can be dammed to prevent erosion of the fill from taking place. Lacking some such site as these, the material must be piled and stabilized by diking or rip-rapping the banks.

Stabilization is needed to prevent leaching and erosion by water, or blowing by the wind. If the waste is in a dry state, it may be stabilized during the active build-up period with water. A completed dump is usually stabilized by covering with rock and soil, by treating with some cementing agent, by planting with vegetation, or by a combination of these.

Although solid wastes are more conspicuous, the liquid wastes frequently present a more serious problem. Liquid wastes are most often thought of in connection with the processing of ores and chemicals. Some secondary wastes can develop as a consequence of mining and burden disposal. An example is the acid mine waste water which is such a cause of concern in the coal mining areas. This is caused by the exposure of pyrite in the mine waste to air which causes oxidation and concurrent leaching by surface or ground water to form an acidic solution.

There are about five ways to dispose of liquid wastes. They are: (1) by incineration, if the waste is flammable; (2) by evaporation if it is a solution, thus leaving a concentrated liquor or solid which can be contained or hauled away; (3) by precipitation of the harmful solute with a chemical reagent and then filtering or settling the solid; (4) by neutralization and dumping the neutral waste into streams or into seepage ponds; and (5) by dumping or pumping it through disposal wells into underground porous formations.

Of these, the last one, or deep well disposal, has grown greatly in popularity in recent years and is one where the geologist is particularly involved. The theory here is to drill a well to a permeable sedimentary formation that is already loaded with a waste — salt water — and which is contained or well sealed off from potable aquifers and which is not under a high hydrostatic head. The well is cased and sealed and the waste is directed to the disposal zone. Other wells in the area can then be monitored to make sure the waste is not escaping.

There are many successful deep well disposal operations about the country but there have been a few spectacular failures too. I hardly need to mention the one at Rocky Mountain Arsenal which has been blamed for causing earthquakes in the Denver area. In another case in Pennsylvania a paper mill dumped approximately 55,000 barrels of spent sulfite liquor into a 1610 foot deep well at pressures between 1100 and 1300 pounds per square inch for four years when it blew out around the casing spewing 150,000 gallons of waste per day into Lake Erie before being capped.

The brown coal mining operations in Europe are excellent examples of planning for solid waste disposal and surface restoration in modern large surface mining projects.

In the northern Rhine Valley west of Dusseldorf, Cologne, and Bonn, there is an area of approximately 1000 square miles which is underlain at depths of up to 1600 feet by a thick bed of brown coal (or lignite). The reserves have been estimated at 60 billion tons in seams ranging up to 330 feet thick and averaging 165 feet. This lignite is young geologically, has a high moisture content of about 60%, an ash of 2 to 8%, low sulphur and a heating value of only 3300 Btu's per pound as compared with four times this value for a good bituminous coal.

At this time, 90 to 100 million tons per year of brown coal are being mined in the district, one-third of which is being dried and briquetted for domestic heating fuel and the remainder is being used to generate electric power.

An old castle has been taken over and restored by the mining company at Garsdorf. It serves as administrative offices and as a public information hall where various citizen groups are shown what plans are being made and how the mining company operates. The company has been very effective with its public relations.

After the coal was laid down here there was considerable tectonic activity. Block faulting has pushed coal beds up and down. Since the overburden is loose soil, clay, loess and alluvium, it is saturated with ground water which must be controlled to keep the pit reasonably dry. Pumps ring the pit and pump water from the formation by means of wells drilled in advance of the mining operation. The water is pumped by way of the Erft River channel and a new canal to the Rhine.

The Frimmersdorf power plant at one end of the pit has a generating capacity of 2,300 megawatts and is the largest thermal power station in the world. The total generation capacity in the area fueled by this coal is 6,000 megawatts, about 26% of the west German capacity.

Both overburden and lignite are excavated by bucket wheel excavating machines made in Germany in plants near the mine area. There are nine of these in operation. These are self-propelled machines weighing from 6,500 to 8,000 tons each. They have capacities on the order of 7,000 cubic yards of material per hour.

The first excavator at the Garsdorf pit was only able to excavate a surface cut of 130 feet but the newer ones can cut a bank of 350 feet. There are three sections, the production, the loading and the connecting bridge. It can pivot 360°. The excavating wheel has a diameter of 57 feet and is filled with ten buckets of five-yard capacity each.

Both belt conveyors and electric railroad trains are used to move the overburden and coal away from the excavator. Of interest is a stratum of loess, an orange earthy material which was carried into the area by the wind. This material is particularly suitable for building a top soil on the reclaimed areas. Unitized electric trains are primarily used for moving the upper stratum of overburden since there are large boulders imbedded in it which cannot be transported on conveyors. The cars hold 130 cubic yards. Heavy rail is supported on steel ties and is moveable.

Seven foot wide, steel reinforced rubber conveyor belts are used to move both overburden and coal and travel at 12 miles per hour fully loaded. These conveyors can be shifted toward the working bank quickly by special moving and aligning vehicles. Stacking machines remove overburden from the belts and pile it in worked out areas of that pit. The boom on these machines is about as long as a football field.

The ash from the power station is collected by electrostatic precipitators and placed back in the bottom of the pit. This is then covered with run-of-pit overburden and topped off with a layer of loess.

For the first few years after land filling, soil building crops are utilized. Later, cash crops are incorporated into crop rotation programs. Crops planted in this area include alfalfa, wheat, sugar beets and pine forests.

The mining company's permit from the government gives them what amounts to the right of eminent domain. However, any farmer displaced by the operation must be offered resettlement on a farm if he chooses. The filled land is brought up to productivity and farm houses are built. These are then ready to accomodate the resettled families.

We have no good data on the overall cost burden on the coal produced caused by this requirement to reclaim and resettle farmers on the mine dumps. However, it must be remembered that German industry, which buys the power from this operation, is highly competitive in world markets.

When all of the coal has been mined, the last hole will be a fresh water lake 10 miles by 4 miles in surface dimension and about 1000 feet deep.

During the next decade we, in Colorado, will see the birth of a new mining and processing industry — oil shale. The rate of production from the oil shale mines will be as large or larger than the brown coal operation in Germany. Planning for the disposition and stabilization of oil shale mining and processing wastes will be the most challenging task to be faced by the industry.

There is no longer any doubt that the nation will need to rely on oil shale and coal for liquid and gaseous hydrocarbon fuels to provide a substantial part of the energy needs of our expanding and increasingly mobile population. Our consumption of liquid fuels alone has doubled in the past 17 years and is currently increasing at the rate of 6.5% per year. On the other hand, new pools of petroleum are becoming more difficult and expensive to find, and the recent discoveries in Alaska are a long way from markets.

In order to obtain shale oil from the marlstones of the Green River Formation in Colorado, Utah and Wyoming, the rock must be heated or retorted at 900 degrees Fahrenheit. There are two fundamental approaches being researched, one involves mining, crushing and retorting in plants on the surface near the mine; while the other involves fracturing and heating the rock in place. Based on the developed technology to date, mining and processing aboveground appears to be the most economic method, at least for the thick, rich shales that crop out on the cliffs in the Piceance Creek and Uinta Basins of western Colorado and eastern Utah. The mining of oil shale by underground room-and-pillar methods has been demonstrated to be practical. In some areas large open pit mines are expected to be feasible. For an underground operation, up to 1.5 tons of shale will be mined for every barrel of shale oil which is produced and 80% of this shale will be waste. If an open pit is developed the tonnages of overburden and spent shale together may approach 2 tons per barrel of oil produced. Thus for an industry producing a million barrels of oil per day, the disposal of waste could well amount to 1.2 to 2.0 million tons per day or enough to cover a square mile to a depth of 2.5 feet each day.

Of the problems of waste disposal and control to be faced by the oil shale industry, the spent shale will be the most difficult. The sulfurous, nitrogenous and hydrocarbon gasses from the retorting and refining plants can be controlled to yield valuable by-products — sulfur, ammonia and fuel gas. Water used in retorting hydrogenation, power production and cooling can be ponded and recycled to extinction and, due to the limitations of water supplies in the oil shale regions, such reuse is going to be a necessity.

The spent shale from different retorting systems which may be imployed will have different characteristics. It may be sintered clinker, porous lumps or fine powder. Depending on the location within the formation from which the shale is being taken, the spent shale will have varying soluble salt content and alkalinity. Also it may be hot, contain some residual combustible matter, and it may be hard to wet or it may take up water easily to form a cementitious material.

Fortuitously there are many large, arid arroyos and canyons which offer large scale disposal sites for spent shale and overburden. Research is needed to establish methods and procedures for placing and controlling the spent shale into the disposal area to prevent dusting, leaching and erosion.

In Colorado, mine waste control and reclamation has been administered by the Department of Natural Resources under voluntary agreement drawn up with the mine operators. The results have been good and the companies involved have been conscientiously carrying out their responsibilities.

For the oil shale industry, in order that all of the producers may know the rules of the game before they make their investment, it would seem reasonable for certain standards of codes covering solid as well as liquid and gasious waste control and disposal be established on a regional basis with the participation of industry, State and Federal governments involved or having jurisdiction. The standard should be reasonable considering not only the characteristics of the geology and climate of the region, but also the benefits that will accrue to the region and the nation from the development of the industry.

Once the standards are set, the primary responsibility for carrying on the research to enable the operators to meet the standards should be on industry. This will bring forth the application of the best scientific talent available in our large private enterprises and in our educational institutions under private sponsorship. Assuring compliance with the standards is the province of the public agencies, as it should be.

I would like to conclude with these comments. Planning for disposal of mining and chemical wastes is a very real concern of the management of the industries involved. The companies that will make up the oil shale industry are conscious of the needs for preventing pollution of the environment and are involved in research today to find the most economic means for disposing of and controlling wastes. The planning should start with a realistic determination of the needs of the particular environment which will be affected — that is, it should not be carried on in a vacuum by people who think they know what is best.

If reasonable standards are set for the oil shale industry, it will develop and prosper at this time when the resource is needed.

GROUND WATER AND OUR ENVIRONMENT

WILLARD G. OWENS

Willard Owens Associates, Denver, Colorado

(This paper was prepared as a stand-by paper for the Conference. Although it was not presented at the Conference, it is included here because of the significant effects of ground water on our environment.)

The subject of ground water must definitely be considered as an important part of environmental geology. Without ground water as an auxiliary source of water supply, and without the hydrogeologist to help locate and develop these supplies, our environment could face critical times during surface water shortages or during periods of major surface water contamination. Another reason for considering ground water in future environmental geology conferences is that ground water is one of the most common factors in the geologic hazards being discussed at this conference.

Ground water is often a complex problem, and the professional person who works in this field has his hands full. Primarily, he is concerned with the supply available on an annual basis, with its quality and suitability for various uses and the economics of development. He must also be concerned in preventing ground water pollution, excessive depletion and, conversely, with an excessive rise of ground water levels that damage soils and crops. He is deeply involved with geology and because he works with ground water, he has been given a number of titles. These include hydrogeologist, ground water geologist, and geohydrologist. No matter what the title, the knowledge and experience of the geologist who works with ground water must include the basics in several areas. He must be thoroughly versed in geology, and have a knowledge of basic hydraulics and hydrology. He must also have a basic knowledge of chemistry, biology and an understanding and appriciation of the water needs of industry, municipalities, and agriculture. And beyond all that, he must have the kind of mind that can visualize something which is blocked from view under natural conditions.

Ground water, also known as underground water, is that water which has seeped into the ground sometime in the past, either yesterday, a week ago, or fifty million years ago. Most people connect the occurrence of ground water with strange, mystic circumstances, and some of these people are well drillers who make their living from developing ground water. This lack of understanding ground water is because the water does occur underground and out of sight, and sometimes is a relatively complex manner.

The occurrence of ground water is controlled by many geologic factors, such as permeability, porosity, the occurrence of surface water and geologic structure. These geologic factors have allowed the water to occur where it is, flow as it does, and be available as a resource for development. The more complex the geologic conditions are, the more complex the ground water conditions are.

I have mentioned what ground water is, and in general, what the geologist who works in ground water needs to know, and now we must consider the role that ground water plays in our environment. To do this we must consider ground water in three aspects. First, ground water often acts as a catalyst or has a major role in most geologic hazard conditions. Second, ground water is often a major problem on construction and excavation sites. Here, it presents de-watering problems, and bogs down construction activities. Finally, ground water can be a source of water supply, and as a source of supply, it ceases to be a negative effect on our environment and becomes a very definite positive one.

Many geologic hazards have been and will be discussed in this conference, and ground water has probably influenced most if not all of these hazards in one way or another. For example, most dam failures result from a hydraulic force of some kind, often due to inadequate spillways. Piping beneath an earth-filled dam is caused by water from the reservoir flowing through or beneath the dam. Landslides and floodflows occur because water plays a part in the liquifaction or in the basic erosion of these earth materials. Soils which have a swell potential do so upon coming into contact with water. Major flooding occurs after the soils have become completely saturated with ground water to the point that there is no more room for water to seep into the soil and the underlying bedrock. Because of this, the rain water thus remains on the surface and becomes flood water.

The stability of slopes in residential areas is often decreased as water soaks into the ground from irrigation of lawns. As these waters move downward into the soils and into the underlying bedrock, the previously dry soils and rock often become less stable. The water creates pore pressure that lowers effective stress and can start slides.

Vibrations from traffic, sonic booms, earth tremors or explosions during construction work sometimes causes this water in the previously dry soils to create liquifaction of the soils. This often results in a slow creep of soils downhill. In some cases the earth movement is rapid. Since the weight and strength of structures on the soil is slight compared to the land mass itself, the roads and the houses migrate downhill right along with the soil. In this case, as in many other cases, the occurrence of ground water has become an important factor in environmental geologic problems.

Another aspect of ground water is the role it plays in excavation. Here, ground water occurs not as a resource to develop, but as a problem to the construction man and to the engineer who must work in the water-saturated soil and rock during excavation, tunnelling, mining, oil exploration or road building. All major excavation projects require a geologic and hydrologic study prior to construction. This includes both major and minor excavation projects. In most cases, the ground water can be handled during excavation. Often, de-watering, or removal of ground water, should be done before excavation is begun. If the ground water situation is bad and the water is not removed, then the problems are obvious. When geologic and hydrologic conditions are not taken into account, time-delays, materials failures, and equipment slowdowns are common. Thousands of dollars are often spent unnecessarily because inadequate preliminary geologic and hydrologic investigations had not been done.

High ground water levels and inadequate drainage cause very high damages in crop losses due to formation of alkali soils, and water-logged ground. Adequate control of such shallow ground water by drainage and high capacity wells has reclaimed millions of acres of arable lands throughout the world.

These examples of ground water as related to geologic hazards and ground water affecting excavation and construction, are obviously putting ground water in a negative role, but this is really the lesser story and by far the lesser role. Ground water, if developed properly, to help supply the water needs of industry, municipalities and agriculture, can become a major cause of economic growth and stimulation.

We know that many cities, water districts, and irrigators in the Rocky Mountain region have been spending millions of dollars annually on the development of surface water supplies, while ignoring ground water supplies, sometimes existing in vast quantities right beneath their feet. However, in the last decade, ground water development has boomed, especially in agricultural use.

A relatively sudden and major development of ground water through irrigation wells has occurred in the eastern plains in Colorado. The results of this ground water development has had to effects. First and most obvious is the agricultural change from dry-land to wetland farming, with tremendous increases in crop yields and the introduction of new crops into the areas. The second change is less obvious but in many ways it is of more concern. This development of ground water has been a thorn in the sides of both our legislators and the owners of surface water rights. Their protests have been and are now being heard in the courts and have resulted in major new state legislation. Their complaint is simple — ground water development is taking water which they claim is rightfully theirs. The law, regulations, policies governing water use and actual geologic and hydrologic conditions must be examined closely and evaluated to determine if their claim is valid. Recent court decisions indicate that the claims are valid in some cases, not valid in others. Unfortunately, geologic evaluation is lagging behind legislation. The people of Colorado are fortunate in that dedicated people are in charge of administration of Colorado's ground water supplies.

The development and use of water supplies in Colorado is under the Doctrine of Prior Appropriation. This means that the man who used the water first has the first legal right to that same amount of water each year, while the man who used the water second has only the second right, and so on down to the point where in times of water shortage, water needed by the people with the most junior priorities is shut off first so the senior can have their water supplies.

To further complicate the picture, there are storage facilities on the surface (i.e., our many lakes in Colorado) that are related to water storage rights. These people with storage rights have the right of priority to capture flood waters, and otherwise excess water, and transport these waters into their usually inefficient storage facilities. During times of low stream flow, water is released from these storage facilities into the irrigation ditches for use.

Much of the ground water in Colorado occurs in the sand and gravel which make up the subsurface portion of our major streams, primarily the Arkansas and South Platte Rivers. The construction of irrigation, municipal and industrial wells is relatively young compared to the diversion of surface water directly from the stream. At best, the users of ground water have rights very junior to nearly all of the surface water diverters. Under strict administration of the Doctrine of Prior Appropriation, these wells would be the first to be shut off during periods of shortage of surface water supplies.

The irony of the situation is that the shutting off of the wells, in many cases, will not result in the immediate availability of that water to surface water diverters. Most often that ground water will not reach the major stream or river for weeks, months, or even years after the prior water right called for the water. There are cases, however, in which high capacity water wells, and here we are speaking of wells which can produce 500 to more than 2000 gallons of water per minute, are close enough to the surface flow of the stream that they essentially pull water almost directly from the stream itself. In these cases, of course, the shutting down of the wells will obviously allow the surface water to either flow downstream to surface water diverters or to infiltrate the soils downstream and again become a part of the ground water flow.

Colorado's State Engineer has been given the responsibility of the administration of ground water supplies as well as the administration of surface water supplies. He is now faced with the problem of setting up rules and regulations which will be fair to everyone with a water right — that is, to people with surface or ground water rights. The State Engineer is to recognize the Doctrine of Prior Appropriation, but an added burden to his responsibilities is that he is to see that the water supplies for all of the State of Colorado are developed and utilized efficiently.

Any rule or regulation which provides for the shutting down of a water well or any water supply, when this will not provide water to someone else, is not beneficial to our economy. If in those cases in which the pumping of a high-capacity well does, in fact, decrease the surface flow which would otherwise be available to a senior rights owner, then this well must be regulated to provide that water to that senior user.

Colorado's legislature has recognized the importance of ground water to agriculture. One Senate bill provided for the formation of Designated Ground Water Basins, where ground water development and management is to be administered by the Colorado Ground Water Commission. This law provides for the establishment of Ground Water Management Districts, so local rules and regulations can be set up which specifically apply to that particular Ground Water Management District. This statute provides for the study of basic geologic and hydrologic conditions to determine whether or not the area studied qualifies as a basin. The study of the proposed basin must be completed and approved by the Colorado Ground Water Commission before it can be designated as a Ground Water Basin by the Commission. The law provides for some modification of the Doctrine of Prior Appropriation, but priorities must be recognized, and the senior rights owners must be protected.

Numerous problems have arisen within these Basins, because the preliminary hydrologic investigation relative to the formation of each Basin has usually been of a general nature. Very seldom have detailed water management studies been done within the Basins to either substantiate the findings of the initial investigations or to fully utilize the new geologic and hydrologic information which could be compiled as more test holes are drilled and wells are constructed. The general feeling seems to be that once the initial study is done, whether it be by private ground water consultant, personnel of our universities, or state or federal agencies, that all has been accomplished by the completion of the initial study. It is a misapprehension to believe that the original maps, which are completed as part of the initial study, whether they be bedrock contour maps, saturated thickness maps, sand or gravel maps, or transmissibility maps, give the final complete, true picture.

Man must maintain an awareness of his environment, and he must plan according to it. It is well known that in any geologic or engineering investigation which involves conditions under ground, new data provides new bases for interpretation. Any maps which are prepared as part of a preliminary or initial investigation must be updated from time to time as new information is brought to light.

In the case of these Designated Ground Water Basins, the new logs of test holes or wells are only rough in nature, recorded by the driller whose job was only to drill a hole and construct a well for his customer. Current policies, rules and regulations do not require that the driller prepare and file an accurate, fully descriptive log to the District or State. If this were required, the logs could be interpreted later by a professional geologist. Therefore this information which would be of utmost importance to the State of Colorado, to the Ground Water Commission, to the Ground Water Management Districts and to all of the ground water users in the area, is not made available. Instead, it is only someplace in the mind of that driller. Even these only moderately accurate logs are filed away once they come into the State's offices and interpreted only in a general sense.

Very seldom is the original study updated so the quantities of water in storage can be periodically calculated and the effects of ground water withdrawals on the overall ground water supply re-projected.

We have been quite fortunate in three cases in which we have had the opportunity to go back into the area originally studied by us and use the newer information to obtain a more detailed picture of the ground water conditions in one of these basins. In one case, a group of citizens who depend on the ground water supplies within the High Plains Basin were dissatisfied with the slow progress of their Ground Water Management District Board. These people volunteered their own funds and paid for a detailed study of their district. Other such studies are needed but most of the people within these areas are anticipating that Governmental agencies making basic research, data compilation and other ground-water studies in the area are there to solve their water management problems. Because of this complacency, adequate management is yet to be initiated and will not be initiated until the local districts recognize that the federal and state agencies can not and do not operate as ground water management agencies. Wise development, use and safe-guarding of our water resources is definitely an environmental problem.

The Ground Water Resources Institute, an organization of persons interested in ground water as a resource, has initiated educational programs through which the general public and professional people can be advised that the development of ground water supplies can be undertaken and should be undertaken in many area. Improved well drilling equipment, well construction materials, and pumping equipment are available now that were not known just a few short years ago. Water supply wells can now be drilled deeper than ever before. Ground water developers are now using the services of the engineering geologist who has a combined knowledge of geologic conditions and of the principles of hydraulics. Well designs and uses of well screen are becoming more refined as more hydrogeologic data are acquired. The role of the ground water geologist in the development and management of ground water is becoming more and more significant. It is the job of the geologist to learn to communicate with the other professions so they can be made aware of this role. Thus, geology can be of vital assistance in the proper utilization of our water resources.

APPROACHES TO PREVENTION OF WATER POLLUTION

WILLIAM N. GAHR

Chief Engineer, Colorado Department of Health

Geologists and planners should become involved in protecting the environment from damages caused by air, water, and soil pollution. The soil, or outer crust of the earth, will probably be the final resting place for most of the pollutants once they are removed from the air and water. Naturally, geologists and planners can provide help in devising solutions and the leadership to carry out the solutions useful in preventing damage.

In our society the people are presumed to rule. It is the people who must indicate the direction to go. These directions may be vague and need a lot of interpretation; they may also require making many assumptions on the part of those who carry out the desires of the people. Furthermore, the people really have little time and probably fewer facts on which to base their choice. Perhaps many apparent expressions of the public's will are more of an emotional response than one based on facts reasonably used. The public is in much need of dependable technical advice.

A clear indication of a public dislike was the foul odor from Barr Lake several years ago. This lake is an irrigation water storage reservoir near Brighton, northeasterly from Denver. The Burlington Ditch fills Barr Lake by diverting water from the South Platte River at a point 1,000 feet downstream of the Denver primary sewage treatment plant effluent outfall. Water diverted at this point during low flows was nearly all primary treated sewage containing decomposable matter. Come the warm spring days, this matter, dispersed throughout the 27,000 acre-feet of Barr Lake water, decomposed. Foul odors then drifted off the lake for days, to the discomfort of nearby residents. Many of these people loudly voiced their anger toward Denver, although their immediate trouble was far downstream from Denver. The real cause was inadequate removal of decomposable matter from the sewage before discharge. Much work, of course, had to be done to convince upstream taxpayers, unaffected by the odors, that they should spend millions of dollars in facilities for removing the decomposable matter causing the odors. Since construction and use of the facilities, no further odor has developed, and today complaints are practically non-existent. The irrigators, though, who want water — smelly or otherwise — have taken legal action to secure the volume of sewage now being discharged downstream of the Burlington Headgate.

Again, in the same general area north and east of Denver, two other incidents illustrate public reaction to ground water pollution [1]. About 1948 and a few years later, the loss of large quantities of gasoline from storage tanks infiltrated into the underground aquifer. Obviously, this ruined the use of shallow well waters for a period of time. Some inconclusive lawsuits were tried, but in the main those injured had to suffer and survive on their own. This incident had some humor — an attornet, tired of his client's indecision to press suit, poured the evidence, consisting of several gallons of high octane gasoline, into the tank of his automobile and drove into the mountains. On another occasion, a farm hand lit a cigarette and threw the burning match into an irrigation ditch. He was put to flight by flaming gasoline floating on the water's surface. There are other incidents of damage to water wells and basements by the infiltration of gasoline lost from storage tanks. Almost all of them came to an end without government intervention or any recompense to the injured.

Another incident involved damage to

crops on some farms lying between the Rocky Mountain Arsenal and the South Platte River. It appears that liquid wastes and leachings from solid wastes discharged by the Arsenal chemical works seeped downward from the receiving ponds into the shallow water aquifer. Apparently the seepage contaminated the ground water sufficiently to damage some of the crops irrigated with this water. In this instance economics, greatly aided by political interest, motivated a solution. First, a 107-acre reservoir to contain the liquid wastes was constructed with an impermeable liner and surrounded by surveillance wells. Although, at a normal manufacturing rate, evaporation could be counted upon to keep the reservoir at a manageable level, any increase in manufacturing would produce excessive wastes and cause a rise in the water level. For this reason, a deep well disposal system was to be the ultimate solution. Unfortunately, putting the liquid wastes two and one-half miles down into the earth has been alleged, politically surely, and scientifically perhaps, to be the cause of earth tremors. For over three years (since February 1966), the deep disposal well has not been used; even so, some tremors have been recorded in this period.

As with water, trying to abate air pollution has not been without creating other problems. Open burning is unlawful in air basins, one of which surrounds metropolitan Denver. Formerly, discarded automobile bodies were prepared for mill scrap by burning before compressing them into bales. High labor costs rule out hand stripping of the bodies as an alternate method of preparation. Meanwhile, car bodies continue to accumulate and sprawl over acres of land because there is no economical method of preparing them for scrap metal.

The sanitary landfill method of refuse (solid wastes) disposal, when properly operated, normally causes no legitimate complaints. Nonetheless, should an operation allow development of obnoxious odors, complaints are soon heard. Even clouds of flies are no match for foul smells in angering numbers of people. In the metropolitan Denver area an otherwise well-operated sanitary landfill ran afoul the wrath of the adjacent residents because of foul odors. These odors issued from the rapid decomposition of garbage and other putrescible refuse which was dumped into standing water of a mined-out gravel pit.

These incidents of public indignation stem from different causes, many of which can be prevented. While some of the causes result in damages easily and economically removed, others could result in long-term damage to the environment. In almost every instance proper planning could have prevented or lessened the injury and, where this is not possible, might have provided the basis on which to make fair compensation to the injured.

One aspect of pollution prevention and abatement is actually a study of people's reactions. A common initial reaction is to simply ignore the problem — that is, do nothing. As conditions worsen, public reactions force another approach or approaches for pollution control. One solution is to stop all causes of pollution. Of course, this is entirely impractical and has given way to the commonly used approach: "take such corrective action as will reduce and limit the occurrence of pollutants". This approach usually involves the application of laws and technology. While laws may be considered a form of direction by the public to their government, technology is not. Technology is used to secure the results the people think they want from the laws they cause to be enacted.

The technology for solving water pollution problems, although useful, has advanced comparatively little when measured against other achievements of science. As an example, those too far to connect to a community sewer usually must make do with a septic tank and leach field. In areas of high ground water, the leach field becomes water-logged or at best has limited capacity in getting rid of the tank effluent. Nor has design of primary and secondary sewage treatment facilities advanced much. Perhaps the oxidation pond, discovered by accident and better known as a sewage lagoon, can be said to be new. It makes good use of nature in treating sewage. Close attention, however, must be given to the soil conditions lest a lagoon lose too much water by seepage, endanger ground water and thereby fail as a sewage treatment facility. These are the sewage treatment facilities presently available; properly employed they can do much to remove pollutants before they reach the streams and ground water. Nonetheless, better and cheaper methods are much needed for removing pollutants from sewage prior to discharge.

Protecting ground water from the entrance of surface pollutants has and continues to need attention because every water well is a potential entry-way of contamination. The many wells that lead from the ground surface into the aquifers of our underground water resources need to be constructed in a manner which prevents the entrance of harmful or deleterious substances. A recent Colorado law makes the proper construction of water wells by drillers a requirement of retaining their licenses. One of the regulations governing the distance of a well from known sources of contamination, such as a clay sewer, for the first time takes into account grouting of the well casings and the depth to the top of the aquifer[2]. Although it still lacks relating the character of the soil to the location distance, the regulation is an improvement over the usual rule-of-thumb distance values.

In comparison to the problem itself, the technology for preventing air pollution is only beginning to develop. Precipitators for removing particulate matter from power plant smoke and gases work well enough, but this attacks about 14% of the entire problem. The large source of air pollution, produced by transportation equipment, is responsible for over 60% of the total problem. The operating automobile engine also produces most of this pollution. By comparison, the backyard incinerator is but a nuisance and no great threat to health. Science could be a long time still in devising cheap and practical methods of keeping the air clean.

There really is no technology as yet that can be used in soil pollution control. Perhaps this is the case because again as yet there is little public or private acknowledgment that there is a soil pollution problem. As mentioned earlier, it does seem important to look into the matter of soil pollution because most of the pollutants removed from air and water will probably be disposed of in the soil. Such being the case, these pollutants ought to be placed in the soil where they will do the least damage to the soil resource.

Solid wastes are being collected at an average rate of 5-1/3 pounds per person per day. Methods of solid wastes disposal consist of burning and controlled decomposition. A high temperature incinerator is the only acceptable method of disposal by burning. Even this adds carbon dioxide to the air; technically, this can be looked upon as pollution. Open or pit burning is as old as man and certainly unacceptable in urban areas. Composting and sanitary landfill may be looked upon as controlled decomposition. Both are quite acceptable methods, but probably neither are new nor the best science might produce. Composting is relatively expensive; nor is it able to decompose metals, glass and plastics. Besides, even the compost itself may have difficulty in finding a market. The sanitary landfill is, so far, the most economical and effective method for the permanent disposal of solid wastes. However, it must be planned and properly operated lest it too degenerate into a smoking, fly and rat infested dump. Attention must be given to the location of a sanitary landfill, and there are certain criteria which need be observed. It should have convenient access year around in all weather. The fill itself should not penetrate ground water, and a sandy soil is the most desirable for regular covering of the compacted refuse. In areas of limited rainfall it is unlikely there will be much, if any, damage to the underlying ground water from leaching through the fill. Unfortunately, under these conditions, decomposition leading to stabilization of the fill material can be expected to be very slow, actually measured in years.

The foregoing briefly describes some of the technology which has been used in protecting air, water, and soil resources. Seemingly, it has easily kept up with demands. Demands in this instance are largely made by laws, and laws only come after a relatively long period of time. Such a period marks that era when the people and those who represent them are trying to "make up their minds". Obviously, the process of deciding to even have pollution prevention laws and then enacting and putting them to work is both difficult and time consuming, as a quick review of this type of legislation will indicate.

Enactment of legislation is a clear cut decision that action is to be taken; it is, indeed, an indication by the people of the solution, or the approach to a solution, they want. Beyond this very general indication, a government regulatory agency finds but little else to guide or perhaps control its approach to solving the problems. We read that Moses found it necessary to establish rules for the disposal of human wastes. It would be interesting to know just how well those rules were obeyed and what they actually accomplished.

In England, about 1810, systems of sewers transferred the filth in the streets directly to the rivers[3]. This situation was aggravated still further with the coming of the Industrial Revolution, which led to the establishment of factories on the banks of rivers and their resulting pollutant discharges. Two Royal Commissions on river pollution, in 1865 and 1868, pointed to the river damage resulting from discharge of domestic sewage and industrial sewage from the textile industry, canneries, paper mills, chemical works, and gas works. Parliament tried to rectify this situation in the passage of the Public Health Act of 1875 and the Rivers Pollution Prevention Act of 1876. This latter act was comprehensive but seeminly was ahead of its time. Even though the act forbade the discharge of solids or liquids or sewage from mines or manufacturers, the sanitary authority was crippled in carrying out enforcement by a requirement in the Act which stated that no material injury was to be inflicted upon the polluter. Several reports later, some accompanied by legislation, brought the British to enact the Rivers (Prevention of Pollution) Act, 1951[4]. The many aspects of the thorny path of securing workable water pollution prevention legislation in Great Britain is interesting but too long to recount here. Suffice it to say that the 1951 act, plus the Public Health Act of 1936, the Public Health (Drainage of Trade Premises) Act of 1937, and the Gas Act of 1948 in the main removed stumbling blocks previously in the way of enforcement by providing adequate pollution control tools. Perhaps British success rests on the unique fact that the responsibility for administration was placed in the hands of industrialists who, having been obligated to expend money for abating their own pollution, saw to it that others did likewise.

The Germans, like the British, have evolved methods for preventing and abating water pollution the difficult way[5]. Existence of German Federal-State Governments and their many laws quickly indicate complexities and preclude offering more than a few remarks here. The elaborate present-day system of river associations in Germany, which are responsible for river regulation and pollution abatement, owe their beginning to a blunt court decision resulting from a law suit. In 1879, a small but suffering Alten Essen downstream of Essen on the Berne River obtained a court injunction such that the Burgermeister of Essen stated he would be forced to wall up the main sewer of Essen and let the city drown in its own sewage. Apparently no such wall was built, but responsible citizens did get busy, all of which resulted in a 1904 law leading to the formation of the Emscher Association. Someone had to be hurt before any action was taken.

It is worth mentioning that from this beginning Germans have devised river associations authorized under law to do just about everything necessary to administer a river water resource. These associations can safeguard drinking water supplies, insure adequate flows in navigation channels, provide sewage treatment facilities even to treating the entire dry weather flow of the Emscher River. The associations have the authority to assess their member water users; this permits them to continue to spend vast sums in protecting and fully developing water resources under their care. All such action is to the apparent satisfaction of their members. Here is an instance of what is commonly understood to be a private organization doing work which in the USA is considered a governmental function.

The Germans, too, have found additional legislation necessary to meet changing times [6]. The comprehensive Federal Water Act of July 1957, and its accompanying Special Act on Detergents permit German state governments wide latitude in handling water problems including pollution prevention and abatement which may arise in any of the river districts. This legislation tends to supplement but does not replace the use of river association type administration.

In the United States, federal control of water pollution was approached in yet a different manner than that used in Great Britain or Germany[7]. Although the federal government has been enacting laws pertaining to specific items of the water pollution problem, our particular interest is in existing legislation. Present water pollution control legislation at the federal level largely started in 1948 and has proceeded with changes on a regular basis. Essentially, federal law recognizes the states' prerogative and responsibility to control water pollution within their boundaries. As recently as 1965, it required the state to establish stream water quality standards and since 1956 has provided construction grants to encourage the building of publicly owned sewage treatment facilities. The federal government itself, with its vast holdings, being a considerable polluter, has been obliged to build several treatment works.

Like other states, Colorado has water pollution control legislation[8]. In fact, Colorado had pollution laws on the statute books in 1874, prior to statehood[9]. These early laws clearly forbade polluting of streams by the discharge of any obnoxious substance such as refuse from slaughter houses, privies, or even fleshy or vegetable matter subject to decay in water. A similar law prohibited the flowing of oil or other petroleum products into any water of the state. The records show very little enforcement of early law; possibly there were only a few violations. A companion law made it unlawful to defile waters of the South Platte River, Bear Creek, or any of their tributaries; the responsibility for assuring obedience to this law was given to the City of Denver, perhaps because these streams at that time provided the drinking water source for the city (10). A common mistake of the public is to believe that water pollution control makes our streams safe for direct use as drinking water. Adequate purification of drinking water supplies in treatment is absolutely necessary.

From Territorial days until 1957 no substantial changes were made in Colorado legislation pertaining to water pollution control. In 1959, effluent standards for domestic sewage were established in law, their enforcement being made the responsibility of the State Health Department[11]. Beginning in 1965, an interim legislative study committee of the General Assembly looked into the matter of providing comprehensive legislation, which was enacted in 1966 and much revised in 1967[12]. The essentials of this law and the revisions closely follow the Federal Water Pollution Control Act of 1965[13]. Neither state or federal laws provide effluent quality standards but rather require stream quality standards. Administration of the Colorado law is the responsibility of the Water Pollution Control Commission, a part of the Colorado Department of Health. The task of developing the stream quality standards has proved to be a time consuming and laborious operation, a situation experienced in all of the states. A period of some time is desirable in which to observe the working effect of any law; however, the lack of effluent standards was quickly discovered to be an important defect.

The present day approach to water pollution prevention and abatement is indeed complicated. It is so largely because of federal law and the federal bureaucracy imposed upon the states and local governments. It has been necessary to establish water uses in various stretches of every stream. Each stream water use is identified with a standard having several elements. Water usage and the controlling standards are usually established after public hearings, then become effective. It is indeed likely few persons can understand them. This is most unfortunate because public backing is needed — a backing which comes only with understanding leading to a willingness to support what is understood.

The required use of stream quality standards entails much labor in collecting the thousands of water samples, doing the laboratory work, and making interpretations of the laboratory results. Obviously, this is very costly. Worse still, it removes not an iota of pollution.

Colorado streams are subject to irrigation water diversion. Several times during the year there are often stretches of streams having little or no flow, simply because the water has been diverted. In such a situation, stream quality standards are quite useless. This is a fundamental point of difference between the western states operating under water rights and the water-rich states of the east. It is quite evident that Congress followed the concept of the water-rich eastern states when it enacted a law imposing stream water quality standards nationwide — a law which is, to repeat, silent upon effluent standards. Already it is being admitted that effluent standards are necessary to develop evidence needed to prove a case against an alleged violator. Presently in Colorado, the Colorado Water Pollution Control Commission must resort to a regulation for effluent control — a regulation having a doubtful basis under law[12].

There are other approaches to devising water quality standards[14]. One simple and understandable approach would be a two-regional classification of Colorado's surface waters. Regionalization of the surface waters would be based upon present quality and general type of watershed. A glance at a map of Colorado will aid in understanding such an approach (see Colorado map, Fig. 1). The crosshatched region represents the watershed of major water production for Colorado. This watershed for the most part is on land at higher elevations. A large share of it is federally owned land having a low population density and producing water of excellent quality. This particular watershed area represents surface water which, if protected from now on, would at one fell swoop prevent significant pollution of Colorado's major water supply. It is suggested that, since the waters produced on the watersheds of this region are of excellent quality, they be designated as "Class A Waters." The remaining areas of the state, about two-thirds, outside the crosshatched region and below elevation 7000 have waters of less than excellent quality. Portions of these areas receive most of their surface water drainage from the upstream crosshatched region;

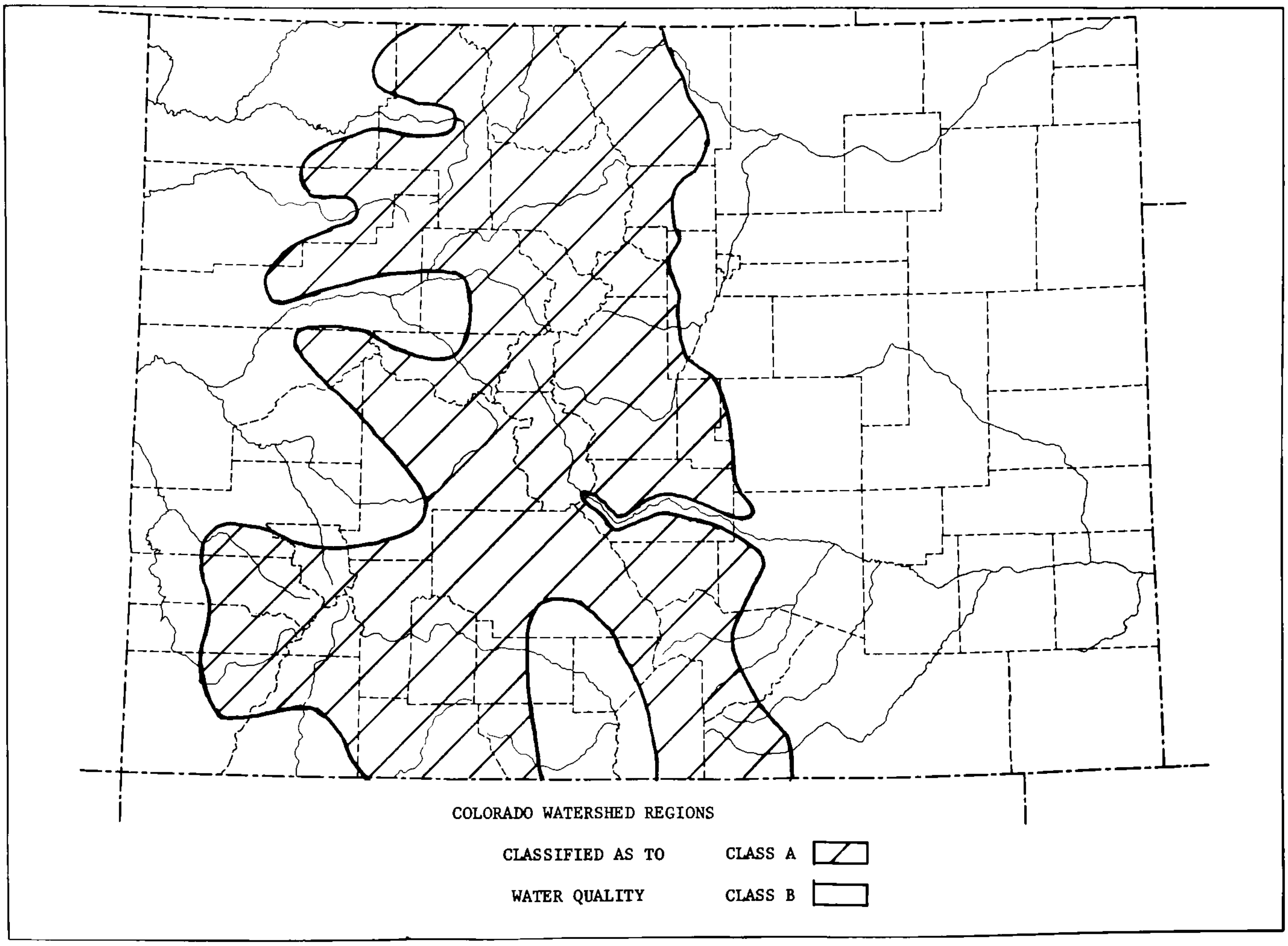


Fig. 1. Regional classification of surface water quality in Colorado. Class A, excellent quality, major water producing region. Class B, variable but generally poorer quality surface waters in the most densely populated region.

others produce water from snow or rain, irrigation return flows, and sewage. These areas are generally marked by considerable variation in surface water quality and are almost entirely privately owned lands. It is on these areas that major irrigation, livestock feeding, and agricultural operations exist. These are also the areas on which industry, commerce, and heavy population density exist. Water pollution problems of Colorado exist mainly in these areas below elevation 7000. It is suggested that, since the waters produced on the watersheds of this region are of medium to good quality, they should be designated as "Class B Waters."

Establishing this two-region approach would accomplish the following: First, those watersheds producing water of excellent quality would be identified and set apart. Second, easily recognizable general boundaries needed for purposes of administration, as well as for public understanding, could be easily fixed. Third, regionalization would simplify and determine where the major (principal) water uses exist. Actually, the boundary of the two regions or areas can be approximately established by drawing it through several points positioned by reservoirs storing irrigation water situated near elevation 7000.

Legislation is presently the moving force in controlling air pollution. Even so, legislation is relatively new. Public concern over the effects of air pollution has existed for some years, but only in specific areas, usually industrial. In 1955, the federal Department of Health, Education and Welfare was authorized to start an air pollution control program, and this study showed that the methods available to deal with air pollution were obsolete and inadequate. A new and more vigorous approach for control was necessary. The Federal Clean Air Act of 1963 gave authority to handle inter-state problems and expanded research into air pollution problems. Two years later, in 1965, the Clean Air Act was amended to provide National standards for the control of automobile emissions beginning with the 1968 models. The present Air Quality Act of 1967 has broader authorities; it attempts to provide the effort needed in dealing with air pollution on a regional basis by emphasizing cooperation at all levels of government.

Beginning in 1965, and each year thereafter, the Colorado Legislature has enacted laws or amendments for the purpose of air pollution control. This legislation is intended to assure a reasonable degree of purity in the air resources of Colorado, making it safe for health, yet not hampering the development of industry nor the propagation and protection of human, plant, and animal life. Accomplishment is to be obtained by using the ambient air standards as the contamination level at which controls are to be applied. Air pollution control in Colorado is administered by the Colorado Department of Health, which utilizes a staff, Board of Health, and a Variance Board. There are similar type administrative organizations in local government. Colorado now has five air pollution basins in which more control can be exercised than in the remaining portions of the state. Apparently, the legislative concept was to provide machinery for control in those areas of the state having an air pollution problem, but allowing the remainder of the state to do with less.

Garbage, trash, refuse, and other unwanted articles to you and to me are now known as "solid wastes." The Congress, in 1965, enacted Public Law 89-272, known as the Solid Wastes Disposal Act. The legislation provided HEW authority and funds to assist states in making statewide comprehensive planning studies for the management of solid wastes. Also under the same Act, the federal government has financed several millions of dollars of research projects intended to discover how to handle problems arising from the production of solid wastes.

Colorado enacted legislation in 1967 providing for the regulation and control of solid waste disposal sites and facilities, all of which was aimed at assisting counties. Prior to this, only municipalities had any considerable authority to deal with solid wastes — such as temporary storage on the premises, collection, and final disposal. Included in the new law, Chap. 36, is a requirement that anyone desiring to operate a disposal facility within a county must obtain a certificate of designation for the site from the county commissioners. Also, the State Board of Health is required to establish regulations pertaining to, and controlling any effects that solid wastes disposal may have upon the public health.

It is interesting to note that, in this instance, legislation seems to be ahead of technology. The fact of the matter is, technology for the disposal of solid wastes is scanty. Another interesting slant is that public leaders are looking more toward preserving and reclaiming items of solid wastes because they believe these represent a usable resource. The technology for both solid wastes final disposal and the removal of contaminants from the air is yet to provide strikingly effective means at desirable prices.

The task of protecting our environment definitely includes preventing the pollution of the air, water, and soil resources. The people have indicated they want the task undertaken and properly handled with as little cost and inconvenience to them as possible. Attacking and trying to properly complete a task of this size requires the cooperative effort of commerce, agriculture, industry, all levels of government, and the people themselves. It is important that the task be correctly evaluated and workable solutions planned. A sound plan gives hope of a satisfactory completion of the task. Now, indeed, do the people need the help of clear thinkers to plan for them and to lead them to the goals they want.

REFERENCES

(1) Gahr, W. N., 1961, Contamination of Ground Water — Vicinity of Denver, Symposium on Water Improvement: 128th Annual Meeting, American Association for the Advancement of Science, Denver Hilton Hotel, Dec. 30, 1961, p. 4-20.

(2) Rules and Regulations, August 8, 1968, State Board of Examiners, Water Well and Pump Installation Contractors, State of Colorado Division of Water Resources, p. 14-21.

(3) Klein, Louis, 1962, River Pollution: Causes and Effects, v. 2, chap. 2, Butterworths, London.

(4) Air and Water Pollution — The Position in Europe and in the United States, 1957, The European Productivity Agency of the Organization for European Economic Cooperation, Paris, p. 33-36.

(5) Fair, Gordon M., 1962, Pollution Abatement in the Ruhr District, Journal, Water Pollution Control Federation, v. 34, no. 8, p. 749-766.

(6) Gesetz zur Ordung des Wasserhaushalts (Wasserhaushaltsgesetz) vom 27. Juli 1957; and Gesetz uber Detergenteen in Wasch - und Reinigungsmitteln (Detergentiengsetz) vom 5. Sept. 1961, der Bundesminister fur Atomkernenergie und Wasserwirtschaft, Bonn.

(7) Gindler, Burton J., 1967, Water Pollution and Quality Control, v. III, Allen Smith Company, p. 359.

(8) Colorado Revised Statutes 1963 and as amended.

(9) Gahr, W. N., An Over-all View of Water Pollution, Governor's Conference on Air and Water Pollution, Denver, Nov. 29, 1965; Water Pollution and the Water User, Colorado Water Congress, Denver, Feb. 10, 1966.

(10) Unlawful to pollute portions of South Platte River and Bear Creek vicinity of Denver, chap. 36-18-4, Colorado Revised Statutes, 1963.

(11) Statutory sewage effluent standards, Chap. 66-1-7(20)(a) through (j) and CRS63, 66-1-8(a), Colorado Revised Statutes, 1963. Colorado Water Pollution Control Commission Regulation requiring secondary treatment of wastes prior to discharge.

(12) Colorado Water Quality Act of 1966 and as amended by H. B. 1004 enacted 1967.

(13) Federal Water Quality Act of 1965.

(14) Gahr, W. N., unpublished paper, Suggested Surface Water Quality Standards and a Plan for implementation, Aug. 27, 1966.

ENVIRONMENTAL DESIGN OF URBAN STORM RUNOFF WORKS

KENNETH R. WRIGHT

Wright Water Engineers, Denver, Colorado

Historically urban storm drainage works, including storm sewers and major drainage ways, have generally been planned and designed in a vacuum; that is, without a direct relationship to their environment. The general procedure has been to either wait until an area was developed and buildings got flooded before constructing drainage facilities, or to wait until the subdivision plans were all laid out and completed before undertaking any serious thinking about storm drainage works.

More recently, because of somewhat stricter city and county regulations, drainage plans and designs have sometimes been submitted to the regulatory body at the time of requesting subdivision plat approval. We find that the usual approach to drainage planning and design in these latter cases has been to use the low man on the totem pole in the engineering office to crank out a design which will satisfy the minimum requirements of the subdivision regulations. This approach is nearly always inadequate, and it nearly always is more expensive than doing it correctly. The home owners who move in later are the ones who pick up the tab for the construction work, and are the ones who are generally saddled with the future maintenance and later corrective problems.

It is our opinion that metropolitan man needs something better in urban drainage than what he has been getting and paying for. The answer, as we see it, is to take stock of the problem and recognize the fact that urban drainage works within the City of Denver alone will require perhaps $150,000,000 to overcome past mistakes. In the remainder of the Denver region, it could well be several hundred million dollars more. Within the next ten years, we believe the money spent for urban drainage works in the United States will be as great as, or greater, than that spent for water pollution control and sanitary sewer systems. By taking stock of this situation and recognizing the facts as they exist, the best engineering minds should be marshalled for the effort in an engineering office rather than its being given to the new graduate, as in the past.

To look at urban drainage in its proper perspective one must first understand the total urban system. The engineer must recognize that urban drainage is a sub-system of the total urban system. He must plan and design his urban drainage works using the best and most forward looking environmental design concepts.

I want to discuss the subject of environmental design or urban drainage; however, first of all, so that we understand what we are talking about, I would like to define a few terms. Turning to the Urban Storm Drainage Criteria Manual, which is in two volumes, published by the Denver Regional Council of Governments this month, we find a philosophy and approach to urban drainage which is based upon two urban drainage systems. One system is the initial drainage, and the second is the major drainage system. The initial drainage system is that which collects, ponds, and disposes of snowmelt, minor flows, and storm runoff. The initial system in a typical subdivision would be designed to handle the two-year frequency storm runoff. The initial system is sometimes called the "convenience system", the "minor sytem", or the "storm sewer system". It may include many factors, ranging from curbs and gutters to storm sewer pipes. The initial drainage system is needed to eliminate inconveniences, frequently-occurring minor runoff, and high street maintenance, and to help create an orderly urban environment. In essence, the initial drainage system can be thought of as being the typical city storm sewers.

It is obvious, that if one is to build storm sewers they cannot economically be designed to handle the big storms which might occur each 100 years; yet, when man builds a home or a factory he should not be expected to take a risk of being flooded out or having his building washed away once each 100 years, which, in reality, a one percent chance in any given year. To safeguard urban man from major property damage, or possible loss of life from storm runoff waters, we need to have a major drainage system. A major drainage system exists everywhere, whether or not it has been planned, and whether or not development exists wisely in respect to it. Storm runoff will seek its lowest level. To get in its way imprudently is costly, uneconomical, and heart breaking. A properly planned and designed major drainage system is based upon recognizing the major storm, one that will occur once each 100 years, and providing for this storm runoff so that it does not cause major property damage and loss of life. Major drainage facilities in an urban area are generally thought of as being the gulches, and land form depressions, coursing through our urban areas, and also artificial channels and some large underground conduits.

The environmental design approach to urban drainage, including both the initial and major drainage systems, is based upon making the drainage systems compatible with the total needs of the community. There are numerous factors which should be considered by the environmental design team planning for urban drainage. These factors include:

1. Neighborhood esthetic needs.
2. The neighborhood character.
3. The urban need for new green areas.
4. The street and traffic patterns.
5. Municipal or county policies.
6. How much pedestrian traffic is there?
7. Recreational needs.
8. The available right-of-way.
9. Sediment yield of basin.
10. What is the land form?
11. What is the available slope?

Furthermore, in planning and designing an urban drainage system, there are additional benefits that can accrue. The engineer should take into consideration the following potential benefits:

1. Disposal of appropriate industrial wastes.
2. Lowered groundwater table.
3. Controlled rising groundwater table after urbanization.
4. Reduced street maintenance costs.
5. Reduced street construction costs.
6. Improved movement of traffic.
7. Improved public health environment.
8. Lower cost open space.
9. Lower cost park areas and more recreational opportunities.
10. Improved quality of classified streams.
11. Opportunities for close-in solid waste disposal sites.
12. Development of otherwise undevelopable land.
13. Opportunities for lower building construction cost.

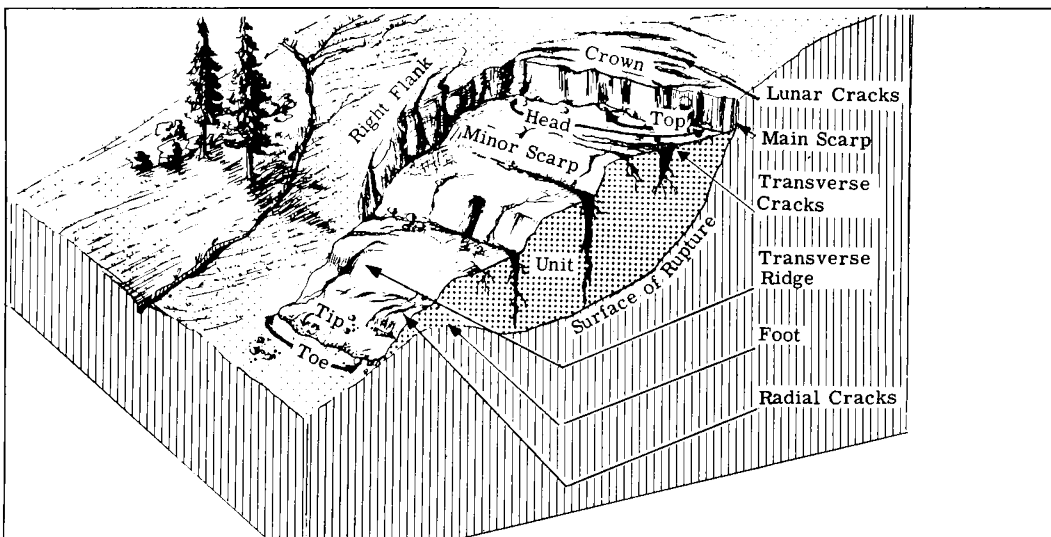
Earlier, I mentioned the environmental design team, and you may wonder what kind of team this is. The make-up of this group would vary from job to job; however, the team is often made up of a lawyer experienced in drainage law, a landscape architect, an urban planner, a parks and recreation specialist, and a civil engineer charged with executing the designs, and who normally is chairman of the team. Depending upon the assignment, others should be added to the team, including a geologist, architect, traffic engineer, a public health engineer, a street design engineer, and an urban sociologist. The environmental design team approach has been used on drainage planning in the Denver region with apparently great success.

One might wonder how the geologist would fit into urban drainage planning and design. I am of the opinion that the role of the geologist will increase in this field. For instance, natural and artificial channels carrying storm runoff must be stable; that is, they cannot be allowed to erode the bottoms and the banks and they cannot be allowed to silt up so that the flood-carrying capacity is lost. The sediment yield of the basin, the erodible tendencies of the soils, the amount of percolation upstream, and the maximum allowable design velocities are important in urban drainage design. How difficult are the soils to excavate? Will the storm sewer trenches be excavated into rock? Where can borrow material come from? — These are all questions which the geologist can help answer.

The old philosophy used in designing storm sewers was that the conduits must be sized to collect and carry off all storm runoff water as soon as it falls. This approach might have been all right for cemeteries and parks; however, when one applies this design technique to a 100-acre shopping center it quickly becomes apparent that storm sewers to carry off the runoff as quickly as it falls are costly. The cost of the storm sewers is one of the primary reasons why so few storm sewers have been built in the Denver region in the last 20 years. We find that if the water can be slowed down or stored, even for an hour, the size of the initial system and the major system can be significantly reduced, both in size and cost. We call this technique "upstream storage", and it includes temporary ponding on flat roofs, on parking lots, back yard swales, and landscaped ponds in planned unit developments. In fact, in the City of Denver it is possible to develop a residential area without using storm sewers. It is reasible to store the entire initial storm and to infiltrate this collected water into the underlying aquifer, which also helps to replenish our ground water supplies.

We have been talking about costly urban drainage works. The main point I want to make today is that urban drainage works need not be costly if the planners, politicians, and government administrators look ahead. By looking ahead, they would quickly recognize the fact that good flood plain regulations can preserve nature's natural easements through our urbanizing areas. When a developer bought a piece of property which had a flood plain zone area through it, he would leave this area in its natural state so that it could carry off flood waters. In fact, he would probably contribute this land to the city as part of his five percent land contribution for parks. Later, after the areas was developed, the city would not have to squeeze in a major drainage way costing perhaps one-half million dollars per mile. In my opinion, the most important single step any municipality or county can take in 1969 toward better urban drainage is to adopt and put into practice good flood plain regulations. These will protect those waterways still in a natural state and those waterways which still have carrying capacity left.

The preparation and the application of flood plain regulations as well as flood plain management in general is the work of a good design team. This environmental design team should very well have as one of its members a good geologist who is versed in urban geology and urban problems.



Length - Horizontal distance, crown to toe.
Width - Horizontal distance, flank to flank.
Height - Vertical distance, toe to crown.

Depth - Thickness of slide mass, between foot and crown. (Foot is line of intersection between the lower part of the surface of rupture and the original ground surface.)

Generalized Nomenclature of a Typical Rotational Landslide

From: Landslide Investigations Field Handbook by Arthur B. Cleaves U. S. Bureau of Public Roads 1961

PROBLEM SOILS IN COLORADO, A SUMMARY

GUY F. TABOR, JR.

Associate, Woodward-Clyde & Associates, Denver, Colorado

There are many types of soil and rock in Colorado, and the in-place condition of each will vary over a wide range. Likewise, there are many types of construction involved and their foundation requirements will vary widely. If the potential variability of soil and rock conditions is combined with the multitude of requirements for the many types of construction, it may seem that nearly every case must be considered to be unique. Construction which will influence environment involves thousands of jobs in Colorado, including large and small buildings, factories, mines, mills, shafts, conventional and nuclear power plants, transmission lines, refineries, missile facilities, airports, streets and highways, bridges, dams, tailing disposal facilities, pipelines, canals, landslides, gravel investigations, land reclamation projects, surface and ground water studies, and others.

In order to evaluate the effect of the underground conditions on planned construction, it has been necessary to inspect many projects, to discuss performance with owners, and to take measurements indicating performance of structures. Data gathered from this work form the primary basis for the following discussion.

Of the many soil types in Colorado, a few are outstanding in the problems they can cause if their characteristics are not properly taken into account in design. The locations of these critical soil types can be given in general terms, but actual site conditions must be studied in detail to provide significant engineering information for a specific type of construction.

There are many highly expansive clays in Colorado that generally cause difficult engineering problems. They influence the environment with a high frequency of failures, with unsightly cracking and consequently reduced values of buildings. The clays cover extensive areas of the state, either as overburden or as claystone or clay-shale bedrock. Their expansiveness varies by orders of magnitude, as does their susceptibility to water absorption. The clays frequently are hard and dry. Their degree of swelling in any given situation depends upon the amount and duration of wetting to which they are subjected. If they are not wetted, they do not swell. The most expansive of the clays are also the most difficult to wet, particularly where there are frequent wet-dry cycle reversals. The greatest frequency of failures has been in those cases where water access is easy, often where there are only moderately or slightly expansive clays.

We have found, through experience, that when there is a swelling clay or claystone, the design of buildings and foundations must take these properties into account or serious and widespread failures occur. Judgment assumptions must be made on the risk of wetting and the depth of wetting; everyone must be cognizant of the risk. If wetting occurs deeper than has been assumed in the foundation design, movement is unavoidable in many cases.

Typical criteria for foundations on swelling clays, developed by experience, call for heavy loads and high unit pressures on spread footings, normally encroaching on the usual large safety factor for shear or settlement. Piers to support the structure are carried below the expected zone of wetting and are also designed for heavy loads and pressures. Criteria for foundation design are primarily based on experience with similar structures and similar soils, supplemented by laboratory or field tests for comparisons of conditions.

Floor slabs founded directly on swelling soils will heave if the soils are wetted. There is no economical method of exercising a sufficient degree of control by loading, as is possible for a footing foundation as described above. Floor slabs may be used where the soils can be protected from extensive wetting, slab movement is relatively unimportant, and the owner is willing to risk replacing slabs if excessive wetting does occur. Where substantial risk of slab movement is not acceptable, structural floors with an air space under them to allow for the heave are used. Even these have a degree of risk.

Fine-grained, very low density soils (usually silty) found in much of Colorado, are also a fairly common cause of building foundation failures. In many cases, these are dry and hard, and in their natural state, they will support moderate to heavy loads. If they become wetted, they soften and settle — in some cases up to several feet. Piling is generally used in the Grand Junction area to support heavy building loads because of such soils. Lightly loaded floor slabs may be placed directly on these soils or on thin fills, since pressure changes resulting from such construction are small. Where thick fills are required, beneath floor slabs for examples, the load of the fill will cause settlement of the underlying soils and damage to the slabs. Structural floors may be necessary in this event.

Where fills over such soft soils are required for highways or dam embankments, slopes must be properly flat to prevent foundation settlement. Excavations in these materials may cave and shoring may be required. Bottoms of excavations are often too soft to support construction equipment, requiring the use of draglines or similar excavation equipment. Typical failures include settled and cracked pavement, floor slabs and building walls and foundations, as well as broken sewer and water lines.

Light footing loads can often be placed directly on the firmer zones of these soils, where movements are not critical. A foundation which has a chance of providing good performance on these soils must have specific facilities to protect them from wetting.

Another foundation soil which has caused problems in certain circumstances in Colorado is loose sand. Loose sand may support moderate static loads, but if subjected to vibration, can settle substantially, or even liquefy. Machinery foundations, which would be subject to this type of failure, can generally be made safer by removing and recompacting the sands, or placing compaction piling.

In urban areas of Colorado, a reoccurring foundation problem is that resulting from man-made fills. These are often difficult to detect and delineate after a few years. These fills are usually placed in random fashion, normally uncompacted, often mixed with garbage and other debris. There is no way of adequately predicting the performance of such fills, so if found at structure sites, they ordinarily must either be removed or the structure be founded with piers or piles below the fill.

Diagnosis of these problem soils and their relation to the proposed structure is prerequisite to good engineering design.

ENVIRONMENTAL ASPECTS OF COLORADO STREETS AND HIGHWAY ENGINEERING

CHARLES S. ROBINSON

Consulting Geologist, Denver, Colorado

INTRODUCTION

The development of Colorado's street and highway systems was not by design — and this is true in any state — but was in response to the location of physical features and natural resources of the state. The earliest Indian trails followed the streams where water and food were available and the grades relatively gentle. Where it was necessary to cross from one drainage to another, the crossing was made at the lowest point in the divide between drainages. The first explorers that came into the Colorado territory followed these same trails, and for the same reasons. The explorers were followed by the trappers, with their pack trains, who penetrated further up the streams in search of pelts — chiefly beaver, which were found in and along the streams to the very headwaters in the highest mountains.

To support the trappers, and to trade with the Indians, trading posts were established at strategic locations. The trading posts were generally along the mountain fronts at intersections of modes of transportation; such as the intersection of navigable streams or the intersection of trails; or where one mode of transportation, such as pack animals in the mountains, was changed to another mode, such as rafts or canoes on the rivers.

To supply the trading posts, the Indians and trappers' pack trails were improved so that wagons could be used to transport the needed trade goods to the posts and the pelts to market. Most of these early wagon trails, such as the Santa Fe Trail, came from the east into Colorado. Wagon trails were then developed north and south along the mountain front. Along the wagon trails east of the mountains, agriculture was started and settlements developed. Figure 1 shows the principle highways in Colorado which, in general, follow these early trails.

The development of access to the mountain areas was directly related to the discovery of precious metals. The first discoveries of gold were made in the gravel deposits along the mountain front. The values in the gravels in the stream beds were followed up-stream to the outcrops of the veins. First pack trails — many just improvement of the trappers' trails — then wagon roads were developed in the stream valleys. Where the veins outcropped, and mining became a year-around business, towns were established. Ore was brought to the towns from the mines, often by pack mule, where it was milled, and from where the values were transported by wagon or stagecoach to the major cities that developed along the mountain front. Supplies were brought in by wagon from these major cities to the mining towns. Within a short time, the major cities were connected to the eastern markets by standard-gauge railroads, and the more prosperous mining districts to the major cities by narrow-gauge railroads.

Then came the gasoline engine. The wagon roads — and eventually the narrow-gauge railroad routes — were made into highways. Now the main purpose of these highways is not the transportation of ore or other raw materials from the mountains, but to give access to the mountains for recreation purposes, and to the land beyond the mountains. For the latter purpose, shorter and better routes could have been developed than those in use today, but the routes connecting the old mining towns — now the centers for mountain recreation — were the ones that were continually improved and are followed by our Federal Highway system today. Figure

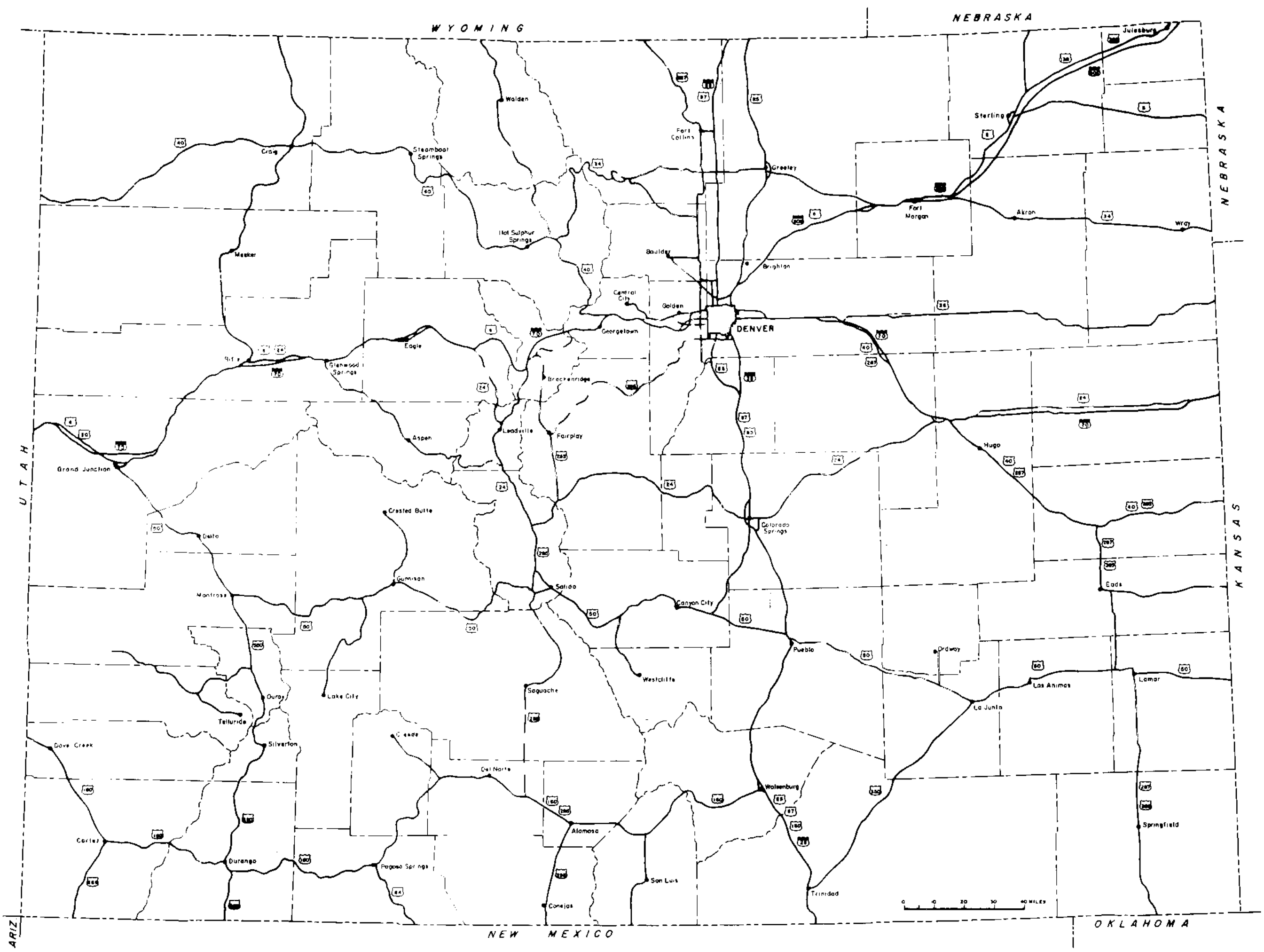


Figure 1 — Map of Colorado Showing Routes of State and Federal Highways

1 shows these routes, and most of the towns in the mountains along these routes were once centers for mining activity.

This introductory discussion on the history of the development of the highway system was presented to illustrate that the highway system was not designed, but was inherited. With it we have inherited a lot of problems related to the environment of the highway system; problems that could have been avoided if the system had been designed from the start.

ENVIRONMENTAL AREAS

Thy physical features of Colorado — as illustrated in the previous discussion — have directly influenced the development of the streets and highway systems. Colorado can be divided broadly into three environmental areas — the high plains; the eastern foothills, western slope and major river drainages; and the mountain chains. These areas are outlined on Figure 2. Each area has environmental characteristics that must be considered in the design, construction and maintenance of a highway system.

High Plains

The high plains of Colorado constitute about the eastern third of the state (Fig. 2). They are characterized topographically by low rolling hills (grass covered) and broad flat stream valleys (lined with cottonwood trees). The streams meander across broad alluvial-filled valleys. The major drainages of the high plains are the South Platte and Arkansas Rivers and their tributaries. In the spring, the stream channels are full as a result of the melting snows

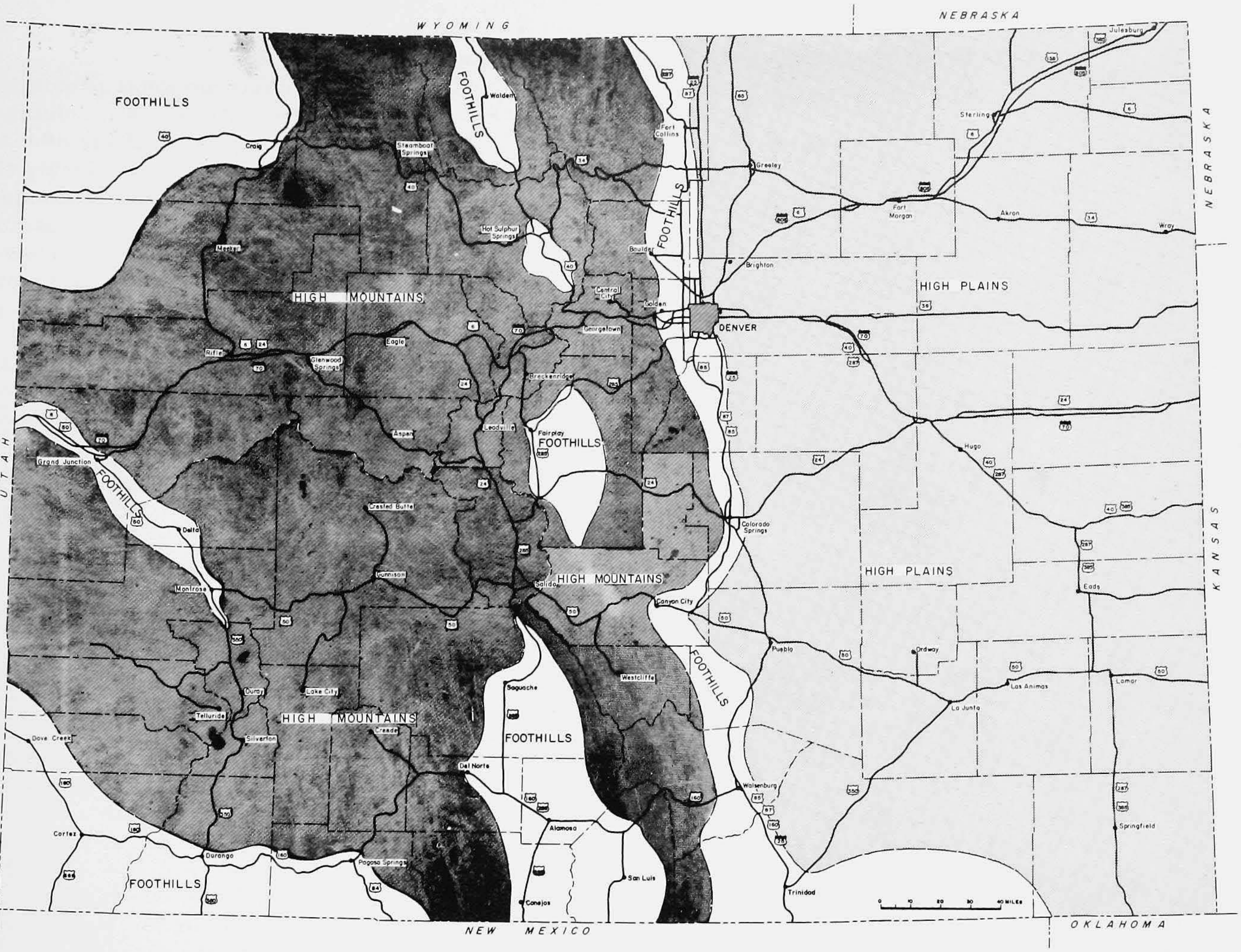


FIGURE 2.--MAP OF COLORADO SHOWING PRINCIPAL ENVIRONMENTAL AREAS FOR HIGHWAY DESIGN, CONSTRUCTION AND MAINTENANCE

in the mountains. By fall, little water flows at the surface except in the larger stream valleys. Climatically, the high plains is an area of extremes. In the summer months it is hot and dry, precipitation being in the form of sudden thundershowers that may yield an inch or so of moisture in a few minutes, but the precipitation is typically restricted to a small area. In the winter months it is cold and raw, precipitation being in the form of wind-driven snow. The total precipitation ranges from about 10 to 14 inches. About half of the precipitation occurs as snow in the early spring months and about half results from thundershowers in the early summer. Temperatures range from 10 or more degrees below zero in the winter to over a hundred degrees in the summer. The wind blows much of the time, mostly from the northwest or southwest. The average velocity is about 8 mph; the range is from zero to more than 40 mph, exclusive of tornadoes where the velocity may exceed 100 mph.

The surface materials of the high plains consist of fine-grained alluvium in the stream valleys, residual soils developed from the underlying bedrock on the uplands, locally terrace deposits adjacent to the major drainages, and locally fine-grained, wind-blown deposits in either the stream valleys or on the uplands. Except for the alluvial deposits in the western part of the high plains, most of the materials were derived from the local bedrock. The high plains are underlain by Cretaceous marine and non-marine shales, siltstones and fine-grained sandstone, and by Tertiary non-marine claystones, sandstone and locally conglomerates. For engineering, the most significant characteristic of the bedrock, and the deposits derived from the bedrock, is that the finer-grained materials contain bentonitic clays — or montmorillonite — which expand upon exposure to moisture.

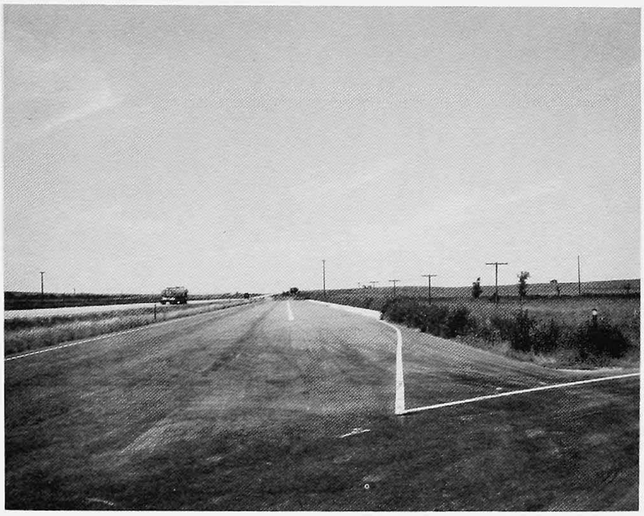


Figure 3. Stretch of typical Federal Highway on High Plains of Colorado.

The first highways across the high plains followed the major drainages (Fig. 3). Here they were subject to flooding as the result of a rapid snow-melt in the mountains in the spring or as a result of summer thundershowers. More recently, the major highways have been constructed at the margins of the alluvial valleys and are not as subject to flooding as the result of the spring run-off — which is now also better controlled. They are still subject to flooding, particularly where they cross tributaries to the main rivers, as a result of sudden thundershowers in the drainage area of a tributary. Such flooding is generally restricted at any one time, or as a result of any one storm, to a small area.

The principal problems in the construction of highways across the high plains are foundation problems and sources of aggregate. Most of the materials of the high plains contain bentonite clays and must be protected from moisture. Some of the Tertiary formations are conglomeratic and locally can be used as a source of asphalt or concrete aggregate. In general, however, adequate sources of aggregate are not available locally for highway construction.

With modern machinery, most of the materials for cuts are easily rippable, and because of the low relief, grades are gentle, and cuts and fills not extensive. Cut slopes are easily maintained in general. Locally, however, where the composition and structure of the bedrocks are right, small slope failures occur in the cuts or fills.

The principal environmental problem to operations on the highways of the high plains is the high winds and blowing and drifting dust and snows. During the spring dust, and during the winter snows, driven by high winds, reduced visibility to the point that driving is impossible and the highways are closed to travel. Snow particularly may drift across highways faster than the plows can clear the roads, and travel becomes hazardous. High winds alone may cause closing of some roads for short periods to semi-trailer trucks and towed vehicles. Little can be done in the design and construction of a highway to deal with these environmental problems. The delays as a result, however, are generally minor.

Foothills and Western Slope

The foothills environment is transitional between the high plains and the high mountains. For the design, construction and maintenance of highways in the foothills area, there are many of the problems found in both the high plains and the mountains, plus a few unique to the transitional environment. The foothills area is generally considered to be an area about 20 miles wide east of the mountain front (Fig. 2). The environment, and related problems, are similar in the intermountain valleys of the high mountains and along the major river valleys of the western part of Colorado — commonly referred to as the "Western Slope".

The climate along the foothills and the western slope is more moderate than on high plains or high mountains. The maximum and minimum temperatures are less than on the high plains and, with few exceptions, wind velocities and frequency of high winds is less. Precipitation is related generally to altitude. Most of the moisture falls in the spring months as a result of frontal systems moving along the mountain fronts. Torrential thundershowers develop locally along the fronts during the summer months.

The foothills and hills of the western slope consist mostly of sedimentary rocks. Intruded into and interlayered with the the sedimentary rocks locally are igneous rocks. The rocks older than the formations of Tertiary age have been folded — the steeper dips being adjacent to, and where the sedimentary rocks lap onto, the Precambrian rocks of the core of the high mountains. Sedimentary rocks of Tertiary age are, in comparison to the pre-Tertiary

Figure 4. Flood damage on State Highway as result of thundershower in foothills region.

sedimentary rocks, flat lying. The more resistant pre-Tertiary sedimentary rocks of the foothills, such as the Fountain and Dakota formations — both composed chiefly of sandstone form conspicuous hogbacks or sharp, narrow ridges, such as in the Garden of the Gods, that parallel the mountain front. The major streams of the foothills area, which originate in the high mountains, cut across these ridges in narrow canyons. Tributary streams have eroded strike valleys in the softer formation between the hogbacks. The flat lying Tertiary sedimentary rocks typically form flat-topped, steep-sided mesas or low hills capped by pediment gravels or, in a few cases, lava.

Repeated uplift of the foothills area and western slope, or changes in the regime of the major streams, have developed pediments and terrace deposits along the mountain front. Locally, alluvial fans have been formed by minor streams issuing from the mountains onto older pediment or terrace surfaces. The terrace and alluvial deposits along the major streams — particularly near the mountain front — are the chief sources of aggregate for the construction industry.

Most of the population of Colorado is concentrated in the foothills or western slope areas. Here water was available for agriculture and power, the climate was more moderate than

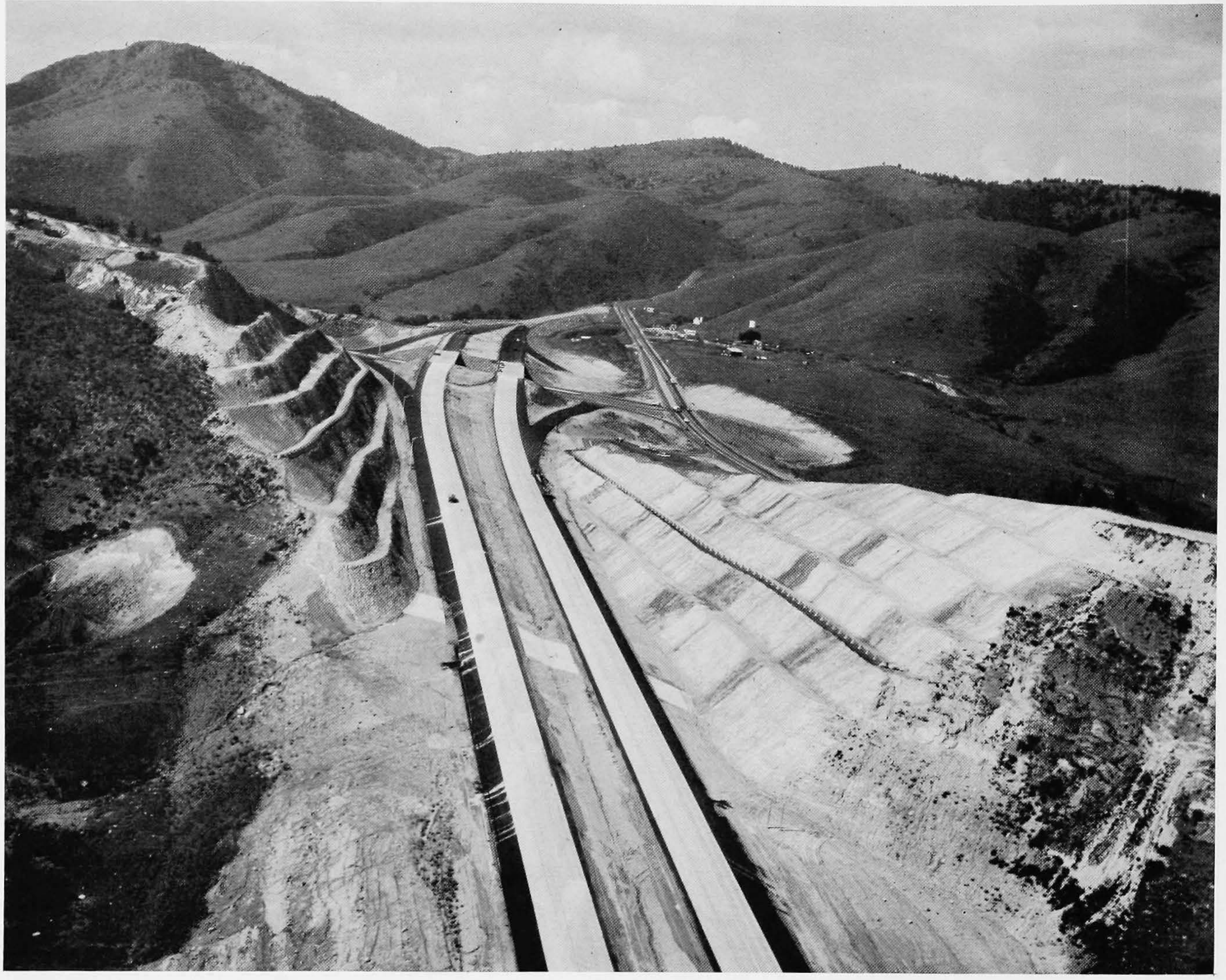


Figure 5. Cut on Interstate Highway in layered sedimentary rocks of the foothills region.

on the plains or in the mountains, and goods to and from the mountains were trans-shipped from one type of transportation to another. The highways come across the plains to the mountain front, then traverse along the mountain front to points — such as the major stream valleys issuing from the mountains — that gave easy access to the mountains. Many of the major cities are at these points of access to the mountains.

The environmental problems in the design, construction and maintenance of the highways in the foothills and western slope areas are floods, incompetent and unstable bedrock for foundations and cuts, and ground water.

Floods result from the rapid melting of the snow pack in the mountains in the spring and from thundershowers in the mountains and along the mountain front. Many of the highways that start into the mountains, and the cities and towns right at the mountain front, are built on flood plains of streams issuing from the mountains. Few dams have been built for flood control on the streams issuing from the mountains. During years of extended warm spells in the spring, the snowpack in the mountains melts rapidly, and the spring run-off may cover the flood plains of the streams through the foothills.

The spring run-off builds relatively slowly and usually there is adequate warning of pending floods. Floods from thundershowers can be more catastrophic. Periodically, as a result of up-slope wind conditions and abundant atmospheric moisture, large thunderclouds will build right at the mountain front over the foothills area. Precipitation from the thunderclouds can amount to more than an inch in a few minutes. The resulting flood, which at any one time is usually restricted to a small area, builds rapidly and there is little time for adequate warning. As a result, damage is usually extensive. Such was the origin of the floods in the Denver and Castle Rock areas in 1965 (Fig. 4).

The relief in the foothills area ranges from a few feet to 1,000 feet or more. Highways built across the hills, to maintain high-speed curves and grades, require cuts and fills of moderate size. Most of the sedimentary rock units of those hills are fine-grained and include shales, claystones or siltstones, which contain expansive clays. Special consideration must be given to these expansive materials when used in fills and in the design of cut slopes in this material. Figure 5 is a photograph of a cut through the Dakota hogback west of Denver, and illustrates a well-designed cut through dipping, alternating beds of sandstone and claystone typical of the foothills area.

Rock structure becomes important in the design of cuts in the foothill areas. The folded sedimentary rocks in general strike north-south and dip east or west. Many highways east of the mountain front go north and south parallel to the strike of the beds. Failure along bedding planes in cut slopes parallel to the strike of the beds occurs where the cut slopes are not properly designed.

The occurrence of ground water has significant effect on the design of highways. Ground water is more abundant in the foothills and western slope areas than in the plains because of the higher precipitation and drainage from the mountains and, exclusive of the ground water in the surficial deposits, is controlled by the porosity and permeability of the layered rocks. The outcropping of an aquifer in a road cut may present a problem in the stability of the cut, and if the natural drainage is dammed by compacted fill, the hydrostatic pressure may build to a point that the fill fails. Figure 6 illustrates the failure of fill as a result of ground water drainage being dammed by fill for a highway.

In the foothills and western slope areas, the cost of design and construction is higher than in the plains. The problems of expansive soil are about the same, but the cuts and fills are more extensive, as a result of the greater relief, and the structure of the rocks and ground water become important considerations. Most of the rock is rippable, but some of the more resistant sandstones or volcanic rocks may require drilling and blasting. Construction is aided by the relative abundance of suitable aggregate. General maintenance would be similar to that of the plains, but winter maintenance is greater as a result of more snow — although blowing and drifting snow does not present as much of a problem as on the high plains.

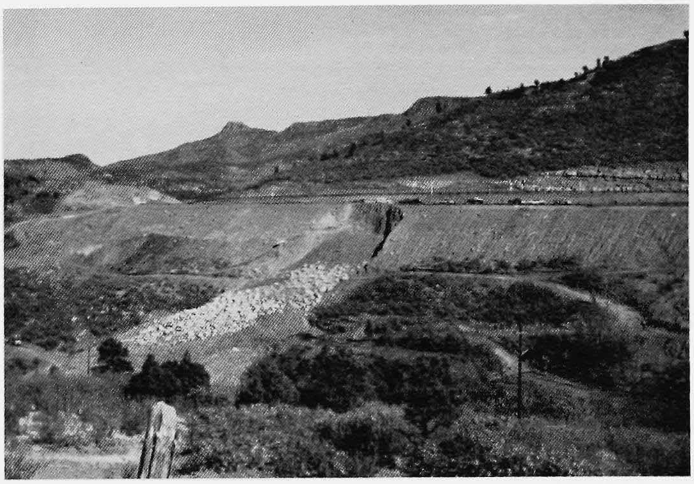


Figure 6. Failure of fill as a result of ground water.

High Mountains

The central portion of Colorado is traversed by a series of mountain ranges that generally trend north-south. The west-central and southwest portions of Colorado are composed of a series of high plateaus. The principal mountain ranges and high plateaus are separated by major stream valleys. The larger stream valleys, such as those of the Arkansas and Colorado Rivers, may be relatively broad and flat, particularly in their lower reaches, and the design, construction and maintenance of highways is similar to that of the foothills and Western Slope regions. As one goes up the river valleys, the valleys become narrower and steep-walled and than, at even higher elevations, the valleys again broaden out. Here the walls are steeper as a result of the scouring out of the valleys by glaciers. The divides between the heads of major streams are typically precipitous. The altitudes in the high mountains

Figure 7. Glenwood Canyon, Colorado River. Site for Interstate Highway 70.

and plateau regions range from about 4,000 to over 14,000 feet, and the environmental problems of highway design, construction and maintenance are related not only to the relief and geology, but also to the climatic conditions as a result of the altitude.

The central part of the higher mountain ranges of the high mountains area are generally composed of Precambrian crystalline rocks flanked by younger sedimentary rocks, both of which have been intruded, and locally covered, by Tertiary igneous rocks. The Precambrian rocks consist of a wide variety of gneisses that during Precambrian time were intruded by granitic rocks. The flanking sedimentary rocks include sandstones, shales and limestones that range in age from Cambrian to Tertiary. These Precambrian crystalline rocks and flanking Paleozoic and Mesozoic sedimentary rocks were folded, faulted and intruded by igneous rocks in Tertiary and post-Tertiary time. Volcanism accompanied the igneous activity and thick sequences of lavas formed mountain areas — such as the San Juan Mountains — and volcanic material is common in the young sedimentary rocks that are found in the intermountain valleys. Pleistocene glaciation, and the accompanying erosion and deposition, sculptured the high mountains and plateaus. In this high mountain region, highway design, construction and maintenance must deal with a great variety of rock types, structures, surficial deposits, physiographic features and climatic conditions — all of which should be understood prior to design and construction.

The first roads into the high mountains followed the pack trails up the stream canyons. These trails were widened to wagon roads, railroads and eventually highways. The purpose of these early roads was to bring supplies to the mining and lumber towns, and to bring the ore and lumber out. The mining towns were located near the ore, which occurs in the most geologically complex areas of the high mountains. The modern highways follow the same routes, and have inherited all the environmental problems related to the development of the high mountains, as well as creating a few new problems because of the requirements for line and grade for modern high-speed travel. Figure 7 illustrates some of the problems faced by the highway engineer. Illustrated is a section of Glenwood Canyon, in which Interstate 70 is to be built. The canyon is already used by the Denver and Rio Grande Railroad and, but not of least importance, the Colorado River,

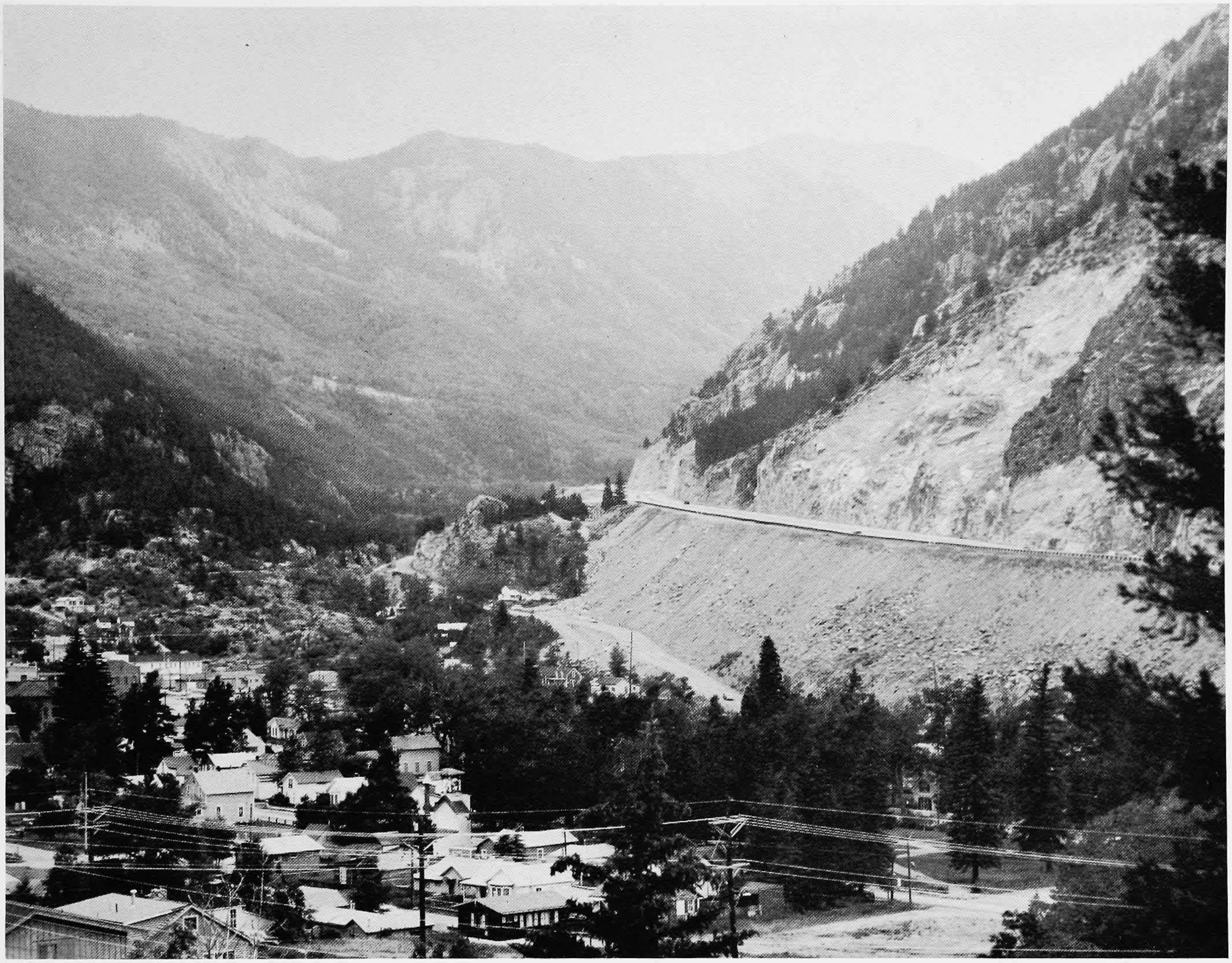


Figure 8. Rock cut above Georgetown, Interstate Highway 70.

which cut the steep cliffs through sedimentary and igneous rocks.

Physiography and hydrology, rock type, structure and alteration, and type and composition of surficial deposits, must be known before modern highways can be designed and constructed in the high mountain valleys. Requirements of line and grade and allowances for flooding, which results from the spring run-off or sudden thundershowers, dictate the location of cuts, tunnels and fills. The geologic conditions, which rarely can be avoided, dictate the design and construction procedures. For example:

The gneisses and the sedimentary rocks have a distinct layering, which is usually the principal direction of weakness. The relation of this principal direction of weakness must be considered in relation to the angle of a cut or the line of a tunnel for stability and the design of support. Faults and joints are directions of weakness and should be considered in slope stability analyses. The present highways go through the old mining towns, which were established near the ore deposits, which were formed in the geologically most complex areas. These are the areas of the most faulting and the most jointing, and the areas of most intense rock alteration. The solutions that formed the ore deposits commonly altered some of the minerals of the adjacent rock to clay minerals, which reduced the strength of the rock, and created squeezing and swelling ground — similar to that found in areas of bentonitic sedimentary

Figure 9. Result of avalanche.

rocks. In glaciated mountain valleys, there is commonly a stress-relief joint system — not always conspicuous — parallel to the valley walls. Failure to recognize and/or design for this type of joint system has resulted in considerable damage, and even loss of life. Figure 8 illustrates a well-designed grade and cut in a high mountain valley.

The occurrence and composition of surficial deposits are critical in the design and construction of highways in the high mountains. Marginal moraines plastered high on the valley walls, mud-flow deposits at the mouths of hanging valleys, peat bogs from filling of old lakes, old landslide deposits, and talus deposits with cores of ice are some of the types of deposits that must be recognized, and designed for.

The climate of the high mountains is a significant environmental problem of the high mountains. Climatic conditions range from desert — along the lower reaches of the major stream valleys in summer — to arctic — along the high mountain ridges in winter. Thundershowers, to be expected on nearly any summer afternoon, can produce heavy rainfall and flash floods that can wash out bridges or cover the highways with mud-flows. Snow and ice at the higher altitudes are the major maintenance problems. A basic rule in the design of a highway in the mountains is to put the highway on the south-facing slopes. The relative abundance of sunshine at the higher altitudes is a significant factor in keeping the highways free of snow and ice. An environmental problem related to the

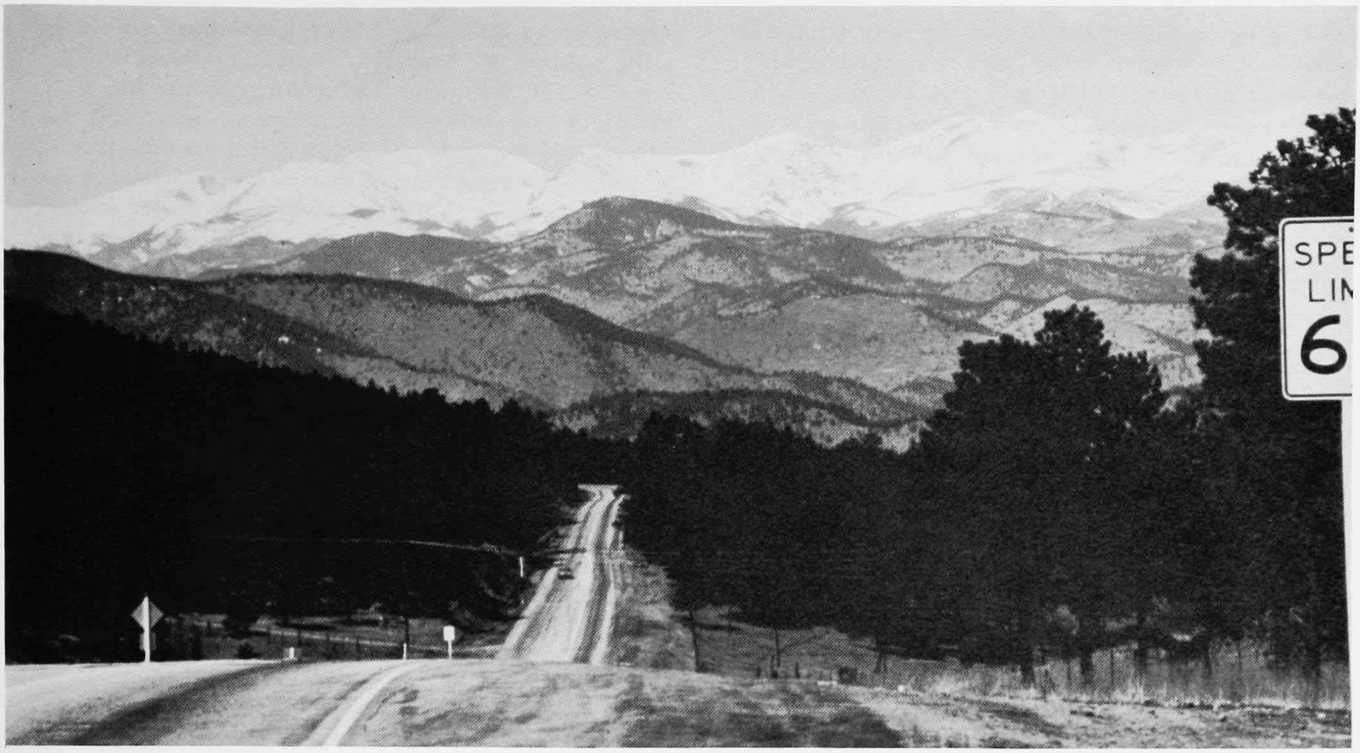


Figure 10. Colorado ferrain.

relief and the climate, and unique to the high mountains, is that of avalanches. In past years, avalanches could occur at any time, close the highways, and often resulted in loss of property, if not life (Fig. 9). Studies by the U.S. Forestry Service in cooperation with the Colorado Department of Highways have developed criteria for predicting avalanche conditions. Now the avalanches are initiated under controlled conditions, resulting in a minimum of hazard or delay to the highway traveler. It is rare now, even under the most severe of winder conditions, that the major highways through the mountains of the state are closed to travel for more than an hour or so.

Man, and other animals, have created many problems for the highway engineer, particularly in the high mountains. The early mining towns and mining claims were located in the narrow mountain valleys. An interstate highway, plus room for the stream, may fill the bottom of a valley, which results in the acquisition and removal of nearly all the houses in an old mining town. Some of the old mining towns along the major drainages have been replaced by a highway. The only evidence remaining of some old towns is a few houses clinging precariously to the mountain slopes above the highways, and yellow dumps at old tunnels and shafts. In some cases, the highways have had to be built on steep slopes above the towns. Acquiring title to land for highway construction is also a problem. Many old mining claims have been abandoned, and the records of their ownership lost, or the ownership has been divided among many heirs scattered all over the country. And there is nothing more valuable than a share of a mining claim — even though it may not have ever produced any ore, or even been worked for years — until someone wants to buy it for a highway.

Other animals create problems for the highway engineer in the high mountains. Beavers are not reluctant to dam culverts, resulting in the flooding out of a stretch of highway. A beaver can build a dam in a night — as fast as the maintenance crew can remove it during the day. The removal of the beaver to a less sensitive location is about the only solution. The interstate highways with their high bordering fences have had a significant effect on the annual migration of wild animals such as deer, elk and bighorn sheep. Design in some areas must include ways for these animals to pass over or under the highways.

The high mountains present the most

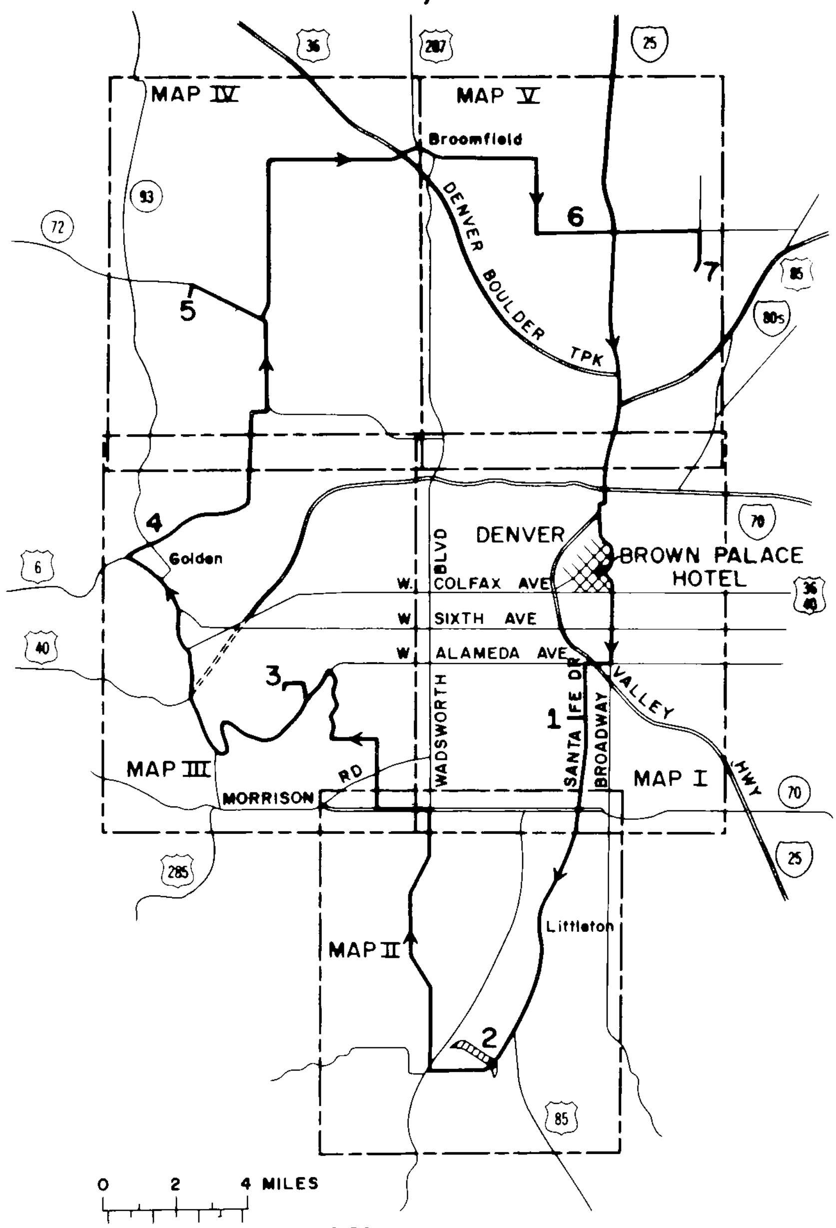
challenging environment to the highway engineer in the design, construction and maintenance of a highway system. This environment presents the extremes in physiography, geology and climate, which must be recognized and understood in order to have an efficient and reliable highway sytem.

CONCLUSIONS

If we could only start all over. For modern-day living and surface transportation, most of our towns and highways are in the wrong places. Hindsight shows us that had modern engineering techniques been available, we could have placed our towns — and the connecting highways — in better environments for more efficient construction and maintenance. But we are where we are. Now for efficient construction and maintenance of our surface transportation system, it is essential that we understand the climate, the physiography, the geology, the surface and ground water hydrology and the ecology of plant and animal life — including man. In Figure 10 are shown many of the principal environment of Colorado that must be understood for the design, construction and maintenance of a modern highway system.

THE GOVERNOR'S CONFERENCE
ON
ENVIRONMENTAL GEOLOGY

FIELD TRIP
DENVER AND THE ROCKY MOUNTAIN FOOTHILLS, COLORADO
MAY 1, 1969



ASSOCIATION OF ENGINEERING GEOLOGISTS, DENVER SECTION

STATE OF COLORADO
JOHN A. LOVE,
GOVERNOR

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS, COLORADO SECTION

AN ENVIRONMENTAL GEOLOGY FIELD TRIP

ROAD LOG

CONFERENCE FIELD TRIP COMMITTEE

The geology of metropolitan Denver is varied, rich and rewarding to man. There are economic riches in its mineral resources. There are aesthetic riches in magnificent views of the Rocky Mountain Front Range; the rolling topography for interesting residential areas and, in turn, the views of the metropolitan area to be had from the western suburbs; the mountain scenery and the geologic story where mountains and plains meet. All in all, we are in an exciting environment. Let us, therefore, make the most of it. This, after all, is the aim of environmental geology.

The field trip is planned to provide one with an opportunity to see a summary, as it were, of the geology of the area. Stops are made at points where it is possible to view man's works and the uses being made of the lands in relation to the geologic conditions. This is not a grim story of geologic hazards and failures in land use, but rather an exhibition of geology as it is; the assets to be developed or preserved; the problem areas with some consideration of their solution by thoughtful planning and wise use of the knowledge and technical means now at our disposal.

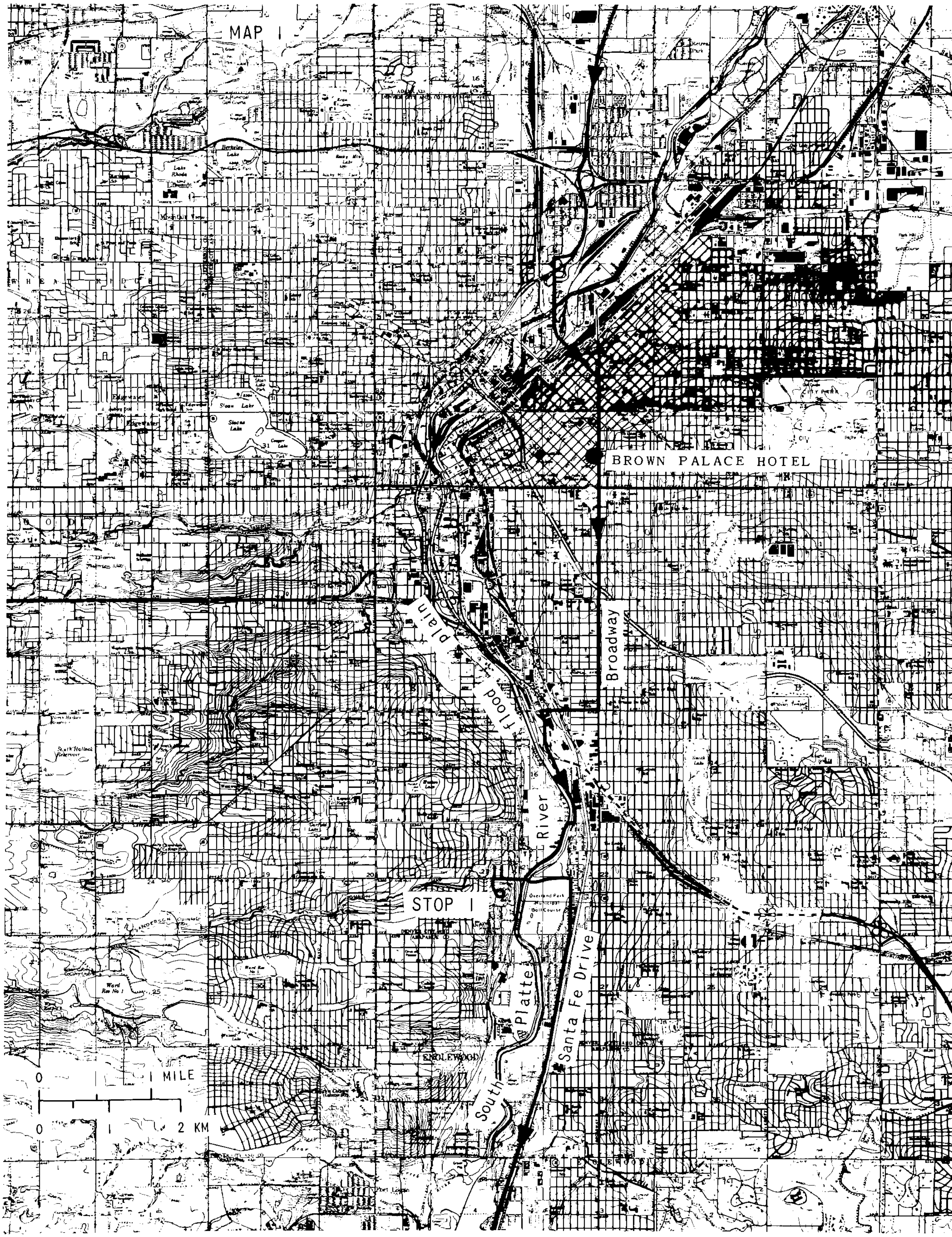
STARTING POINT - BROWN PALACE HOTEL, DENVER

The route for two and one-half miles southward on Broadway from the Brown Palace Hotel lies on a topographic terrace bordering the flood plain of the South Platte River. The terrace is covered with sand and gravel, of Late Pleistocene age, deposited by the river before it had cut down to its present level. The slope to the left (east) is covered chiefly with windblown sand and silt deposits that rest on mudstone of the Denver Formation (Late Cretaceous and Paleocene age) which is many millions of years older, and constitutes the "bedrock" under most of the city and surrounding area.

STOP 1. RUBY HILL

This is a good vantage point to view the landforms in the region, from the South Platte River and its flood plain, westward across the uplands of relatively soft rocks, alluvial terraces and low hills to the foothills; the remnants of the ancient land surface at the lava-capped Table Mountains near Golden; the abruptly rising wall of hard rocks in the first main ridge of the Rocky Mountains and on westerly to the high crest of the Front Range and the Continental Divide.

Ruby Hill, itself a good example of multiple use of land, is the site of a former clay pit. When this mineral resource was exhausted, the pit was used for a sanitary fill. It has now developed into a fine park for open space and recreation. The South Platte River valley too provides an example of good use of a flood plain area where the golf course and other recreational facilities are laid out. It also provides examples of how disaster areas may be man-created when a natural event, a flood, wrecks industrial developments (now restored) on the river's flood plain. In June 1965, exceptionally heavy rains caused a flood that by itself would have been very damaging. The effect was increased and extended over even wider areas when flood debris lodged against low bridges. The increased head of water then destroyed the bridges, releasing a still greater flood upon downstream areas. Extensive damage from the 1965 flood re-initiated pressure for construction of Chatfield Dam, our second stop.


MAP 1
BROWN PALACE HOTEL
Broadway
flood plain
South Platte River
Santa Fe Drive
STOP 1
ENGLEWOOD
0 1 MILE
0 1 2 KM

1-A. The Columbine Golf Course where two greens were washed out in the 1965 flood.

1-B. Gravel pits along South Platte River flood plain. When worked out and abandoned without being regraded or having the vegetation restored, such pits are unsightly and detract from property in adjacent residential areas. The ponds also can become dangerous play areas for children and mosquito-breeding sites unless controlled.

STOP 2. CHATFIELD DAM (under construction)

Chatfield Dam, on the South Platte River immediately below the mouth of Plum Creek, is under construction by the Corps of Engineers, U.S. Army, as a flood control reservoir with incidental recreational benefits. The earth-fill dam will be 148 feet high and 12,500 feet long. A permanent pool covering 1150 acres will provide a lake for recreation. The dam is being built, as a direct result of the 1965 flood, to offer protection to downstream areas. However, we must be aware that "flood control" is a relative term, and that it is not economical to build a reservoir that will completely control all foreseeable possible future floods. There is still some chance, although a very small one, of a future flood that would exceed the ability of the reservoir to control it within the channel capacity (5000 cubic feet per second) below the dam. Releases through the outlet works are expected to be held below this figure; however, the outlets have a designed capacity of 8000 c.f.s. for emergency use. There remains, therefore, some degree of flood hazard through Denver and on downstream which should not be forgotten in the use of those lands.

An adverse effect of the project is its impact on the sand and gravel reserves in the Denver area. The U.S. Bureau of Mines estimates that at flood capacity, the reservoir will cover about 100 million tons of valuable aggregate materials. It may, of course, be possible to recover much of the sand and gravel during low reservoir stages. In some situations, with long-range planning and favorable economic conditions, it is possible to extract valuable minerals before a project goes into construction. The flood flows that formerly carried sand and gravel along the river course through Denver will now deposit them in the reservoir which may thus become a locale of future mining operations.

2-A. The industrial plant of the Martin-Marietta Corporation is located behind the hogback ridge to the southwest; it is out of sight and the beautiful view of the mountain front is preserved.

2-B. At an excavation for the Platte Canyon highway relocation around the reservoir site, a landslide moved a few hundred cubic yards of shale (Pierre Formation) onto the new road.

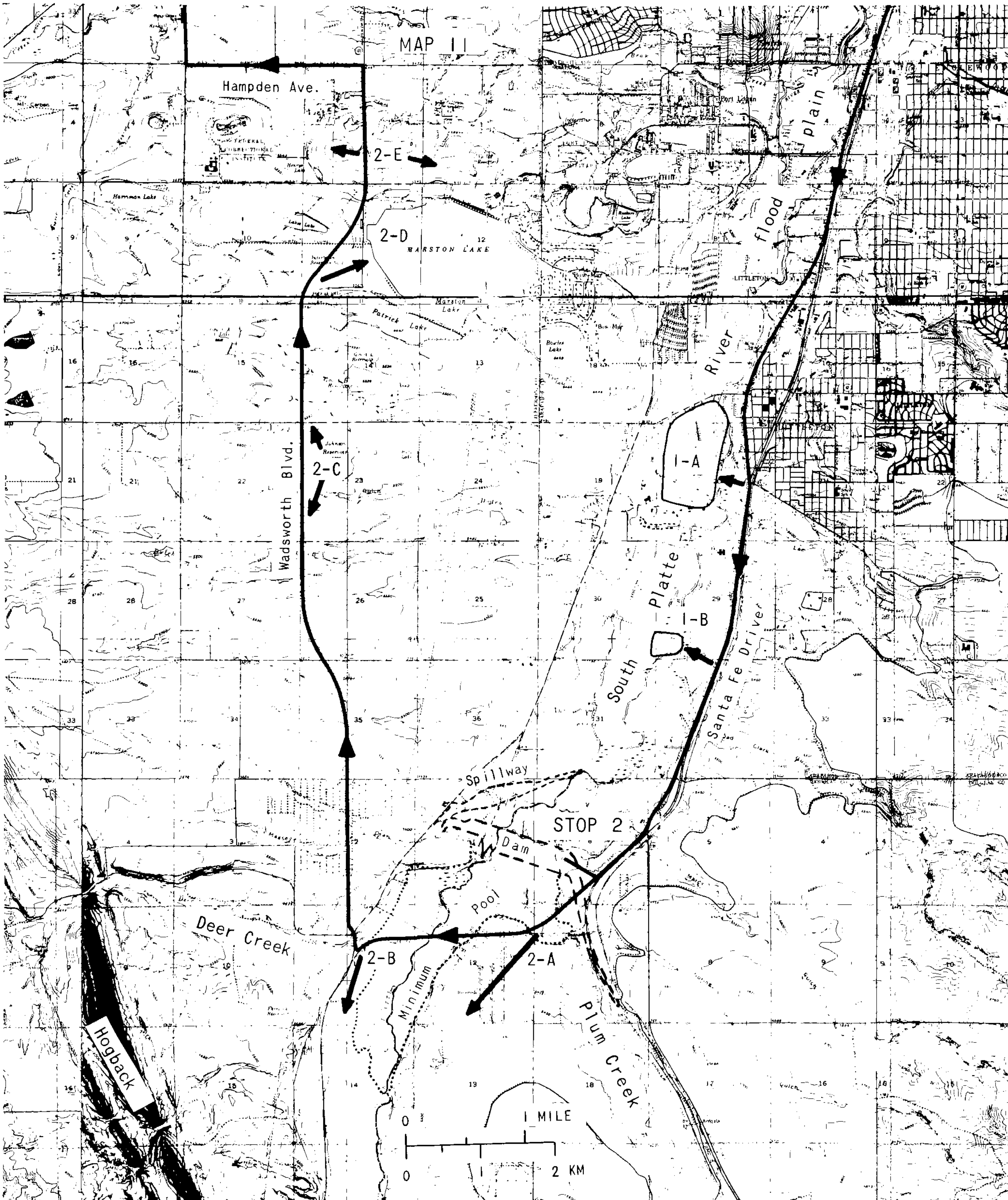
2-C. Exposures along here show deposits capped by thin reddish-brown wind-blown silt which is sensitive to moisture; excessive loading by heavy structures can cause differential settlements. Structures with light unit loadings, on the other hand, may be subject to heaving if appreciable volumes of water come into contact with the swelling clays below the silts.

2-D. Marston Reservoir and filtration plant provide water for the southern part of the Denver area; the supply comes by aqueduct from the Waterton Plant on the South Platte River.

2-E. Gravels capping the tops of hills are remnants of older alluvium (Early and Middle Pleistocene age) deposited by Bear Creek and its tributaries when flowing at those higher elevations. Subsequently, of course, the streams have cut down to their present elevations and, in doing so, have eroded and carried away a great volume of material. The gravels still remaining on hilltops are only fair to poor quality for aggregate because they have become partly weathered and unsound.

2-F. Mount Carbon damsite is about one and three-fourths miles to the left (west) up Bear Creek. It is a proposed flood control project to protect newly developed residential and shopping areas along the Bear Creek flood plain. It too will have a minimum permanent pool of about 130 acres in area for recreational use. Some further protection would also be afforded the South Platte River area in Denver.

2-G. A Denver Formation outcrop of brown


MAP 11
Hampden Ave.
2-E
2-D
MARSTON LAKE
Marston Lake
Patrick Lake
Wadsworth Blvd.
2-C
1-A
1-B
South Platte River flood plain
Santa Fe Drive
Spillway
STOP 2
Dam
Pool
Deer Creek
2-B
2-A
Minimum
Plum Creek
Hogback
0
1 MILE
0
1
2 KM

mudstone and interbedded pebble conglomerate. The former contains clays derived from volcanic material (tuff) that swell when wetted; the conglomerate provides good, well-drained foundations. This area has been platted for residential development although the slopes may exceed 30%. Grading for streets and homes, unless carefully planned and designed, can cause slope stability problems in this geologic situation. A house generally needs some level area to be built upon. On a slope, the level spot is made economically by partly cutting into the hill and partly by a fill of the dumped excavated material. In time, water from garden irrigation and precipitation percolates through the relatively loose fill causing it to settle. The soils engineer describes this decrease in volume as consolidation which, by proper practice, can be obtained during construction. If the fill settles after the house is built upon it, the result is an unhappy homeowner.

Garden irrigation in new areas may also contribute in a major way for the first time, or where there are moisture-sensitive clay, it will cause them to swell and heave doing considerable damage to structures with improperly designed foundations.

Storm drainage in hillside areas is a major problem. Paved areas and roofs cause faster and increased runoff which adds to the danger of serious erosions and sedimentation. At other places, fills may cause ponding of storm waters on the uphill side and result in flooded homes.

2-H. The small artificial lakes in this area are relics of agricultural days when they were built to check soil erosion or provide stock watering ponds. The larger ones were used for irrigation storage. Some of them are now being drained and backfilled for urban development.

STOP 3. GREEN MOUNTAIN

This area is a laboratory illustrating many of the problems mentioned under "2-G" above. There are swelling clays in the Denver Formation, uncompacted fills on hillsides, and problems of storm drainage in that material is washed down cayons, onto streets, lawns and even through basement windows. A gully that crosses Alameda Parkway to the southwest shows the effect of concentrated runoff. On the upstream side of the street, the gully is 5 to 7 feet deep, whereas on the downstream side it has eroded to a depth of about 15 feet. This after the flow has been concentrated at the culvert, and runoff from the paved street has been added to it.

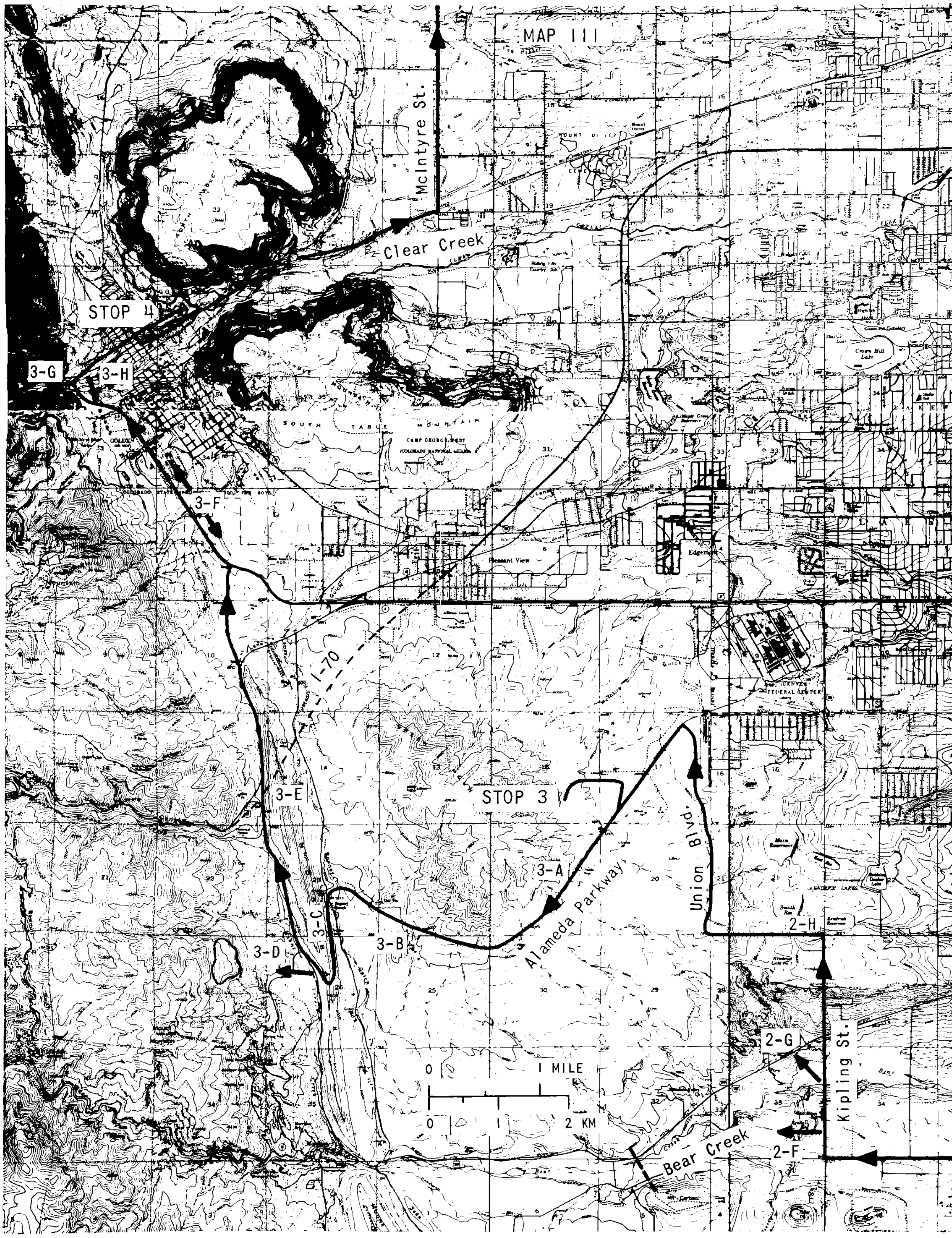
3-A. The conglomerate in the upper part of the Denver Formation at the top of Green Mountain (right) is about 300 feet thick but it is not suitable for aggregate because much of it is weathered and unsound, or the gravels are too well cemented together.

The Mount Carbon damsite on Bear Creek is visible to the left (south); its right abutment is the scarred, flat-topped hill, Mt. Carbon. The hill is capped with one of the older Pleistocene alluviums (Verdos Alluvium) of Bear Creek. The Arapahoe Formation is a conglomerate that underlies the Denver Formation beds. It is a good ground water zone farther east and, at one time, yielded flowing artesian wells in downtown Denver. The recharge areas for the artesian zones are in the valleys and outcrop areas of the foothill region. Very large pumping drafts on ground water in the zones lowered the pressure surface by about 600 feet in the Denver area. As a consequence of this drop in pressure, there has been about one foot of subsidence in Denver as indicated by precise re-leveling surveys over a period of years.

3-B. The Satanic Mine that until the mid-1920's mined a vertical coal bed about four feet thick, was located just west of the present Chieftain Mine, a clay-pit complex. Now, 40 or more years later, subsidence over the coal mine is causing small pits to open on the ground surface.

The Chieftain Mine clay pits are in the Laramie Formation (Upper Cretaceous age).

The route westerly goes deeper into the stratigraphic section, across progressively older formations through the Laramie Formation (sandstone, clay and coal), Fox Hills Sandstone and the Pierre Shale. The hogback ahead (west) is held up by the steeply dipping beds of hard, erosion-resistant Dakota Sandstone (Lower Cretaceous). The Golden Fault near the base of the ridge is a major structure that trends subparal-


MAP III
McIntyre St.
Clear Creek
STOP 4
3-G
3-H
SOUTH TABLE MOUNTAIN
CAMP GEORGE WEST
3-F
I-70
3-E
STOP 3
3-A
Alameda Parkway
Union Blvd.
3-C
3-D
3-B
2-H
2-G
Kipling St.
0 1 MILE
0 1 2 KM
Bear Creek
2-F

lel to the ridge and, in this area, cuts out a thickness of about 4500 feet of Pierre Shale beds, all of the Niobrara Formation (limestone and shale) and the upper part of the Benton Shale. The fault is known here only because of the missing formations between the upper part of the Pierre and the lower part of the Benton. It is a steeply dipping thrust fault in that the block west of it is thrust up and over some of the younger formations on the east side of the fault.

3-C. Very small slides occur in road excavations that may undercut beds dipping (inclined) easterly more or less the same as the hill slope (dip slope). Sandstone blocks slide down on thin beds of shale; this type of geologic situation is a classic one to produce slides.

An excellent view of the formation, Dakota Sandstone, is in the cut where the road crosses through the hogback.

After passing through the hogback, steeply dipping beds of red sandstone (Fountain Formation) can be seen across the valley. The Red Rocks Mountain Park amphitheater is located in this formation, and is an outstanding example of scenic values, well-blended architecture and land use.

Continuing northerly, the route passes from Dakota Sandstone to the older, underlying, multi-hued beds of shale, sandstone and some limestone comprising the Morrison Formation (Jurassic age). The small town of Morrison, near here, gave its name to the formation because this is the type locality where it was first described. The Morrison was deposited over a vast region in what is now the Rocky Mountains, and has been identified in deep wells as underlying much of the plains region.

3-D. An old landslide is on the slope to the left (west) where the Fountain Formation is broken by the Cherry Creek Fault.

Formations between the Morrison and the Foundatin are, in sequence of increasing age, the Ralston Formation (vari-colored claystones), Lykins Formation (red mudstone) and the Lyons Formation (red sandstone). A note of interest about the Lyons Sandstone is that the stone quarried near Lyons, Colorado, is the building stone for the Boulder campus, University of Colorado. The Fountain is the oldest sedimentary formation in the area (Pennsylvanian age), but the oldest rocks of all are the dark, crystalline "basement" rocks on the steep ridge beyond the Fountain "red rocks."

3-E. The new roadcut where Highway I-70 crosses through the hogback provides a beautiful exposure of the Morrison Formation and the overlying Dakota Sandstone. This will become a nature-study rest stop to view the geologic features along the benches and ledges. Signs will identify each formation, and give information on the geologic features and plant ecology of the area.

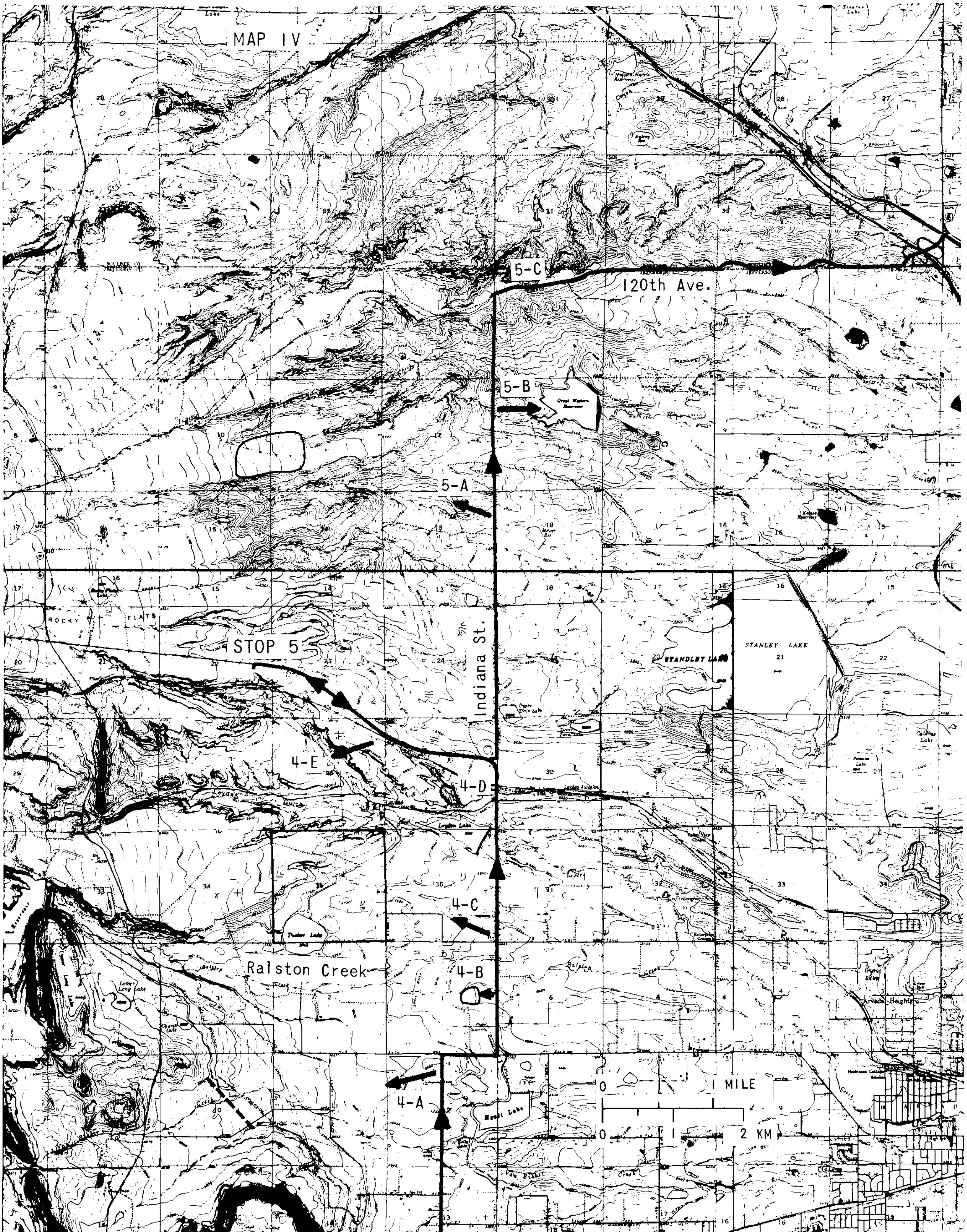
Fire-clay pits are adjacent to the highway east of the hogback.

3-F. Clay pits along here have been abandoned mostly without any rehabilitation work. At the Colorado School of Mines, however, further along the route, similar pits have been very economically reclaimed and the land used for student housing apartments. Some settlement at places in the backfilled pits caused some damage to buildings.

3-G. A quarry is in the crystalline basement rocks about one-third mile up Clear Creek. Fracture (joint) planes in the rock dip steeply toward the quarry face and highway. Although movement along these planes has not been detected at the quarry, there is a landslide mass of loose rock and soil perched precariously above it.

Rock falls from steep canyon walls or from cliffs such as those formed by the Table Mountain lava caps, are hazards to be considered when developments in these situations are undertaken. Sometimes expensive protective measures involving scaling, walls, wire nets or extra heavy roofs may be necessary. In this climate, rock falls are particularly prevalent during a thaw when ice-locked, unstable rocks are released.

3-H. The trace of the Golden Fault, to the right (south) on the hillside across Clear Creek is identified by the change in vegetation. The smooth, grassy slope to the left is on shale, whereas the rocky, greasewood covered slope (right) is on Fountain Sandstone ("Red Rocks"). Major movements along this fault started about 65 million years ago, and there have been recurring movements since. Newly discovered evidence in the Golden area indicates that there was


MAP IV
5-C
120th Ave.
5-B
5-A
STOP 5
Indiana St.
STANLEY LAKE
4-E
4-D
4-C
Ralston Creek
4-B
4-A
0 1 MILE
0 1 2 KM

very minor movement as late as 700,000 years ago, but none is known to have occurred since then.

STOP 4. GOLDEN

The flanks of North and South Table Mountains are mantled by thick landslide masses. Intermittent movement of the individual slides has affected the railroad, irrigation ditches and roads since 1878. As many as six different slides have moved within the past year. At one locality on 44th Avenue where it crosses a slide, the asphalt is estimated to be 13 feet thick as successive layers of pavement are laid to keep the street up to grade.

The many landslides are not an unexplainable mystery. They are due to a simple geologic situation that is well-known. They occur on slopes underlain by the Denver Formation that contains much swelling clay derived from volcanic ash (tuff). The slopes are oversteepened, that is, they are steeper than would ordinarily be developed in such materials, and this contributes to their instability. The slopes are oversteepened because the Denver Formation here underlies the cap of hard lava that does not erode easily and retreat back to where a flatter slope would form on the Denver Formation. In this combination of swelling clays and oversteepened slopes, a development should carefully plan the location of cuts and fills, the means of handling drainage and runoff and the type of water use in the area. If it were ideally possible to make the excavations near the tops of slides to unload them, and to make the fills at the toes to buttress the slides, if the drainage system got water out of the area without it seeping underground or causing surface erosion, and if there were no heavy garden irrigation or liquid waste disposal, the slopes would be reasonably stable. If just the reverse happens, there will surely be slides. Obviously, there must be compromises; one would be to utilize slide areas for open space.

On the route down 44th Avenue, many sand and gravel operations may be seen along Clear Creek east of the canyon section. Clear Creek supplies some of the best quality aggregate materials in the metropolitan Denver area. They are rapidly being depleted by construction demands and severely limited by urban and industrial encroachments. Planning for multiple land use may be the answer. An alternative source is being developed from older Clear Creek gravels on the terrace followed by 44th Avenue, and a pit can be seen just west of McIntyre Street.

4-A. A view toward Van Bibber damsite, about two miles to the west. The south (right) abutment will be in a landslide; the north (left) abutment is a faulted mass of shale. The reservoir would be for a local water supply.

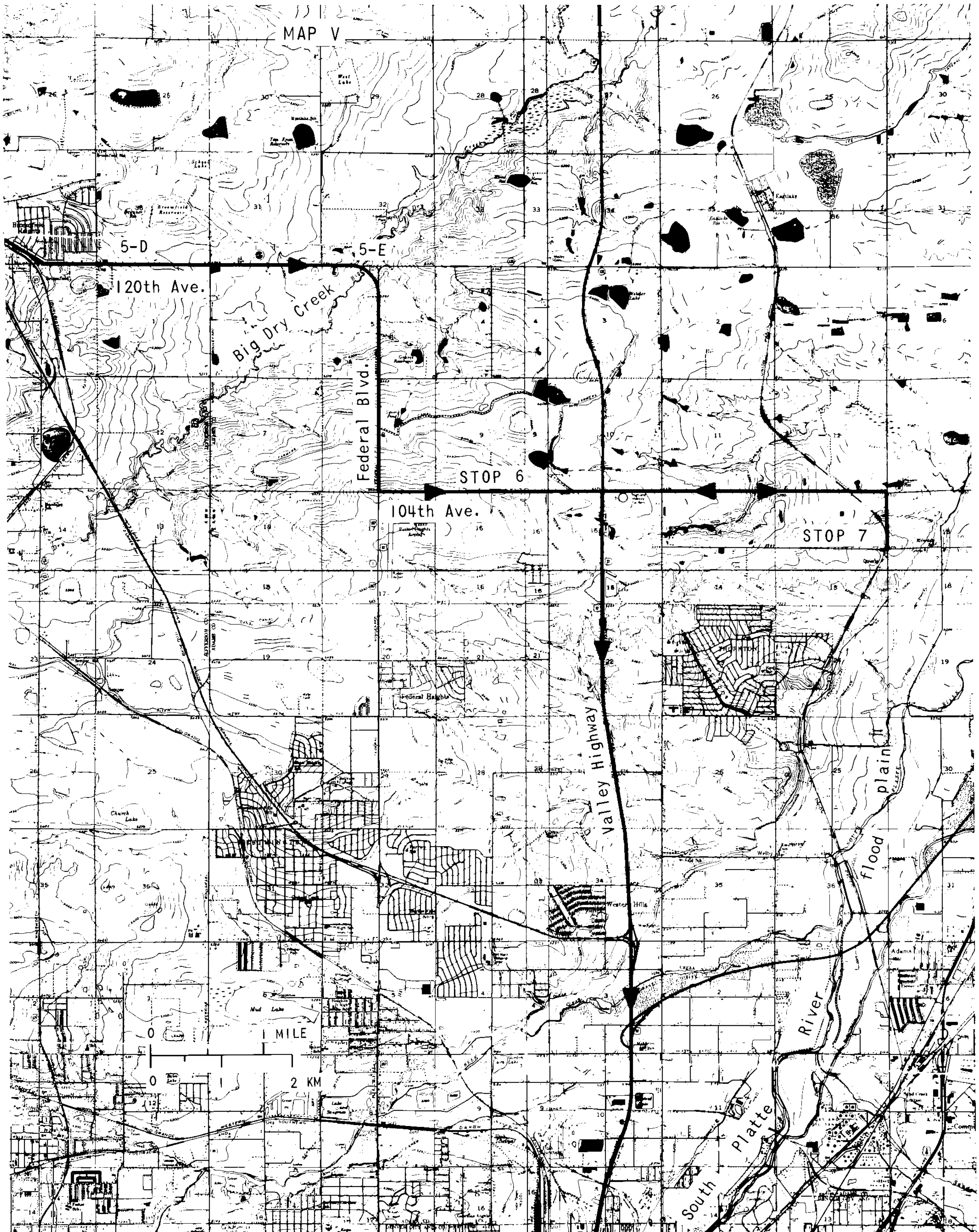
4-B. A sanitary fill here is in a geologically poor location in that the permeable gravel alluvium of Ralston Creek, which is drawn upon for ground water downstream, is being polluted by seepage from the fill located in the same gravels. This is an example of how an action in one place may affect seemingly remote areas.

In this same context, another ground water situation in the Metropolitan Denver area may be considered. Under the city of Denver, there is an important ground water zone at a depth of about 500 feet in the Arapahoe Formation, and other zones are still deeper in the Laramie and Fox Hills Formations. These zones are overlain by impermeable beds and, therefore, their areas of recharge are many miles to the west where the formations crop out, such as in the areas we have seen east of the Dakota Hogback. If pollution were to happen in the recharge areas over a considerable period of time, there would be danger of degrading the ground water in the zones under Denver.

4-C. Proposed Eldorado subdivision: The developers were advised by the Jefferson County Planning Department of potential landslide problems as divulged by geologic studies of the U.S. Geological Survey. As a consequence, geologic and engineering advice was sought from consultants in these fields to aid in minimizing or eliminating the problem. This set a precedent in Jefferson County for the use of basic geologic information prior to platting new subdivisions in known problem areas.

4-D. A sanitary fill in a geologically good location where relatively tight, impermeable shale minimizes seepage through the fill and out of it; therefore, any pollution from the fill is minimal.

4-E. Former Leyden Coal Mine where coal was mined from two very gently dipping beds about 100 feet apart


MAP V
5-D
5-E
120th Ave.
Big Dry Creek
Federal Blvd.
STOP 6
104th Ave.
STOP 7
Valley Highway
flood plain
River
South Platte
0
1 MILE
0
1
2 KM

vertically, and about 600 feet below ground surface to the upper bed. The mined out blocks are now used as a reservoir to store imported natural gas, and provide flexibility to meet fluctuating customer demands.

STOP 5. ROCKY FLATS: TOSCO OIL SHALE PLANT

Here the handsome office building is a visible example of excellent landscape architecture, while the plant itself is hidden below the brow of the escarpment.

5-A. The Rocky Flats Dow Chemical Plant is visible about two and one-half miles to the left (west) on the gently sloping gravel-covered plain of Rocky Flats. Waste disposal at the plant must be retained within the site because drainage is easterly, and poses a pollution hazard to Great Western and Standley reservoirs.

5-B. Great Western Reservoir to the right (east) was in construction when an embankment failure occurred that was attributed to one of the more severe "Denver" earthquakes.

5-C. Escarpment slopes to the left (north) are unstable and landslide prone. The road here is uneven because of poor drainage and moisture-sensitive (swelling) clays.

Irrigation and liquid waste disposal in the type of situation where there is a gravel-covered upland surface underlain by clays, intensifies the potential landslide problems on the steep, bounding escarpment slopes. The gravels generally meet percolation standards for septic-tank soil-absorption systems. However, the water from irrigation and septic systems moves along the base of the gravels, and exits as seeps along the hillsides, or saturates the overburden and slides ensue.

5-D. Broomfield: Ground water is discharged in the lowland area, and the dissolved alkaline salts are highly corrosive to steel pipe and other buried metals.

5-E. Big Dry Creek drainage is from run-off at Rocky Flats, and seepages along the escarpments. There is little or no gravel, and the ground water is confined and probably alkaline.

STOP 6. NORTHGLENN

Weathered claystone and clay derived from it on the slopes are covered by as much as 30 feet of highly compressible windblown silt. Differential settlement may occur in the silts when loaded and water will cause the clays to swell.

STOP 7. QUINBY

This is the site of the Colorado School of Mines seismic monitoring network to record the earthquake activity that has been attributed to liquid waste disposal in a deep well. The well is at the Rocky Mountain Arsenal approximately five miles to the southeast on the other side of the South Platte River valley. Deep disposal was undertaken, starting in 1962, after complaints that percolation from surface evaporation ponds was polluting shallow ground water aquifers in the surrounding areas. The liquid wastes were pumped into fractured, crystalline "basement" rock at depths of about 12,000 feet. Soon afterwards, earthquakes, some of them damaging, were felt in a region where none had been noted since 1882. Pumping ceased in February 1966, and although there have been earthquakes since the, including the one of largest magnitude, the number has very significantly decreased.