ENGINEERING GEOLOGY OFFICE MANUAL

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Engineering Geology Office Manual

Basic Concepts and Procedures

April 1988

United States Department of the Interior
Bureau of Reclamation
Denver Office
Denver, Colorado

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

Acknowledgments

The preparation of this manual has involved nearly every engineering geologist and geophysists within Reclamation. Many geotechnical engineers offered comments that have been incorporated into the manual. Their input is greatly appreciated.

Special recognition is given to Mr. Jerry S. Dodd, Chief, Division of Geology (Retired) who initiated the manual; to N. B. Bennett, III, Jerry's Successor who kept the manual moving. To Richard H. Throner, who probably wrote more paragraphs, served on more committees and has more contact with authors and consultants than any other Reclamation geologist and to Sam R. Bartlett who compiled and printed the early version of the manual we extend our thanks and appreciation.

Also, to the Regional Geologists and their staffs we extend our thanks and appreciation for their work into the manual. The manual would not be complete without the drawings and figures; to the engineering and physical science technicians we extend our gratitude and thanks.

FOREWORD

This version of the Engineering Geology Office Manual presents the requirements and procedures for the collection of geologic data obtained by the Bureau of Reclamation. The intent is to establish common guidelines, procedures, and concepts for the collection, evaluation, and presentation of geologic information. The analysis of geologic conditions, the preparation of designs and specifications and effective construction monitoring require consistent, comprehensive, and timely geologic information. The use of these guidelines by all Reclamation engineering geologists collecting, documenting, and evaluating geologic information will promote consistency, help to assure that the required evaluations and data are complete, and promote integration and coordination of geologic and engineering activities.

It is hoped that this Engineering Geology Office Manual, in conjunction with the Engineering Geology Field Manual, will form the basis of the exchange of ideas which will be mutually beneficial to all Reclamation geologists.

Experienced geologists will find useful reminders about new procedures and special techniques, while the newer employees can look upon the guide as an opportunity to expand their familiarity with geology as practiced in the Bureau of Reclamation.

The new direction of the Bureau of Reclamation undoubtably will require that changes to the manual be made when changes in procedures or technical processes dictate.

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Chapter 1

INTRODUCTION

The purpose of this manual is to provide the philosophy behind geologic investigations, and to provide guidelines for geological and geotechnical data presentation.

To conduct an adequate investigation, the designer must provide the geologist with the reasons for gathering and interpreting data. Providing these reasons is the intent of this philosophical portion. Guidelines and concepts for methods of evaluating geologic data issues are also included for this purpose. A chapter on sources of existing data provides the tools for better research of geologic areas or problems. Memorandums and geologic documents are provided as useful "philosophy" for Reclamation geologists.

The guidelines for presentation of geologic data comprise the field part of this manual, and were derived and updated in part from the "Geology for Designs and Specifications of the Assistant Commissioner, Engineering and Research, 1981." These guidelines are included for two reasons. First is the necessity to standardize geologic presentations, throughout Reclamation, regardless of the origin of such standards. Second, most geologic data ends up in the Denver Office and the included guidelines are the standards of acceptance for that organization. If we, as geologists, can talk the same language through common standards, the better we can communicate our ideas to the designers.

This manual is intended as an office reference, as it covers functions most commonly performed in the office environment. This volume should be most useful during final compilation of geology reports, by geology staffs charged with compiling and presenting the final geology data report and interpretations.

Critical comments, including suggestions for improvement are solicited from all geology users in Reclamation. The ultimate goal of this manual is Reclamation-wide use of the guidelines.

Chapter 2

BASIC CONCEPTS FOR ENGINEERING GEOLOGY PROGRAMS

GENERAL

This chapter briefly outlines Reclamation's fundamental concepts for engineering geology programs. The following discusses the objectives of an engineering geology program and presents the stages the program should evolve through to ensure that proper and accurate geologic data are collected and used. The Engineering Geology Evaluation presents a decision process for engineering geology issues and guidelines for categorizing, evaluating, and discussing those issues.

Geologists in Reclamation perform primarily in the field of engineering geology. The definition of engineering geology, modified somewhat from *Glossary of Geology* [1], is as follows:

> The application of geology to engineering practice, especially civil engineering. It includes the application of geologic data, techniques, and principles to the study of naturally occurring bedrock and surficial materials and of ground water, geologic hazards, and environmentally related issues for the purpose of assuring that geologic factors affecting the location, planning, design, construction, operation and maintenance of engineering works and the engineering aspects of development of ground-water resources are properly recognized and adequately interpreted, presented and utilized, in engineering practice.

THE ENGINEERING GEOLOGY PROGRAM

The objectives of an engineering geology program are to identify adequately all of the relevant geologic considerations, and to address them to the extent necessary to provide a professional engineering geology report, which will present data and interpretations; define the data necessary for further analysis, and decisions; and provide for the incorporation of geologic conditions into the design or study.

All of the varied and diverse engineering geology issues associated with a program can be assigned to one or more of the following groups of considerations:

- Engineering considerations;
- Geologic hazard considerations;
- Environmental considerations;
- Economic considerations; and
- Operational and maintenance considerations.

Most issues to be addressed by the geologist fall into engineering, geologic hazards, or environmental considerations, and the great percentage of these can be resolved by a thorough knowledge of the physical aspects of engineering geology. Economic, and operational considerations, while not always included in technical reports, must be evaluated and resolved with a recognition of institutional structures and economic, political, and social standards. These nonphysical aspects of a program are the social aspects of engineering geology.

Engineering geology programs for Reclamation may be categorized as:

- Planning studies;
- Designs and specifications;
- Construction;
- Operation and maintenance;
- Safety Evaluation of Existing Dams (SEED);
- (SOD), Safety of Dams programs;
- Remedial actions for hazardous waste sites; or
- Research.

Reclamation geologists may find themselves working in one or more of these engineering geology programs for a particular feature. Each will have its own particular monetary, operational, or organizational constraints which must be considered to complete the program.

Before starting any investigation, it is important to understand fully the purpose of the investigation, and the concepts and implications of the planned features. Aspects to be considered include the size and type of feature; the physical environment, which includes the location with respect to the public; geologic hazard potential; design requirements; cost; and legal issues and concerns. Phasing of a program to evaluate these aspects from the general to the specific encourages better definition and ranking of all issues and focusing of activities. For hazardous waste sites consider the need for protective clothing and the classification of that clothing. Safety considerations must be emphasized to all who undertake the work at these sites.

During each phase, identifying the geologic issues requiring resolution and the data to solve those issues is important. Each phase of the program should evolve through the processes listed below to ensure proper and accurate resolution of all geologic considerations:

- Delineation of site geology and hydrogeology;
- Identification of engineering geology issues and their importance;

- Collection of data;
- Collation, analysis, and interpretation of data; and
- Preparation of findings.

ENGINEERING GEOLOGY EVALUATIONS

The impact of the geologic considerations and their specific issues upon the proposed engineering works must be evaluated throughout the engineering geology program. Conclusions, decisions, and recommendations to address these issues must be provided during interim data submittals and in the final engineering geology report. To accomplish this, those relevant geologic issues which must be addressed during the engineering geology program must be identified. A convenient way to approach the identification and selection of issues is to consider separately the geologic considerations groups on a site-by-site and structure-by-structure basis. This should be done by: (1) referring to the checklist of common issues in chapter 6; (2) discussing the program with involved parties; (3) seeking the assistance of experienced engineering geologists and other professionals; and (4) reviewing and studying similar case histories.

The issues should be categorized as to their relative importance for a safe and economical design, proper operation of the feature and also the issues' impact on the cost of the design, construction, and operation and maintenance. Critical issues should be emphasized to make certain they are thoroughly scrutinized and evaluated.

Throughout the entire process of arriving at a decision or conclusion, the engineering geologist must exercise sound judgment. A discussion of each issue and its evaluation, including the data required to reach the conclusion should be documented in the "Geotechnical Considerations" portions of any geologic report. The amount of detail of the discussion of any issue generally will depend upon its criticality and the type of the engineering geology report under preparation. Individual discussion of each issue will ensure that relevant issues have been identified and addressed, are subsequently given proper consideration for design concepts and constructability, and are appropriately monitored during construction and operation.

BIBLIOGRAPHY

[1] *Glossary of Geology*, American Geological Institute third edition, American Geological Institute, Falls Church, VA., 1987, page 788.

Chapter 3

TOTAL DESIGN PROCESS

GENERAL

This chapter discusses the roles of Reclamation geologists pertaining to the Total Design Process. The discussion is not a repeat of the process, but is an explanation and clarification of it and its effect on both field and ACER (Assistant Commissioner, Engineering and Research) geologists and how they should interrelate among themselves, with designers, and other engineering staffs.

The Total Design Process contains four items that have a direct effect on geologic activities in Reclamation:

1. It requires the formulation of three teams for most ACER designs or studies. These teams are the PMT (Project Management Team), the Design Team, and the Exploration Team.

2. It provides a means of scheduling milestones, estimating staff resources and measuring accomplishments.

3. It emphasizes the importance of timely interpretative geologic data for designs and specifications.

4. It emphasizes that design continues during construction and identifies requirement for geologic data collection during construction.

GEOLOGISTS' PARTICIPATION ON TEAM

Project Management Team

The makeup of the PMT does not include a geologist as a full-time member. Specialists, such as geologists, may be invited to meetings. The PMT determines when the Design Team is to be formed, determines schedules, and commits the necessary resources from both the field offices and the ACER organization.

Design Team

The Design Team is established when it is determined a feature probably will proceed to construction. The PD (Principal Designer) is always the Design Team leader. The makeup of the Design Team is determined at its inception but, depending on the type of work, may not always include a geologist.

Exploration Team

Early in the design process, if the work requires geologic exploration, an Exploration Team will be formed to develop an investigations program for the feature under study. This team will prepare a technical memorandum concerning data needs. The Exploration Team may be the most important part of the Total Design Process as it applies to field geology staffs. It includes the field geologist as well as the PG (Principal Geologist). Other members of the Exploration Team include the PD and/or design representative(s) and the laboratory representative. In most cases, the PG is the leader of the Exploration Team. Full-time or part-time additions to the team may include a geophysicist or a seismologist. In cases of unique drilling problems or programs, a drilling foreman or his representative may be considered for a part-time membership of the team.

The Exploration Team is required (as a subgroup of the Project Design Team when designated) for each feature or project. For example on a major construction project, the Exploration Team will include Principal Designer or design representative(s), the Research representative, the Principal Geologist, the Regional Geologist or the Project Geologist, and the Project Construction Engineer or representative (the Construction Liaison Engineer if PCE has not been assigned). These representatives will meet to plan and formulate the exploration program which will be transmitted to the field by ACER memorandum. The Project and/or Regional Geologist will attend key meetings. The Principal Geologist will convene the initial meeting of the Exploration Team. At the initial meeting, the team will determine appropriate participation by other segments of the organization so that a complete and realistic exploration program can be developed. Frequent additions to the team will be a geophysicist and a Structural Behavior Section representative. A coordinator (usually the Principal Geologist) will be designated to provide coordination within the Denver Office and with the field regarding the exploration program. Examples of exceptions to this are construction materials investigations for embankment dams for which the Principal Designer will be the primary point of contact, and instrumentation programs for which a Structural Behavior Branch representative will be the coordinator. Regular meetings will be held to formulate the program and all participants will review the final exploration requirements prior to transmittal to the field.

Responsibilities of the coordinator are:

1. Start the formulation process;

2. Arrange for team meetings;

3. Document the investigation program on the ACER Field Exploration Request form;
4. Prepare transmittal memorandums;
5. Inform other representatives of field inquiries and of any actions taken. This may require discussion and decisions by the group;
6. Monitor the exploration program;
7. Prepare memorandums modifying original investigation program; and
8. Assure that data reports are distributed.

Other members of the team are responsible for notifying the coordinator of any inquiries, discussions, problems, or information received from field personnel.

The initial meeting of the Exploration Team should be held at the feature site. It is highly desirable that the team meet at the site with field geologists and materials specialists who will be performing the investigations before the program is formulated. It is very important that the investigation program be systematically thought out and rationalized. For this reason "on-the-spot" or hastily derived investigations programs should be avoided. Prior to this meeting, the field geologist should have become very familiar with the site geology and anticipated geologic design and construction considerations. Much of the initial exploration program will be based on the field geologist's knowledge of local geologic conditions. It can be of great value if the field geologist prepares a preliminary or recommended exploration program based on his knowledge of the area. It is recommended that the preliminary program be distributed to Exploration Team members prior to the site visit. The program should attempt to answer both geologic and geotechnical concerns. Although the program may not be used in its entirety, it does offer a starting point. By the time the program is finalized, the Exploration Team should be able to justify fully all aspects of the program. Additional coordination meetings will be held as necessary during progress of the program to resolve problems and make required modifications.

The goal of the exploratory or investigation program is to prioritize and produce the amount of data required for that level of study or design. These data are to be obtained in the most efficient manner and at an economical cost. The team then transforms these data into a report or the specifications in the most efficient manner possible.

No attempt should be made to formulate an all-inclusive final program while in the field. The initial and following programs require much thought and discussion. A phased program is usually the most efficient and economical. The rationale for any exploration should be documented so that all understand the use and value of the data. The TDP requires a Technical Memorandum (formerly the Engineering Geology Review Memorandum) to document these data and known conditions. Additional exploration should be dependent on the results of the earlier explorations and any corresponding changes in design concepts. It is very important that the field geologist have full input into any stage of the exploration program and that he or she concur by initialling (or authorizing their initials) on the final program, as concurring, on Bureau of Reclamation Form 7-2145, "ACER Field Exploration Request." It should be emphasized that the team geologists' responsibilities do not end after formulation of the initial exploration program.

Most schedules are based on political decisions and are certainly budget oriented. Therefore, our data collection may or may not be allowed adequate time for the amount of data specifically required. The Exploration Team must make a reasonable evaluation of time required to collect these data and make the necessary adjustments that will accommodate both the project and the Denver Office. Team members must realize that commitments should be met, and they should not make a commitment that can't be met.

If scheduling problems arise, they should be referred to the PMT. This team has the authority to address schedule changes or reduce the program. They also realize that when a program is reduced, the degree of risk increases.

Other important duties of the field geologist, as a member of the Exploration Team, include the submittal of interim data, interpretation of data, communicating schedule or program problems and completion, recommending modifications to the exploration program, and preparation of the Geologic Design Data Report. The Geologic Design Data Report serves to document the data collection and results. These data can be adjusted and supplemented as needed. Just how these data are to be formulated and used should be clearly defined prior to issuance of the ACER Field Exploration Request.

INTERPRETIVE GEOLOGIC DATA AND PRESENTATION IN REPORTS AND SPECIFICATIONS

In an effort to improve the overall quality of Bureau of Reclamation specifications and reduce construction changes and claims, the Total Design Process calls for the inclusion of geologic information that conveys both the known and anticipated geologic conditions. To accomplish this, accurate and timely data and interpretations of these data must be presented. Design assumption and criteria, as well as constructability, are based on our knowledge, portrayal, and documentation of geologic conditions.

Most of the interpretations must come from the person who is most familiar with the geologic conditions of the site. In most cases, this will be the field geologist working closely with the PG. The PG and designer usually will determine the location of required geologic cross sections; however, the field geologist should interpret the geology at that section. If the PG does the interpretation, the final product should have the concurrence of the field geologist. The field geologist or PG should feel free to develop as many sections or other drawings as necessary to thoroughly understand and portray subsurface geologic conditions. To obtain a better idea of the geology and to strengthen the interpretations, it may be necessary to drill more holes than required by the ACER Field Exploration Request. The field geologist should recommend the locations for the additional drill holes to the Exploration Team. That team must approve the additional drilling and ensure that the drill holes are located to obtain the optimum amount of data. Sufficient time must be budgeted to allow for analysis and review of data to formulate interpretations.

One word of caution regarding interpretative geology: the geologist must be able to defend any interpretations. Designs and contract specifications will be developed from these interpretations. Sound judgment and incorporation of all pertinent data are paramount.

GEOLOGY DURING CONSTRUCTION

Field geologists should review specifications drawings and paragraphs during the review process for portrayal of geologic conditions, geotechnical considerations, and constructability. Other important duties of the field geologist include the gathering of geologic information and presenting and documenting these data for features under construction. Construction geology can include geologic mapping, topography, cross sections, lab testing, monitoring of instrumentation, or additional exploration, just to mention a few. The field geologist should prepare brief descriptions of the geologic conditions in the L-29 Construction Progress Report and communicate any change in geologic conditions during construction to the PG. *Reclamation Instructions* 171.6.4 require at least biweekly geologic reports on major jobs.

MILESTONES

Table 3-1 shows significant geologic milestones common to most designs. Table 3-2 shows geologic actions necessary for the Total Design Process. A more detailed discussion of milestone documents is provided in Chapter 8. In working with schedules and milestone events, four important items should be remembered by participating geologists:

1. In the early stages of a program, the field geologist may be required by project management to start exploration on a feature before a field exploration program has been developed or a Design Team appointed. If this happens, the ACER Geology Branch Chief should be notified. The Branch Chief can then start the proceedings necessary to appoint a Design Team. Once a Design Team has been formed and a PG appointed, the PG has authority to put together an Exploration Team. If this is not done, the result may be unnecessary drilling and increased exploration costs. In all cases, early completion of surface geological mapping is advised to formulate the exploration program and is usually maximum data for minimal cost.

2. The field geologist should have input into the development of any schedule affecting him or her. Quite often schedules are developed around the amount of time it takes to develop engineering design data. Usually this is not enough time to gather, interpret, and write a geology report for conceptual design. Schedules often are dictated by other requirements, but the field staff needs sufficient time to collect, interpret, and document the geological conditions. The PG needs sufficient time to review the data, and ensure that appropriate geological design and construction considerations are incorporated into the design and to prepare specifications.

3. It is important that interim submittals of data be made by the field geologist. By doing this, modifications can be made to the investigations program designs can proceed, and the effects of late data may be minimized.

4. Geologic input to the Specifications must be the culmination of data collection, interpretation, and the analysis of test results by both the field and Principal Geologist. Only through common goals, communication, time monitoring of input, sound professional judgment, efficiency, and development of skills can appropriate documentation of geologic conditions be incorporated for safe, cost effective design and construction.

Table 3-1. – Geologic Milestones and Responsibility.

Flags and stages	Geologic Milestones	Primary responsibility
NO WORK	None	
Sched	None	
START		
Concept	TM (Technical Memorandum)	Exploration Team Members.
	ACER Field Exploration Request(s)	Principal Geologist with team approval.
	Preliminary Ongoing Submittals	Field Geologist.
	Geologic Design Data Report(s)	Field Geologist with approval by Principal Geologist.
	Geologic Design Data Review Memorandum(s)	Principal Geologist.
	Engineering Geology Considerations for Conceptual Design TM	Principal Geologist.
CONCEPTC		
Design	Final Geologic Design Data Report	Field Geologist.
	Geologic Design Data Review Memorandum	Principal Geologist.
	Draft Engineering Geology Considerations for Design and Construction TM	Principal Geologist.
DESIGNC		
Draft Spec	Supplements to Geologic Design Data Report	Field Geologist.
	Specifications Paragraphs and Drawings	Principal Geologist.
	Final Engineering Geology Considerations for Design and Construction TM	Principal Geologist.
SPECD		
Review REVIEWC	Review spec paragraphs and drawings	Principal and Field Geologists.
Revise	Review of Specifications	Principal Geologist.
	Specifications Drawings and Paragraphs Signed through Approved (anytime from SPECD to SPECB)	Geology Division/Branch Chief.
SPECB		
Book pre	Geologic Requirements During Construction Memorandum (at least two months prior to AWARDC)	Principal Geologist.
BOOKC		

Table 3–1. – Geologic Milestones and Responsibility – Continued

Flags and stages	Geologic Milestones	Primary responsibility
Bid BIDC	Supplements to Specifications	Principal Geologist.
Award AWARDC	None	
Con-struction CONSTRC	Reports on Construction Geology Foundation Acceptance Reports (when required) Final Construction Geology Report (when required)	Field Geologist. Principal Geologist and others Field Geologists.
Comp COMP	Claims evaluation and documentation	Field Geologist. Principal Geologist. Geology Division/ Branch Chief.

Table 3-2. – Required Action by Geologic Staff.

Flags and stages	Action required by Geology
NO WORK	None officially. However, if geologic map of feature is not available, field geologist could start mapping if approximate alignment or location is shown. Also, compile, review, and summarize available data.
Sched	Field geologist provides scheduling information to Project Management Team. Site mapping, data review.
START	
Concept	Site mapping and preliminary interpretations. Field geologist proposes explorations. Design and Exploration Teams formed. Site visit(s). Geologic exploration program(s) developed and ACER Exploration Request(s) and TM completed. Geologic exploration program monitored, revised, or added to. Periodic formal or informal data submittals. Interim geologic data reviewed and provided to design team. Geologic Design Data Report submitted, reviewed, and approved. Documentation of geologic design and construction considerations (TM).
CONCEPTC	
Design	Geologic exploration program monitored and revised as necessary. Identification of additional data needs. Geologic Design Data Report supplemented (if required). Geologic data reviewed, additional analysis. Input to design concepts and parameters. Documentation of geologic design and construction considerations (Draft TM).
DESIGNC	
Draft Spec	Prepare spec paragraphs and drawings. Finalize geologic design and construction considerations. Furnish spec paragraphs and drawing to coordinating design branch. Signed through technical approval.
SPECG*	
SPECD	
Review	Review spec paragraphs and drawings; review all paragraphs, not just geology.
REVIEWC	
Final Spec	Revise specifications paragraphs and drawings if necessary. Agree upon geologic requirements during construction.
SPECB	
Book-Pre	Supplements to specifications. Document geologic requirements for construction.
BOOKC	

Table 3-2. – Required Action by Geologic Staff – (continued).

Flags and stages	Action required by Geology
Bid	
BIDC	
Award	
AWARDC	
Construction	Foundation mapping and comparison of predicted versus actual conditions. Periodic Construction Geology Reports or input to L-29's. Construction monitoring and acceptance.
CONSTRC	
	Claims evaluation. Preparation and review of Construction Geology Report (if required).
COMP	

*SPECG is an internal flag. Geology portions of the specifications are due 5 weeks ahead of SPECD flag.

Chapter 4

GEOLOGIC DATA RESOURCES

INTRODUCTION

Before the geologist becomes involved in expensive and complicated field studies, it is essential that he/she checks the results of previous studies. A site investigation study may already exist, or if it does not, previous studies in the same general area may provide invaluable information as to the best methods to employ.

PUBLISHED SOURCES OF INFORMATION

Professional Journals

Journals.—This includes professional journals, such as *Bulletin of Association of Engineering Geologists, American Association of Petroleum Geologist Bulletin, Geological Society of American Bulletin, Journal of Geophysics,* and pertinent American Society of Civil Engineers titles, as just a few examples.

Indexes to Journals.—Discusses such indexes as the *Bibliography and Index of Geology* by American Geological Institute and *Engineering Index.*

Abstracts

Several organizations publish periodic abstracts of geotechnical and engineering geology related subjects. Among these are *Engineering Geology Abstracts* by AGI and *Geotechnical Abstracts* by the International Society for Soil Mechanics and Foundation Engineering.

U.S. Government Publications

Bureau of Reclamation Publications.—Appropriate publications are listed in "Publications for Sale, 1986." Many of these publications are probably a part of your library, or should be. Other guidelines for specific features are presented in the "Reclamation Instructions."

U.S. Geological Survey (USGS) Publications.—Summarizes the various formats, including Bulletins, Circulars, Professional Papers, Open-File Reports, and others. Give special attention to USGS publications and maps, as well as distribution points for these. Offices which offer specialized services within the agency are identified. The use of 'Suggestions to Authors" should be helpful to all report writers.

U.S. Bureau of Mines Publications.—Principal publication series, including Report of Investigations, Bulletins, and Information Circular. Agency distributes principal maps and has repositories and libraries.

Soil Conservation Service Publications.—Soil Surveys often contain pertinent information about soil characteristics which may impact engineering construction.

Nuclear Regulatory Commission Publications.—This agency does extensive geologic studies in connection with their Safety Analysis Reports for nuclear powerplant siting.

Other Federal Government Agencies Publications.—Agencies such as the Corps of Engineers, Bureau of Land Management, and others do extensive geologic investigations during planning design and construction. If your work is sited in an area where any of these agencies has active projects or has conducted feasibility studies, a check with their libraries and file systems may produce documentation.

State Geologic Surveys

Addresses are available from USGS.

Commercial Press Publications

Basic handbooks such as Roy Hunt's *Geotechnical Engineering Investigation Manual*, Legget's *Geology and Engineering, Principles of Engineering Geology* by Attewell and Farmer, and tools such as *Books in Print* can be used to locate recent publications still in print and available for purchase.

Theses (Master and Doctoral)

Access to university theses are available through Reclamation's library including use of *Comprehensive Dissertation Index.*

UNPUBLISHED SOURCES OF INFORMATION

Frequently the geologist may find that the best sources of information are hidden. Internal files and personal files of associates often contain a gold mine of information. Be sure to check these sources before heading to the field. Notes kept by previous field teams may contain extensive data. Other sources for very specialized data formats are also important.

Aerial Photograph and Satellite Imagery

The Earth Resources Observation Satellite (EROS) Data Center provides access to LANDSAT data as well as aerial mapping done by Federal agencies, primarily within U.S. Department of the Interior. A similar office is operated by the U.S. Department of Agriculture in Salt Lake City, Utah. Several other sources are referenced in the Engineering Geology Field Manual, with annotations as to coverage, including National Oceanic and Atmospheric Administration (NOAA), the National Archives, Bureau of Land Management, and the Remote Sensing Section (D-1542), Denver Office.

Data Centers

Other specialized data centers can be accessed. These include the National Geophysical and Solar-Terrestrial Data Center for earthquake data, Goodyear Aerospace Corporation, Side Looking Airborne Radar (SLAR) Imagery Depository, and the Defense Mapping Agency.

Public Utility Companies

These companies may retain studies done during site feasibility investigations. The *Directory of Electric Utilities* is a good source of addresses for these companies.

METHODS OF TAPPING THESE SOURCES

Libraries

Most of the materials discussed in this chapter are available in libraries. Give special attention to unique collections such as the Bureau of Reclamation, USGS, Corps of Engineers, State libraries, university sources, and the depository system. Using interlibrary loan to access materials not available locally can expand the geologist's scope considerably.

Directories

A partial list of directories such as *Directory of Geoscience Departments, Worldwide Directory of National Earth-Science Agencies, Information Resources in the United States—Geosciences and Oceanography, Industrial Research Laboratories, Government Research Centers Directory,* and *Geothermal World Directory,* provides information about locating names and addresses to use as contact points.

Computer data bases

These machine-readable files index several thousand journals, books, conference papers, dissertations, maps, government publications, and technical reports. While the primary data bases for geologic information, such as GEOREF and GEOARCHIVE, should be accessed, many other data bases contain relevant information and should not be overlooked, such as NTIS, COMPENDEX, TRIS, NWWA, and Dissertation Abstracts.

By allowing keyword searching, accessing titles, abstracts, and indexing terms, this method of searching is both more comprehensive and more efficient than manual searching.

SUMMARY

The geologist who makes efficient use of these existing data sources will be in a better position to make good use of his field time. Tables which list contact points, such as those for State geological surveys and Federal agencies, will speed up the information gathering process.

Chapter 5

COLLECTION OF GEOLOGIC INFORMATION

INTRODUCTION

This chapter provides guidelines for the collection, completeness, and description of geologic information. Geologists should apply these guidelines, using good judgment to elaborate upon them as required by the particular geologic setting and engineering requirements. Also, the geologist must be aware of the design concepts and engineering geology issues for which this information is being collected and used (see Chapter 6). However, if used appropriately, these guidelines will provide adequate guidance to formulate and initiate a data acquisition program for planning as well as final design investigations. These guidelines should ensure that adequate data are collected and analyses for design and construction considerations are completed in a timely manner. Minimum foundation data and investigation requirements for many structures are defined in *Reclamation Instructions, 133*, Design Data Requirements [1]. These minimum requirements may be supplmented by investigation requirements described in the pertinent Exploration Team Technical Memorandum or requests for exploration. Many of the items provided in the following guidelines are adapted from California Division of Mines and Geology Notes, No. 44 [2].

THE GENERAL GUIDELINES FOR THE COLLECTION OF GEOLOGIC INFORMATION

Compile, summarize, and document Reclamation and non-Reclamation geologic activities in the project area with special attention to the sequence and results of studies and explorations.

Prepare geologic drawing(s) and map(s) showing location of explorations. Locations of all existing explorations are to be indicated by coordinates and/or stationing and, when possible, by using the permanent survey control system for the feature. Develop surface geology maps, a stratigraphic column, geologic cross sections at appropriate scales to portray surface and subsurface conditions, and special purpose drawings (such as joint contour diagrams and contour maps for top of rock, weathering, and water levels) for sites with complex geology or design concepts (see Chapter 7).

CHECKLIST GUIDE FOR SOIL DESCRIPTORS

Prepare a narrative description for surficial deposits and specify the geologic properties, especially those which may affect design or construction. These may include, but are not restricted to, the engineering characteristics such as swelling minerals, low-density materials, presence of gypsum and other sulfates, caliche, dispersive soils, loose deposits subject to liquefaction or consolidation, permeable materials, erodibility, and oversize materials (Earth Manual [3]). The following checklist is useful as a general, though not necessarily complete, guide for descriptions. Instructions for logging and describing soils in geologic explorations are provided in Chapters 3 and 11 of Part I of the Engineering Geology Field Manual (PI, EGFM). The geologist should determine:

1. Geologic identification and general classification of materials. Soils should be classified according to USBR 5000, Determining Unified Soil Classification (Laboratory Method) or USBR 5005, Determining Unified Soil Classification (Visual Method).

2. Physical characteristics (e.g., color, grain size, consistency or cohesion, cementation, moisture content, mineral deposits, content of expansive or dispersive minerals, alteration, fissures, or fractures). Use descriptors established by Reclamation standards.

3. Dimensional characteristics (e.g., thickness, variations in thickness, shape, occurrence, and distribution).

4. Relationship with present topography; relative age and correlation with features such as terraces, dunes, and undrained depressions.

5. Altered zones (distribution, extent and significance).

6. Response to natural surface and near-surface processes (e.g., raveling, gullying, subsidence, expansion, creep, slope washing, slumping, and sliding).

GUIDELINES FOR ROCK DESCRIPTORS

Prepare descriptions of bedrock emphasizing geologic properties and engineering geologic properties such as strength, swelling minerals, presence of gypsum and other sulfates, depths of weathering, joints, faults, and other planes of weakness. The following checklist may be useful as a general, though not necessarily complete, guide for descriptions. Appropriate terminology and descriptors are provided in Chapter 4 of PI, EGFM. The bedrock description must include:

1. Bedrock units.—Traceable geologic units of similar physical and engineering properties should be identified as described, including:

a. Identification as to rock type (e.g., granite, sandstone, mica schist). Relative age and, where possible, correlation with named formations.

b. Physical characteristics (e.g., color; texture; grain size; nature of stratification, bedding, foliation or schistosity; hardness; and chemical features such as calcareous or siliceous cementation; concretions, mineral deposits, alteration other than weathering).

c. Distribution and dimensional characteristics (e.g., thickness, outcrop breadth, areal extent).

2. Distribution and extent of weathering and alteration.—Weathering should be divided into categories that reflect definable physical changes in the rock mass due to weathering. Significant differences should be identified and weathering profiles developed.

3. Structural features.—Bedding joints, foliation joints, joints, contacts, shear and fault zones, folds, zones of contortion or crushing are to be described in terms of the following:

a. Occurrence and distribution.

b. Orientation and changes in attitude.

c. Dimensional characteristics (e.g., width, spacing, continuity).

d. Physical characteristics and their effect upon the rock mass (describe the conditions of planar surfaces, such as openness, roughness, waviness of surfaces, striations, mineralization, alteration, and infillings or healing).

e. Statistical evaluations of distribution, orientation, and physical characteristics.

f. Relative ages (where pertinent).

g. Specific features of shears or faults (e.g., description of composition of the fault, zones of gouge and breccia, healing, displacement directions and amounts, attitude of striations or slickensides, relative age of movement[s]).

h. Prepare accurate and complete logs of explorations using terminology consistent with the narratives (Chapters 4 and 5 of PI, EGFM). Give consideration to appropriate indexes (e.g., RQD [Rock Quality Designation], Hardness).

4. Response to natural surface and near-surface processes (e.g., raveling, gullying, mass movement).

OTHER PERTINENT DATA

Include laboratory determinations of engineering properties of surficial deposits and bedrock.

Provide black and white photographs of representative or particular geologic conditions, all drill hole core, samples, and test pits and color photographs or transparencies if appropriate or desired.

Summarize data from remote sensing and geophysical surveys (seismic, resistivity), if performed and correlate with other geologic information.

Run appropriate borehole geophysical logs in drill holes and other appropriate surveys to delineate subsurface conditions.

Describe past, present, and possible future petroleum, water, and mineral extraction operations in the vicinity.

Describe investigations undertaken to ascertain geologic conditions which may affect construction methods such as boulders, marshes, drilling conditions, stability of grout or footing holes, ground temperatures, and gases.

Map land uses, particularly along linear features such as canals, transmission lines, distribution systems, and highways.

Corrosion surveys should be considered for all Reclamation distribution systems, including pipelines, aqueducts, discharge lines, and siphons, in addition to power/pumping plants and tunnels.

GROUND-WATER DATA COLLECTION

To describe investigations of ground-water conditions, note seeps, water levels or piezometric surfaces and record their seasonal fluctuation, the occurrence of unconfined and confined aquifers, potential seepage, water-producing capabilities, chemistry, and ground subsidence. The following checklist may be useful as a general guide for descriptions:

1. Distribution, occurrence, and relationship to topography (e.g., streams, ponds, swamps, springs, seeps, subsurface basins).

2. Existence of confined and unconfined aquifers and relationship to geologic features (e.g., impervious and pervious strata, fractures, faults).

3. Recharge sources and permanence.

4. Variations in amounts of water and dates the measurements where recorded (e.g., intermittent springs and seeps).

5. Evidence for earlier occurrence of water at localities now dry (e.g., vegetation, mineral leaching or deposition, relict karst, historic records).

6. The effect of water on the properties of the in-place materials including field and laboratory observations.

GUIDELINES FOR EVALUATION OF MASS-WASTING

Evaluate landslides, avalanches, rockfalls, erosion, and floods. The following checklist may be useful as a general guide for descriptions:

1. Features representing acceleration erosion (e.g., cliff re-entrants, badlands, advancing gully heads).

2. Features including subsidence, settlement, or creep (e.g., fissures, bulges, scarplets, displaced or tilted reference features, historic records, and measurements).

3. Slump and slide masses in bedrock and/or surficial deposits their distribution, geometric characteristics, correlation with topographic and geologic features, age, and rates of movements.

GUIDELINES FOR SEISMOTECTONIC INVESTIGATIONS

Describe seismotectonic investigations undertaken to evaluate the age and recurrence of faulting in the project vicinity, especially if ages are suspected to be late Pleistocene or Holocene, to assist in the determination of design earthquakes for critical structures.

BIBLIOGRAPHY

[1] Reclamation Instructions.

[2] *California Division of Mines and Geology Notes, No. 44* Department of Conservation, Sacramento CA.

[3] *Earth Manual*, Second edition, Bureau of Reclamation, 1974.

Chapter 6

CHECKLIST FOR ENGINEERING GEOLOGY AND GEOTECHNICAL CONSIDERATIONS

USE OF THE CHECKLIST

This checklist helps identify important engineering geology considerations that should be addressed during an engineering geology investigation. Depending on the scope of the study, the geologic conditions, and the engineering geologist, a checklist item may be a significant issue, or may be only a question that must be answered during the evaluation of an issue. The checklist is presented merely for what it is; other issues or subissues may be identified for more complex foundation conditions. It is understood that many geologic phenomena are not singular in nature. They may be attributable to a combination of strength, deformational, chemical, and hydrological characteristics, and may be logically related to more than one element. Therefore, many of the checklist items belong under more than one heading and should be discussed or evaluated as such because they are interrelated. The issues may be related strictly to geologic and geotechnical considerations (rock excavation versus common excavation, confined or unconfined aquifers), or more general (such as the need for engineering analysis or requirements for foundation monitoring during construction). However, organizing the issues by appropriate geologic and geotechnical consideration and by elemental classification provides a rational framework by which these engineering geology issues may be classified and thereby identified and addressed.

GEOLOGIC AND GEOTECHNICAL CONSIDERATIONS FOR DESIGN AND CONSTRUCTION

Engineering Considerations

Because engineering considerations comprise the majority of issues addressed for design and construction of features, it is convenient to group these issues by physical elements with which they are commonly associated. These elements are the geomechanics, geologic fluids, geochemistry and geothermal.

1. Geomechanics.—Geomechanics is divided into two subelements: stability and deformability.

a. Stability of Geologic Materials.—This topic deals with the capability of materials to resist rupture, disaggregation, or disintegration; and therefore, the issues involve the strength of the material as well as the magnitude and direction of applied loads. Loads may be body forces (e.g., unit weight of material) or surface forces (e.g., loads imposed by or upon structures), and strength may be divided into strength of the material and strength of planes of weakness (including time and fluid pressure effects). The following is a checklist for stability of materials issues:

(1) Loads and load patterns (static and dynamic),
(2) In situ stresses,
(3) Strength of earth materials, layers, or zones, (brittle, overconsolidated, plastic, viscous),
(4) Strength variations due to water content,
(5) Shear strength as a function of cleft or pore pressure,
(6) Strength loss from blasting damage,
(7) Strength variations due to weathering,
(8) Dynamic strength (liquefaction and response),
(9) Bearing capacity,
(10) Slope stability (natural and cut),
(11) Stress relief,
(12) Fracturing of foundations and embankments by drilling and grouting,
(13) Erosion (formation of rills, degradation, or aggradation of channels or wasteways),
(14) Piping (washing of fines from soils or fractures, dispersive soils),
(15) Sliding of structures,
(16) Overloading (compressing) of ground (fracturing, yielding, squeezing) in underground openings,
(17) Loosening (tensioning) of the ground in underground openings,
(18) Damage, deterioration, or slope instability due to construction activities,
(19) Ground collapse due to solutioning or mining,
(20) Rock or common excavation,
(21) Ability to be trimmed or shaped,
(22) Stability of construction roads, embankments, and cut slopes,
(23) Excavation or drilling and blasting of boulders,
(24) Stability of borehole walls (grout),
(25) Strength changes from freezing,
(26) Blasting techniques and fragmentation characteristics,
(27) Stability of trench walls (grout cap, pipeline),

(28) Standup time in tunnels,
(29) Movement of rock by grouting pressures,
(30) Index requirements (indirect indications of strength such as RQD, density, SPT [Standard Penetration Test], Atterberg limits), and
(31) Monitoring and instrumentation needs.

b. Deformability of Geologic Materials.—This topic deals with the movement of materials, usually without rupturing, when subjected to stress changes or because of nonlinear and time-dependent deformation characteristics. The following is a checklist for deformation of materials issues:

(1) Load and stress patterns (static, dynamic),
(2) Deformation characteristics (moduli) of earth materials,
(3) Deformation moduli variations due to weathering or stress relief,
(4) Deformation moduli variations due to construction activities,
(5) Consolidation by stress changes or withdrawal of fluids,
(6) Benefication of deformable materials (grouting, treatments, refill with select materials, or other methods),
(7) Rebound and heave,
(8) Differential settlement or expansion,
(9) Effects of permafrost,
(10) Ground sag,
(11) Fault movement in foundation,
(12) Squeezing and swelling ground in underground openings,
(13) Hydrocompaction—deep subsidence—fissuring,
(14) Ground support capability for construction machinery,
(15) Jacking (heave) due to grouting,
(16) Creep,
(17) Subsidence of soils,
(18) Dispersive clays,
(19) Expansive clays,
(20) Organic soils,
(21) Indices (indirect indications of deformation moduli) requirements (RQD, density, SPT), and
(22) Monitoring and instrumentation needs.

2. Geologic Fluids Element.—This topic deals with the preconstruction, construction, and postconstruction geologic fluids regimes and their behavior.

a. Ground-water Occurrence and Behavior.—This subelement deals with ground-water regimes, as well as the anticipated behavior of subsurface waters during and after construction of a facility. The following is a checklist for ground-water issues:

(1) Occurrence, definition, and number of aquifers,
(2) Confined or unconfined aquifers,
(3) Perched ground water,
(4) Configuration of piezometric surfaces,
(5) Primary and secondary permeability/hydraulic conductivity (transmissivity),
(6) Storage coefficient (storativity),
(7) Seasonal fluctuations of water levels and runoff due to precipitation or irrigation,
(8) Preferred seepage paths,
(9) Permeability change due to stress-relief,
(10) Permeability change with time (solutioning, consolidation, deposition, piping along fractures),
(11) Chemistry of ground water (Stiff diagram); contaminants (hazardous waste),
(12) Temperatures of ground water,
(13) Effectiveness of constructed subsurface water barriers (grout curtains, slurry trenches),
(14) Subsurface ponding of water ahead of subsurface water barriers,
(15) Effectiveness of drainage systems,
(16) Filter or drain criteria,
(17) Reservoir water-holding capability,
(18) Unwatering and dewatering requirements and effects,
(19) Groutability (type of grout; hole orientation, spacing, and depth; grout pressures and mixtures),
(20) Grout travel,
(21) Drill cuttings sealing grout hole (examine borehole walls during explorations),
(22) Sediment in bedrock fractures impeding grout flow,
(23) Dam underseepage,
(24) Waterflows into and from tunnels and underground excavations,
(25) Chemistry of reservoir water,
(26) Structure effects on ground water,
(27) Effects on ground water on structures, corrosivity, uplift,
(28) Ground-water withdrawal or recharge, and
(29) Monitoring and instrumentation needs.

b. Other Fluid Occurrence and Behavior.—Similar issues pertaining to porosity, storage, occurrence, configuration of fluid reservoir, provided under Ground-water Occurrence and Behavior are appropriate. In addition to those issues, the following is a checklist of other geologic fluid issues:

(1) Dispersion potential of toxic fluids,
(2) Corrosion by liquid waste,
(3) Petroleum gases,
(4) Nonpetroleum gases,
(5) Crude oil,
(6) Contamination by or combustibility of natural, refined, or waste products (methane, gasoline or other unknowns from chemical or hazardous spills),
(7) Laboratory testing requirements and documentation, and
(8) Safe sampling and identification of hazardous waste
(9) Monitoring and instrumentation needs.
(10) Containment requirements, both temporary and permanent.

3. Geochemical and Geothermal.—The geochemical and geothermal element pertains to both existing conditions and conditions to be imposed at a future date which may affect either the earth materials or affect manmade structures or materials by chemical or thermal agents. The following is a checklist for geochemical and geothermal:

a. Hydration and anhydrite,
b. Solution or carbonates and evaporites,
c. Chemical and mineralogical changes with time,
d. Alkalinity effects on clays,
e. Leaching of cementing agents,
f. Ground conductivity (corrosion, grounding mats),
g. Adversity of chemical deposits (plugging drain holes, ocher clogging),
h. Corrosion potential,
i. Fluid temperatures,
j. Thermal expansion,
k. Underground construction temperatures,
l. Permafrost,
m. Temperature effects on construction materials such as expansion, durability, and set of cement,
n. Geochemical reactions with cement and grouts,
o. Laboratory testing and documentation requirements,
p. Engineering analyses required,
q. Monitoring and instrumentation needs, and
r. Slaking.
s. Hazardous waste sites.

Geologic Hazard Considerations

Many of these issues should be identified early in the planning stages of a project, irrespective of the design concept, and further identified and resolved during investigation and design phases. The most common geologic hazard issues are presented below:

1. Seismicity and faulting (earthquakes include reservoir-induced seismicity);
2. Volcanoes and associated eruptions:
3. Floods;
4. Ground failures:
   a. Landslides, mass wasting, and avalanches,
   b. Expansive or collapsible soils, and
   c. Subsidence (collapse, consolidation, earth fissures due to withdrawal of fluids, and solutioning);
5. Surface erosion;
6. Sedimentation; and
7. Tsunamis and seiches.

Environmental Considerations

The environmental considerations pertain to both social and physical effects as a result of exploration, construction, or operation. The most common environmental issues follow:

1. Buried objects,
2. Dust and mud,
3. Inundation of mineral deposits and mine and mill tailings,
4. Inundation or destruction of important paleontological, archeological, or geologic features,
5. Sediment contributions and pollutants from shoreline development, mining activities, or chemical solutioning,
6. Explosive, vibration and hydraulic fracturing adjacent to structures,
7. Benching, slumping, or landslides along reservoir shoreline,
9. Raising of ground-water levels,
10. Degradation and aggradation of downstream channel,
11. Devegetation,
12. Fire hazards, and
13. Aquifer or site pollution.
14. Hazardous waste sites, buried objects or contained in rusted barrels or dumped on the ground surface.

Chapter 7

INTERPRETATION AND PRESENTATION OF GEOLOGIC DESIGN DATA

OBJECTIVES

The objectives of this chapter are to establish a policy to encourage the use, evaluation, and portrayal of geologic design data to describe adequately the geologic conditions affecting design; and to provide guidelines and standards for the presentation of geologic design data. To accomplish these objectives, both factual and interpretative data must be used. These data must be presented in a three-dimensional format to be most beneficial to the design and construction process.

PRESENTATION OF FACTUAL AND INTERPRETATIVE DATA

Factual data generally are specific information obtained from drill holes, test pits, trenches, surface exposures, and test data. The value of the factual data for understanding the geologic conditions that influence design and construction is enhanced by interpretation and presentation. This includes:

1. Projecting geologic contacts, discontinuities, weathering profiles, and physical and engineering properties on plan and section drawings.

2. Developing various contour maps depicting top of bedrock or top of lithologic units with significant or adverse properties, ground water piezometric surface, geologic structure, weathering, permeability, and isopach maps.

3. Compiling statistical data for fractures such as polar plots and contours (Stereographic projections), joint roses, and tabular summaries of properties such as continuity and spacing of joint sets or ground water.

Interpretative data, in conjunction with the factual data, provide a more complete picture of the geologic conditions, and serve to point out weakness in the data base and the need for further investigations.

Interpretative data also provide the means for relating geologic conditions to design; allows an avenue of communication within the appropriate design team; and for contract specifications, provides the bidder with geological data and assumed foundation conditions used for design.

Results of in situ tests, as well as laboratory tests and geophysical data, should be correlated with other geologic information in the report narrative and displayed, if possible, on appropriate drawings or tables.

Differentiating between interpretative and factual data is important, and some indication of the relative reliability of data by the use of dashed or queried lines must be made. Sections, like maps, must be clear and concise; must focus attention on problem areas; and must differentiate between fact and interpretation. Geologic sections and associated maps must be accurate and compatible with each other.

The interpretative drawings and conclusions should be developed from an adequate data base consistent with the geologic complexity and nature of the engineering structure.

An adequate number of plan and profile drawings, which may be supplemented by tables, are to be prepared to show all geologic conditions pertinent to the design. Factual information should be presented on these drawings so that the basis for interpretations can be evaluated. At a minimum these drawings should delineate the following:

- Surficial deposits and lithologic units;
- Top of bedrock (if present);
- Weathering profile(s);
- Ground-water conditions;
- Geologic structure:
  Bedding or foliation,
  Joint sets or fractures,
  Fault or shear zones, and
  Folds.

Other items are to be added as needed. A more detailed discussion of geologic drawings and appropriate symbols which may be used to display these data are provided in the following section.

These drawings should be at a scale which will depict clearly the geologic conditions and allow for interpretation and analysis. In most cases, geologic sections and profiles with no vertical exaggeration should be used (i.e., true scale drawings).

Factual data such as geologic logs, are to be submitted with associated interpretative drawings.

The collection, interpretation, and presentation of geologic design data are dynamic processes that require periodic submittals for review and evaluation and continual updating of information. This process will facilitate communication between all design team members and will help result in final designs which reflect the geologic conditions.

GUIDELINES FOR PREPARATION OF GEOLOGIC DRAWINGS

Preparation of Geologic Drawings

General.—The purpose of these guidelines is to promote Reclamation uniformity in the preparation and presentation of high-quality geologic maps and sections and to assist in preparing geologic drawings that may be readily understood by the user. Uniformity, accuracy, clarity, and proper emphasis in the presentation of the data are important requirements. Drafting standards and symbols are presented in the following section.

A geologic drawing should stand by itself. The user should not have to read the text of the report to interpret the map. The drawing must be clear; symbols must be uniform; different types and weights of lines must be chosen to illustrate different geologic data. To achieve this, major geologic data must be most prominently displayed, and supporting geologic data less prominently displayed. Map explanations must be concise, descriptive, and complete. Stratigraphic or columnar sections should be used as part of the explanation when significant and practicable, with appropriate symbols used on other drawings.

The purpose and scale of the map is important. A regional map may show only generalized contacts and structures. A damsite map focuses attention on detailed conditions in a small area. Ingenuity and sound judgment are essential to the presentation of the diverse details required in engineering geologic studies.

Accuracy in Engineering Geologic Drawings.—Present-day geologic maps range from strictly factual to highly interpretative; even the most factual outcrop map is based in part on interpretations. Any geologic fieldwork which ultimately results in a geologic map starts by a visual study of existing cut slopes and outcrops, is supplemented by consideration of vegetation, soil composition and color, float, aerial photographs, and trench or drill hole data, and then progresses to a composite map which presents the geologic data. Careful plotting of data to ensure correct locations, adequate review and checking, careful choice — and good drafting — of contrasting symbols for factual and interpretative data will enable the user to see the facts and to judge independently the soundness of the interpretation, probable accuracy, and reliability of the geologic program.

Accuracy is essential, and complete conformance between facts and interpretations placed on a geologic map and the related sections is vital. Such maps and sections prepared for use in geologic reports are used for, or form the basis for drawings prepared for inclusion in specifications for, bidding purposes and thus become legal documents. Such drawings, and the originals appearing in the geologic report, may be used in negotiations of contractor claims and in litigation. Recognition of errors in the drawings or the original geologic maps may cast doubt on the reliability of all data shown.

Suggestions for Preparation of Drawings.—Present the essential geologic information consistent with the purpose and scale of the drawing in such a way that it is readily grasped by the user. The drawing should "stand by itself" in the sense that the user should not have to read the text of the report to visualize the geologic relationships being presented. It should be easy for the user to distinguish between different types of information such as lines representing joints and faults, areas of outcrop, manmade exposures, surficial materials, weathering profiles, and design concepts.

Avoid packing a drawing with such a volume and variety of data that it becomes laborious to decipher. By using two or more drawings (with the same base and scale) and placing selected groups of data on each, or by using several overlays, packing can be avoided.

Suitable choice of line weight and type of symbol enables the user to read the map quickly and "see" the major elements of geologic structure or of joint system trends or distribution of units. The user may look closer and "see" details such as dip-strike data on joints, faults, or foliation without laboring to differentiate between the several types of data shown. Lettering size and line weight standards for geologic drawings used for Denver specifications are portrayed on figure 7-1. Line weights and symbols shown are based on the reduction of a standard-size drawing to half size as used in contract specifications.

Avoid placing nonessential data on the drawing, thereby obscuring the important information. Such data should be excluded. If it is necessary to include them for record purposes, they should be placed elsewhere and suitably referenced on the map, or drawing.

The clarity of any geologic drawing may be severely damaged by poor drafting even though the choice of symbols is excellent. The draftsman generally is not a geologist; consequently, the geologist must make technically accurate and adequate preliminary sketches so the draftsman may produce an acceptable final drawing. In complex geologic maps, small but important areas may be so crowded with detail that they can be understood only by the geologist who made the map even though the draftsman was reasonably successful in showing all data. Complex areas should be redrawn at a larger scale and inserted on the same map or shown as a completely separate drawing.

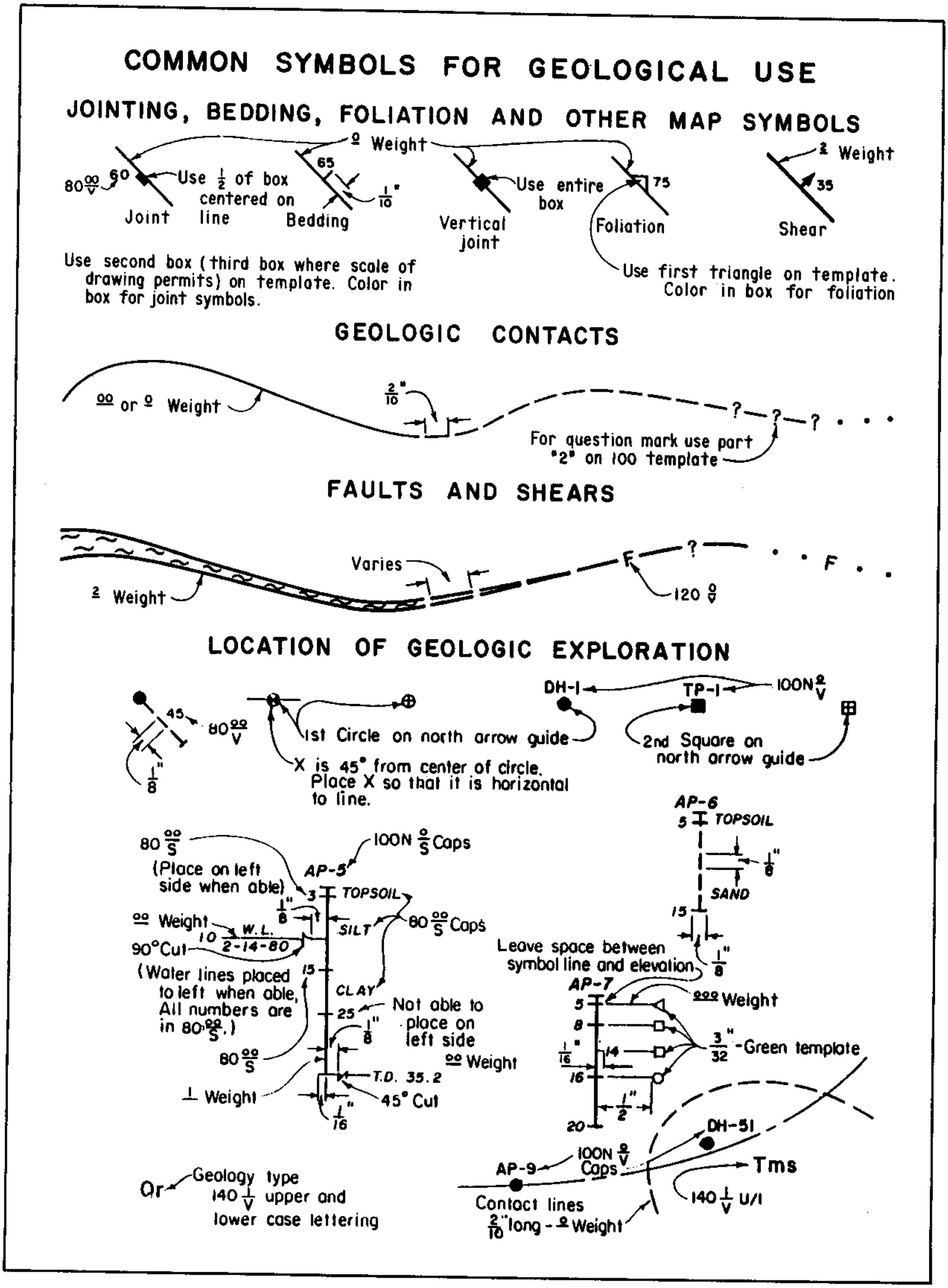


Figure 7-1.—Standard lettering sizes and line weights for geologic drawings.

Dense line patterns used to differentiate various geologic units are objectionable and should be avoided since they obscure other important geologic and base map data such as topographic contours. Adequate labeling and the use of stippling or random patterns of V's or dashes are preferable to line patterns. The choice of line and geometric symbols made to present data on a geologic map should be that which will enable black and white prints to be read and used without difficulty. Use line or bar scales on drawings since many geologic drawings in the course of their use may be enlarged or reduced.

An arrow indicating true north must be given. The coordinate system, triangulation stations, section corners, or other surveyed points should be shown to permit accurate location of points on the map.

Whenever a topographic map with closely spaced or dark contours is to be used as a base map, it is often desirable to subdue the intensity or fade out the print of contour lines. Similarly, geologic conditions may be shown directly on design base drawings with the proper emphasis if less significant data are displayed less prominently. This is accomplished by a duplicating process known as screening. The use of screened topographic or other bases allows the superimposed data to stand out more prominently and clearly on the subdued, but still readable, background. In addition to reducing clutter on the drawing, if the screened data are placed on the back of a photographic mylar, revisions and corrections may be made without the loss and redrafting of contours or other data. Also, screening may eliminate the need for overlays, thereby reducing printing costs of specifications, and making available full-size geologic drawings to the successful bidder after contract award; or it may allow the use of overlays to either highlight or show other data.

Geologic Maps

Base Maps.—Geologic information may be placed on a variety of base maps, such as U.S. Geological Survey topographic quadrangles, State highway, county and Forest Service maps, project topography, or maps which are a composite of data from such sources. A base map may consist simply of traverse lines (surveyed by transmit and level or compass and pacing methods) along which geologic data are recorded.

Vertical aerial photographs may serve as a base. Geologic data may be placed directly on the photographs while in the field and subsequently copied on a translucent overlay or as a line drawing. Geologic maps which are line drawings based on aerial photographs must include a note that defines the nature of the base and warns the user of horizontal distortion, and variation of scale, depending on the distance from the center of the photograph. The note also should include whether the air photograph base is a "controlled" or "uncontrolled" mosaic, ordinary vertical air photograph, rectified photograph, or orthophotograph.

Geologic data recorded on air photographs in field-mapping operations may be transferred to topographic maps by "eye" or by more accurate photogrammetric methods. The method used should be stated in the note.

Photogeologic maps prepared from interpretation of aerial photograph should be labeled as such.

Types of Maps.—The types of geologic data selected and the degree of detail shown on any geologic map depend largely on the objective or intended use and the scale of the map. Thus, a regional map using a small scale may show simply the generalized position of major geologic formations and structures. In contrast, the objective of a damsite map using a large scale is to focus attention on the detailed conditions of a small area.

Ingenuity and judgment are essential to effectively present diverse data without obscuring the topography or position of existing or proposed engineering structures. Such data might be major formational contacts and regional joint system trends together with localized joint system and pertinent facies changes or ground-water contours and the location of springs and wells.

Many types of general and special purpose maps are available; a few in common use are:

Outcrop.—Position and boundaries of outcrops and manmade exposures are shown. This type of map is usually of limited value unless combined with other drawings.

Surface geology.—Location of outcrops, contacts between rock types, and distribution of and distinction between types of surficial materials such as glacial moraine or outwash, stream deposits, talus slopes, and terraces are shown. Relative geologic ages of various units as well as structural and geomorphic features may be recognized by the choice of map symbols. Where surficial materials are relatively shallow or nonexistent, the distribution of formations or various rock units and structures (as if surficial materials were nonexistent) with contact lines are drawn solid, dashed, or dotted as appropriate.

Rock surface contours.—Contours drawn on "top of rock" or on top of a moderately or slightly weathered rock horizon.

Structure (subsurface contours).—A contour map with contours drawn to depict a surface such as a top of a particular rock unit, selected identifiable horizon of a formation, or the top of a structure such as a significant shear or fault.

Isopach.—Lines connecting points of equal thickness, that is, "contours" show variation in thickness, of some selected zone of material or formation.

Hydrogeology.—Often used to show the shape or piezometric surface of the ground-water body at a specified time. Contours on the top of an aquifer or isopachs are sometimes used to show thickness (shape) of aquifers. Hydrogeologic maps and sections may show type of aquifers, varying degrees of transmissibility, quality of ground water, rise and fall of water levels, and the amount of ground-water withdrawal or recharge and any effect on such action. If several ground-water bodies exist, identify or distinguish between them such as perched, unconfined, or confined. The water table and piezometric or pressure "surface" must not be confused.

Special purpose.—Maps not fitting foregoing categories such as block diagrams and isometric diagrams, or which show only joints and faults, or sand and gravel deposits, or pertinent geologic data adjacent to a proposed canal or transmission line (strip main or plan and profile sheets). In some cases, only the types of geologic materials actually "on the line" are shown by brackets with suitably described symbols.

Composite or overlay.—Many of the engineering geologic maps are a composite of several of the types mentioned previously, or are developed as a composite using overlays.

Geologic Sections and Profiles

General.—Geologic sections and profiles are drawn to convey to others the geologist's conception of subsurface conditions such as occurrence of ground water, distribution of geologic units, weathering profile, geologic structure, and completed exploration. That conception is fundamentally and largely interpretative and is based on all the factual information available such as outcrops, topography, vegetation, soils, drill holes, regional geologic history, and geophysical data. Therefore, when constructing the section, it is most important to assure that the user can differentiate between the facts shown and the interpretation.

Four primary objectives of sections are: (a) to compile and correlate surface and subsurface geologic data; (b) to present the geologic interpretations; (c) to save the user time by concisely and accurately displaying pertinent geological conditions; (d) to graphically show in one, two or three dimensions the subsurface conditions which cannot be read with ease from the geologic map, particularly those interpretations which may be significant to engineering planning or design and (e) indicate probable geologic structure excavation limits and show geotechnical considerations or treatment. To be informative, the geologic section must be unambiguous, and an easily read presentation of geologic data. It must attain the objectives and use similar techniques outlined for geologic maps.

Method of Showing Drill Hole Data.—In many instances, it will be neither practicable nor necessary to compile all of the available data onto one section. Judgment must be used in selecting all data pertinent to the objective of the section, such as to show correlation of high water-loss zones with various geologic units or degree of jointing, correlation of high core-loss zones, geophysical log evidence of lithology or shearing between drill holes, and structural thickness and sequence of sedimentary strata. The use of overlays to portray specialized data is encouraged; in this manner, a "basic geologic section" is developed and one or more overlays are constructed to illustrate significant parameters.

The following are common types of drill hole data, some combinations of which may need to be shown:

- Percent core recovery; zone(s) of core loss;
- Drill water losses;
- Water-pressure tests;
- Significant ground-water conditions such as water levels or artesian conditions;
- Geophysical logs, TV camera, or televiewer data;
- Lithologies;
- Structures (including fracture density or shears and faults);
- Penetration test data;
- Grouting conditions; and
- Classification of materials.

Scales.—A natural (or un-distorted) scale, is much preferred. However, some geologic sections must be drawn to an exaggerated scale, with the vertical dimension expanded as compared to the horizontal dimension, to show the geologic data in the upper 100 to 400 feet and avoid excessively long drawings. Exaggeration results in distorted ground surface slopes and distorted attitudes of subsurface features such as dip of bedding, contacts, and faults. The unwary user may retain a mental picture of such features in the (distorted) relation shown on the section. In such cases, conclusions on matters such as the probability of landslides, the stability of excavation slopes, and the attitude of inclined drill holes will be erroneous. As a partial guard against this potential error, a small, natural scale "skeleton" of the surface profile showing major faults or dominant bedding planes should be included as an insert on the drawing.

A similar device which helps the map and section user when very long sections must be broken into parts is to use natural scales or to retain standard drawing sizes. In such cases, the small-scale skeleton section will show the position of match and turn lines relative to key features on the long, large-scale section.

The section should be annotated in such a way that its orientation is clear; this is usually done with either a letter and a letter prime, and showing the bearing of the section at the top. A photographically reduced plan view may also be entered on the section so the user not only visually sees where the section is, but also may determine other sections of interest.

Special Purpose Sections and Diagrams.—Special purpose sections and diagrams range from complex "fence" or block diagrams using isometric or oblique projections to simple line or bar graphs. Their construction, characteristics, and principles of projection are familiar to most geologists and are explained in many textbooks of geology and drafting. The ingenious geologist can devise modified sections and invent or develop special diagrams which will reveal graphically the relations or conclusions one wishes to show, but not to the extent that facts are omitted to bias the conclusion. Simplicity is the essential guide; complexity may defeat the purpose of the diagram.

The value and use of geologic reports may be increased by including a simple stratigraphic section which shows at a glance the normal sequence of strata as well as the relative geologic ages, youngest at the top and oldest at the bottom. Listing of geologic units in order of age with color-coded "boxes" that also show the letter-code (map symbol) is common practice. Also, standard geologic symbols used for geologic sections and columnar sections are shown on drawing 40-D-6533 (figure 7-2).

The simple stratigraphic section can be amplified with ease to form a columnar section which presents the main elements of geologic history at a glance. Thus, the columnar section may show information such as comparative thickness of formational or engineering rock units; conformable, unconformable, or faulted contacts; relationships between sedimentary strata and intrusive-extrusive igneous formations; differential weathering characteristics and resulting topographic expression; faulting; and other features important either to comprehending the geologic history or to formulating engineering conclusions.

Both the simple stratigraphic section and the more sophisticated columnar section should be color-coded in conformance with the map to facilitate user comprehension. Standard geologic symbols on figure 7-2 also may be used.

GEOLOGIC DRAWING DRAFTING STANDARDS AND SYMBOLS

Previous subsections presented requirements and general guidelines for the presentation of data on various geologic drawings. What follows are the guidelines and standards for geologic drawings and overlays. The requirement and advantages of Reclamation-wide conformity in the presentation of basic geologic data are self-evident. Conformity assures that the same types of information will be shown by the same symbols. The use of field-office-prepared geologic drawings or overlays for specifications drawings is encouraged to eliminate redrafting and to reduce drafting errors. Principal Geologists and technicians at the Denver Office and Project and Regional Offices should discuss the use and content of field drawings early in the data collection period to work out details necessary to incorporate field drawings if possible.

Standard Drawing Sizes

The use of standard-size drawings is preferred. Oversize drawings, in particular surface geology drawings, may be used during data collection and design because of ease of revision, layout and construction of sections, and display. Oversize drawings are not used in specifications, such drawings will be either redrafted, reduced, or usually, cut into several standard-size drawings with match lines. All specification drawings are to conform to ANSI (American National Standards Institute) Y14.1-1980. These are "A"-size, 8½" × 11"; "B"-size, 11" × 17"; "C"-size, 22" × 17"; "D"-size, 22" × 34" (inside border dimensions). The "D"-size is preferred. For special work, Reclamation Instructions permit oversize drawings up to 68-inches long.

Explanation Drawings

A single geologic drawing should, if space is available, have its own legend, explanation, and notes. If multiple drawings are used, then a single drawing with general geologic legend, explanation, and notes should be used. Other geologic drawings would only require a note to see the general geologic legend, explanation, and note drawing unless specific notes are required to explain or clarify a particular drawing. Examples are available in most of the recently issued specifications. Notes pertinent to one or a few drawings should be shown on the individual drawings only.

Overlays

Overlays for design, topographic, or geologic drawings for specifications are usually printed in red. When necessary, other overlay colors or multiple overlays may be used for specifications drawings (See figure 7-3).

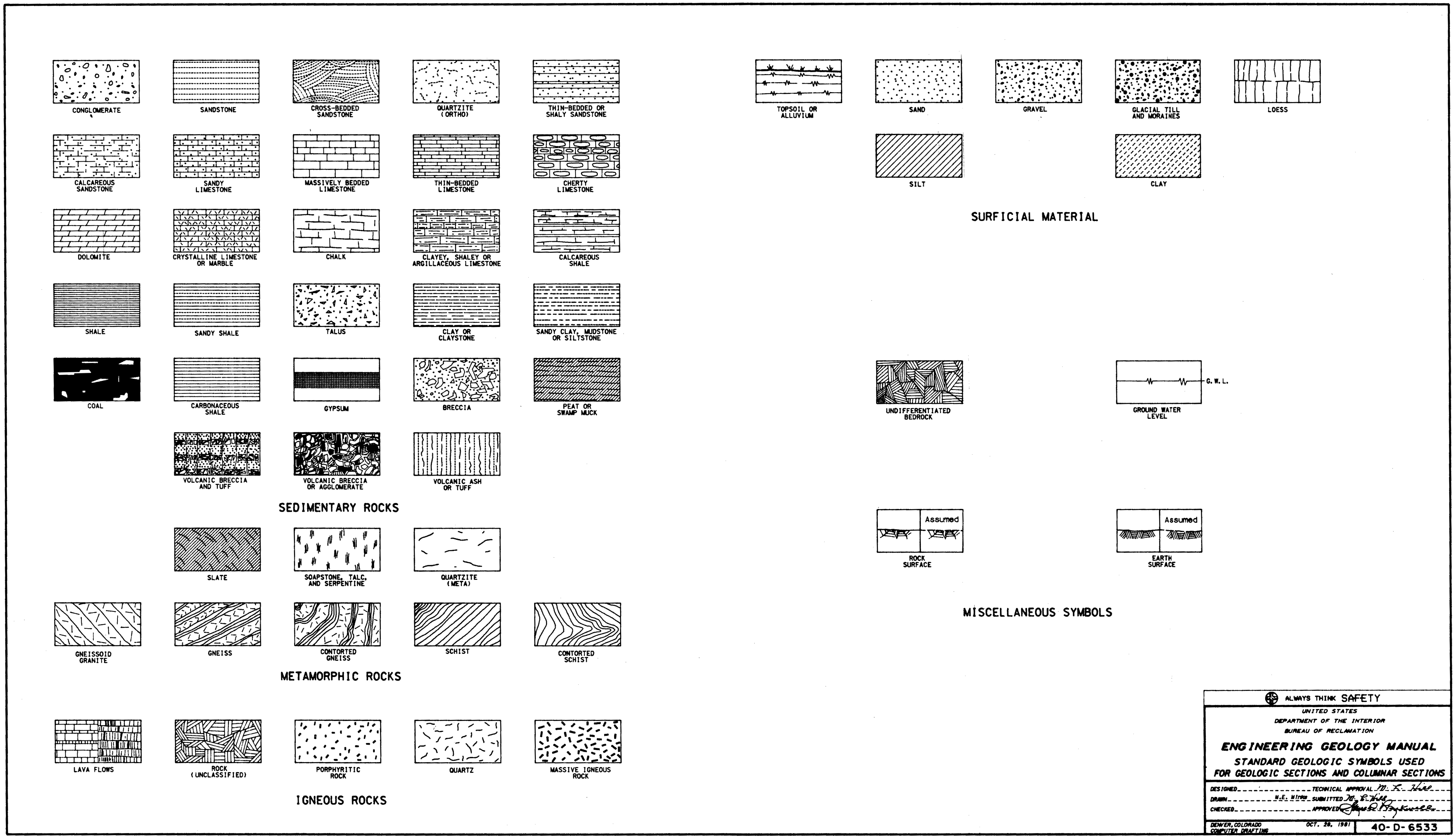


Figure 7-2.—Standard geologic symbols.

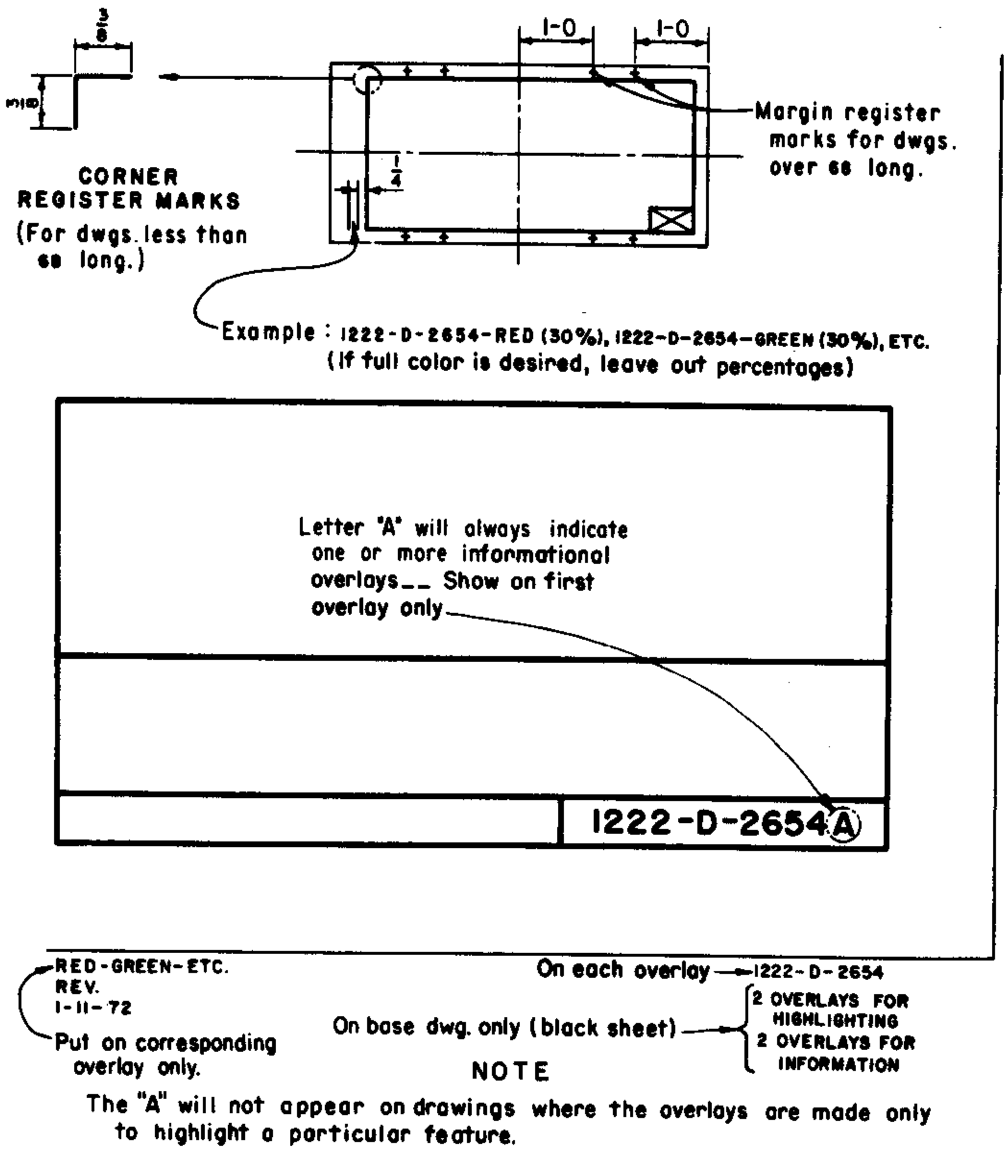


Figure 7-3.—Identification of overlays.

Lettering Sizes and Line Weights

Figure 7-1 provides guidelines for lettering sizes and line weights to be used for specifications drawings. It is important to remember that specifications drawings are normally half-size overlays or drawings. Depending on the scale of the drawing and amount of data shown, good judgment is required in selecting sizes of symbols and the use of abbreviations to avoid "cluttered" drawings.

Standard Geologic Drawing Symbols

The requirements for Reclamation conformity in commonly used geologic map symbols is to assure that the same type of information — joint systems, geologic contacts, and faults — will be shown by the same symbols no matter whether the map was prepared by a geologist in New Mexico or in Montana. The advantage to those who use the map — geologists, engineers, contractors, and others — is self-evident. It provides greater assurance that the geologic map, a form of communication, will actually perform that function effectively. Otherwise, the time invested in fieldwork, drilling, interpretation, and drafting will have been partially wasted.

Standards symbols for geologic plans and sections are provided on figures 7-4 and 7-5. These drawings include or revise the standard symbols shown in *Reclamation Instructions, 134*. Where optional symbols are shown, judgment should be exercised in the choice of symbols based on the scale of the drawing, complexity of the geology, and amount of detail to be shown.

Symbols depicting attitudes of structural features such as joints, faults, folds, and cleavage should have the strike direction labeled if it does not clutter the drawing. The strike may be labeled as either azimuth or the traditional bearing in degrees from north. This procedure will assist those in the field and E&R Center offices who must use the information for analyses.

Special symbols or devices, such as a joint contour diagram, should be used wherever they will clarify, emphasize, or summarize important elements of the geologic conditions which the user must otherwise laboriously extract from the map and text and mentally compile. A stereographic plot of joint attitudes or contoured diagram is very useful in showing the degree of dispersion and abundance of joint sets; often it may be reduced or redrafted for inclusion on a plan map to help others visualize the effects of jointing on various existing or planned excavations.

The type of line, geometric symbol, or line weight as well as drawing layout may be used to convey information on reliability or relative accuracy (of position) in addition to differentiating between the types of information. Thus, for contacts weathering horizons, water levels, and shears or faults, a solid line indicates the feature is located with appreciable accuracy; a dashed line means that the location is approximate; a short dashed line with question marks, that the location is inferred, or projected; a dotted line that the location of the feature is concealed.

The previously referenced standard symbols for types of geologic data most commonly shown in engineering geologic maps are to be used for Reclamation geologic drawings unless there is a good technical reason to do differently. However, any "standard" symbol may be modified or a new symbol be devised if it will improve the clarity of a map and enable the user to more easily distinguish between fact and interpretation, between minor and major geologic data, or between adjacent or overlapping types of geologic data. For geologic data rarely shown on the average engineering geologic map, symbolization should follow those used by the AGI (American Geological Institute), available on AGI data sheets.

Standardization of geometric symbols (and color codes) for geologic sections has not progressed to the degree common in maps. General practice has produced some symbols (and colors) with generally accepted meanings, but conformance is less essential than in maps. The objectives of primary importance are: (1) conformity (in geometric symbol and color code) to the geology map to which the section is related; and (2) clarity. Figure 7-2 illustrates standard symbols shown in *Reclamation Instructions, 134A*. Most of the symbols are very time consuming to draft and, if used in excess, hinder either readability of the drawing or obscure other data. Abstract symbols or preprinted symbols on dry film transfers and shading film such as "Zipatone" may be used in lieu of those lithologic symbols shown on figure 7-2. Geologists should develop symbols that accurately portray the individual rock units. All symbols must be shown in the legend, explanation, and notes.

Computer drafting or Computer Aided Drafting and Design (CADD) will expedite drawings. Standard symbols and line fonts have been or are being developed.

SIGNATURE BLOCKS FOR DRAWINGS

Figures 7-6 through 7-10 show the title blocks and signatory approval to be used for the drawings prepared for ACER specifications. All signatures and initials within the signature/title block should be in waterproof ink.

Engineering drawings prepared in the Denver Office that have geology shown on them shall have the signature block shown on figure 7-6. If geologic information is depicted on an overlay(s), which will be printed in color, the geologic title block also should be on the overlay(s). However, if the geologic information is depicted on the base, which will be printed in black, then the geologic title block should be on the base.

Engineering drawings prepared for the Denver Office by regional, project, of field offices that are included as part of the Denver Office specifications and will be signed as "Approved" in the Denver Office, should be signed for "Field Approval" prior to being transmitted to the Denver Office. When geology is shown on them which has been prepared by the Division of Geology, Denver Office, a modified signature block as shown on figure 7-8 is used.

Engineering drawings prepared by field offices which are included as part of Denver Office specifications will be signed as "Approved in the Denver Office." These drawings should be signed for "Field Approval" prior to being transmitted to the Denver Office. When geology is shown on them which has been prepared by the field office, a modified design signature block and geology signature block are used as shown on figure 7-9. "Field Approval" for the geology title block would be signed Project or Regional Geology, and "Technical Approval" will be signed by the Principal Geologist.

Specifications drawings involving only geology may have "Geology" substituted for "Designed" in the signature block. If there is inadequate space in the title block for all of the names of the geologists who prepared the geology, "Project Staff," "Regional Staff,"

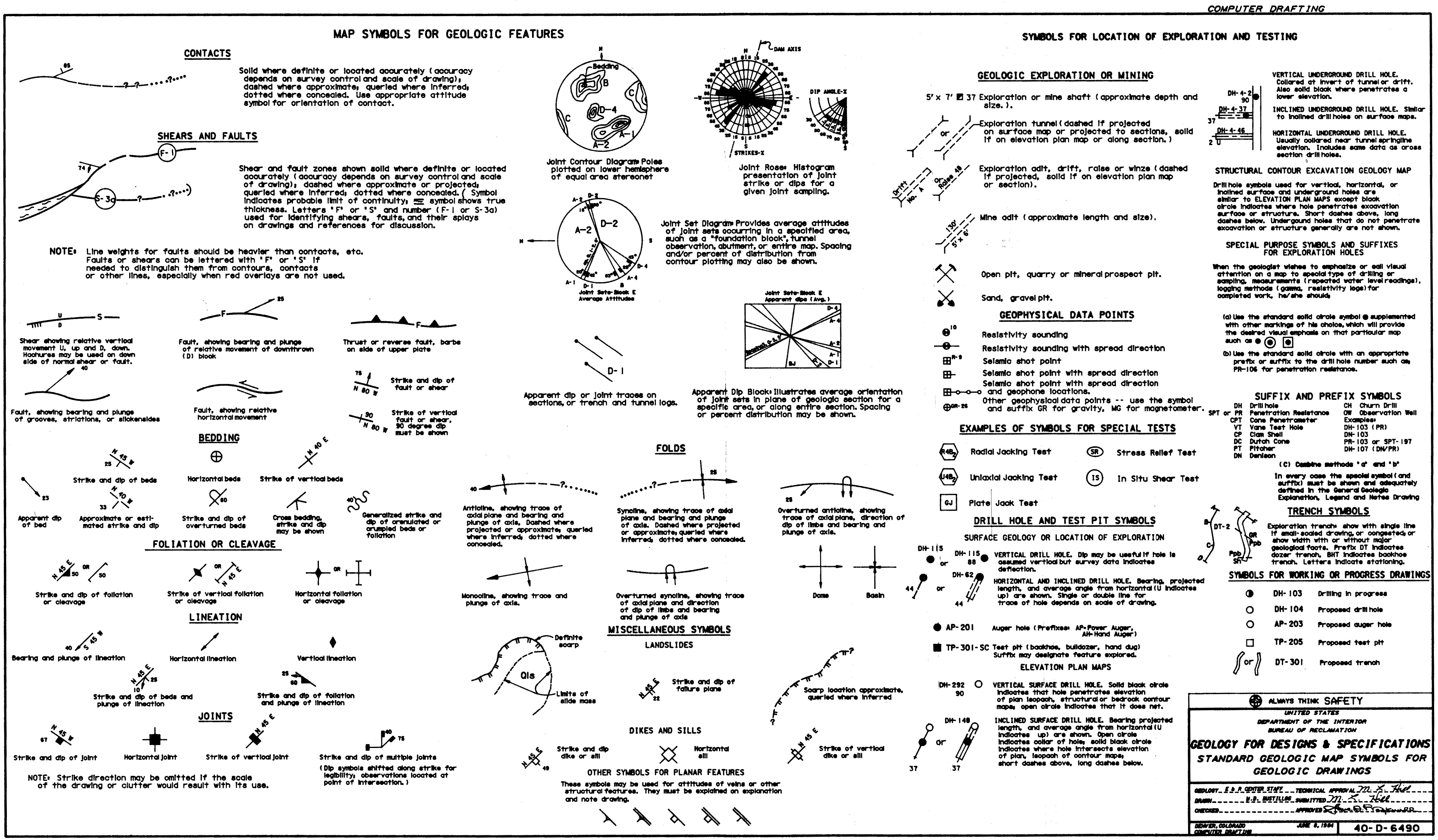


Figure 7-4.—Standard geologic map symbols.

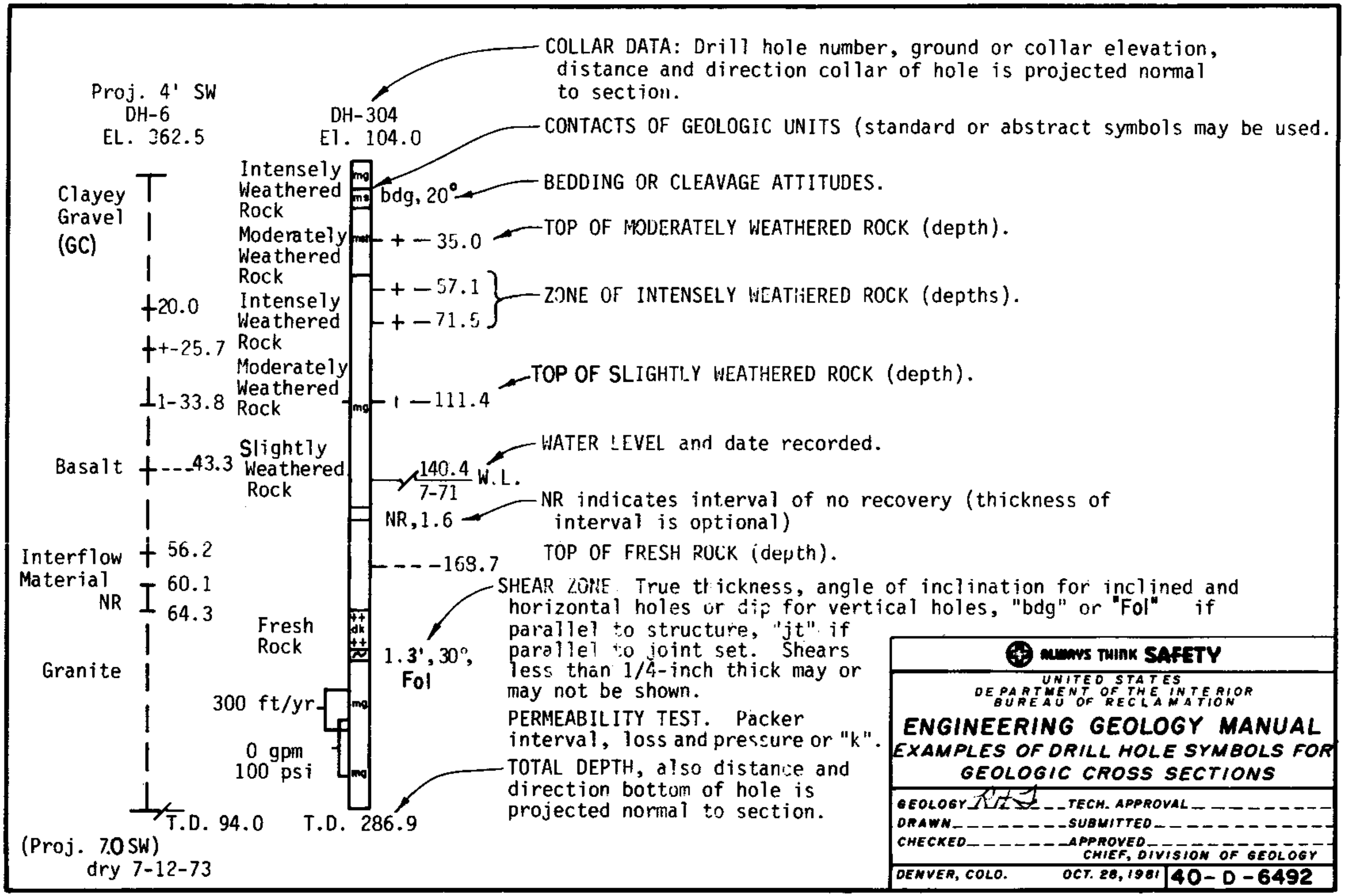


Figure 7-5.—Drill hole symbols.

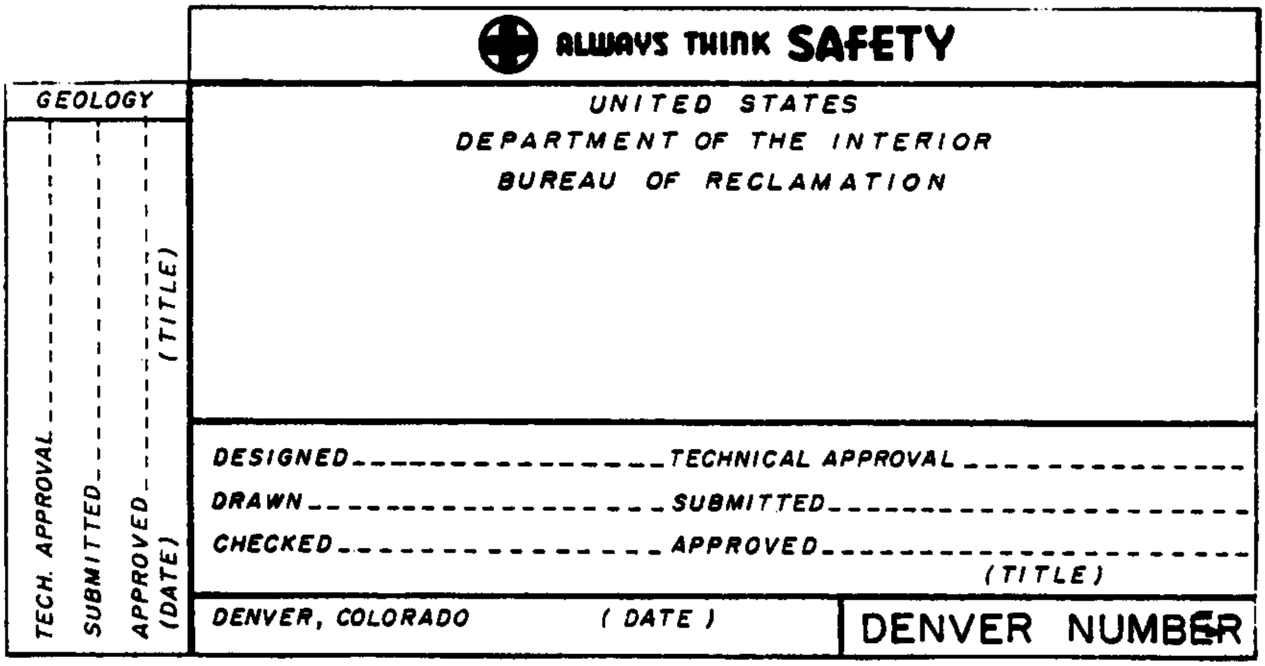


Figure 7-6.—Signature blocks for Denver engineering drawings with geology prepared by the Division of Geology, Denver Office.

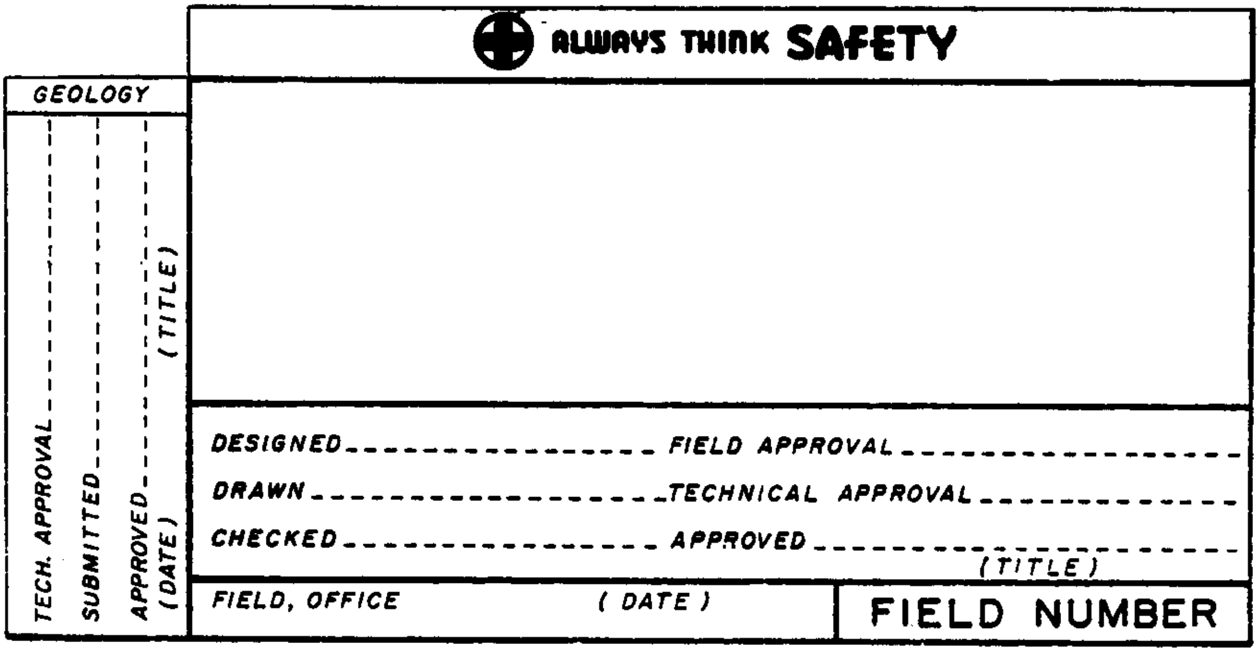
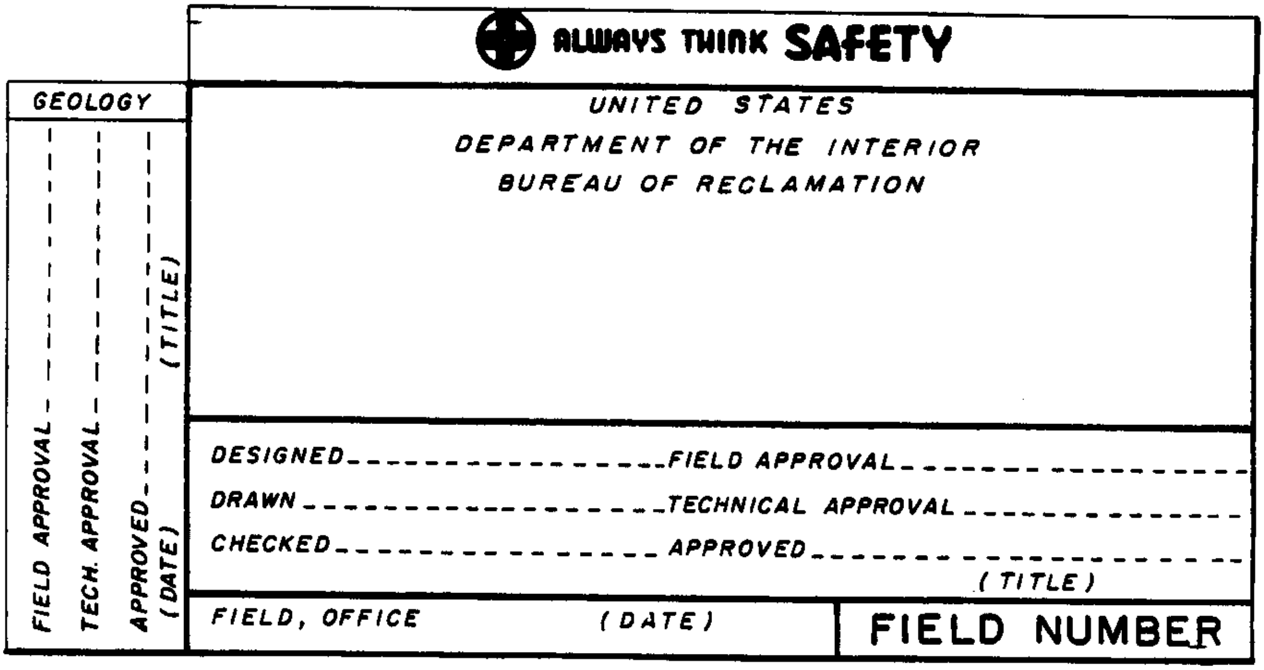


Figure 7-7.—Signature blocks for engineering drawings prepared by regional, project, or field offices with geology prepared by the Division of Geology, Denver Office.


ALWAYS THINK SAFETY

GEOLOGY

FIELD APPROVAL

TECH. APPROVAL

APPROVED

(TITLE)

(DATE)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DESIGNED ________________ FIELD APPROVAL ________________

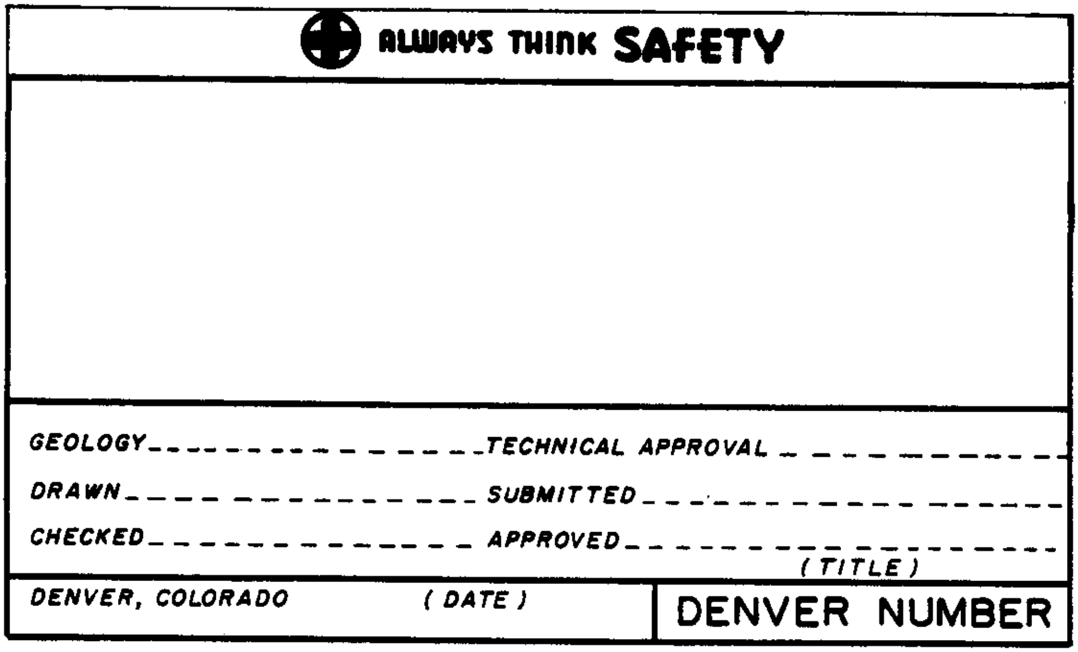
DRAWN ________________ TECHNICAL APPROVAL ________________

CHECKED ________________ APPROVED ________________

(TITLE)

FIELD, OFFICE (DATE) FIELD NUMBER

Figure 7-8.—Signature blocks for engineering drawings prepared by regional, project, or field offices with geology prepared by the regional, project, or field office.


ALWAYS THINK SAFETY

GEOLOGY ________________ TECHNICAL APPROVAL ________________

DRAWN ________________ SUBMITTED ________________

CHECKED ________________ APPROVED ________________

(TITLE)

DENVER, COLORADO (DATE) DENVER NUMBER

Figure 7-9.—Signature blocks for geology drawings prepared by Denver Office.

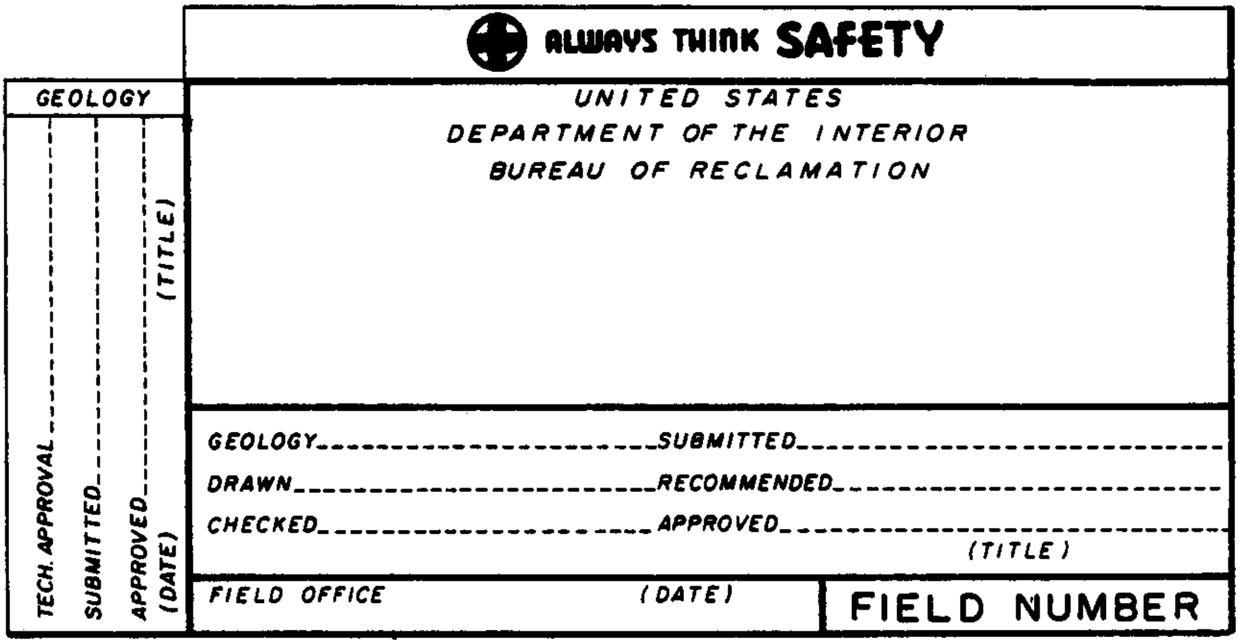


Figure 7-10.—Signature blocks for geology drawings prepared by field offices.

or "Denver Office Staff" may be used, and the geologists' names should be referenced in the drawing notes (who and when).

Geology drawing prepared by the Division of Geology for Denver Office specifications and reports will use the signature block shown on figure 7-10. "Technical Approval" will be signed by the Principal Geologist.

Geology drawings prepared by the field, which are included in Denver Office specifications, shall have the signature block shown on figure 7-10. In this case, "Submitted" and "Recommended" on the main title block would be signed by the geologist who prepared the drawing or the Project Geologist. "Approved" on the main title block would be signed by the Field Engineer, Project Construction Engineer, or Regional Engineer or Geologist (depending on delegation of authority). "Technical Approval" in the small "Geology" title block will be signed by the Principal Geologist who is accountable technically for the geologic information depicted on the drawing.

Chapter 8

GEOLOGIC DOCUMENTS FOR BUREAU OF RECLAMATION DESIGN AND CONSTRUCTION

GENERAL

Most of the milestone documents for Denver Office specifications and designs described below shall be authored by, or reviewed and approved by, the Principal Geologist. Other documents will be prepared jointly by design teams or exploration teams which include geologists from Region and/or Project Offices. The preparation of these documents will help ensure the recording of geologic conditions and geotechnical considerations, will permit a review of the geologic issues and their impact on both design and construction, will include requirements for data and analyses, will promote cost effective data collection programs and will convey conclusions or recommendations to designers and engineers or other design team members to design and construct Reclamation facilities. Chapter 3, and Tables 3-1 and 3-2 illustrate appropriate team membership, responsibilities and participation, submittal flags, and action required.

EXPLORATION TEAM FIELD DATA REQUESTS AND TECHNICAL MEMORANDUM

Soon after the Exploration Team is formed (Chapter 3), they identify a systematic engineering and geological data collection program and prepare adequate documentation for the proposed investigations. A TM (technical memorandum) identifying and explaining the data collection program is required. This TM outlines the engineering and geological considerations that need to be addressed, the reason for the concerns, and the types of investigations proposed to obtain data to resolve the concerns. The TM should document adequately the available data, be as concise as possible, and ensure that personnel involved in data collection (and management required to allocate resources) understand the value of the required data and the resources required to accomplish the task.

A draft of the geological portion of this TM should be prepared by the Principal Geologist, in coordination with design engineers and in consultation with field geologists, prior to the team's site visit. The TM will reference available geologic data for the site, any known geologic issues to be evaluated, such as foundation deformability, slope stability, and any geologic hazards. It should discuss the identifiable engineering geology issues and the resolution of those issues, a proposed schedule of the geologic activities, including phasing of the investigations, and preparation, submittal, and review of geologic data and reports.

When properly completed early in the design process, this procedure will summarize geologic conditions at the site, enable the team to directly observe those geological conditions, provide the team with known and potential geotechnical issues to be evaluated during the data collection and design process, identify requirements for sampling and testing, and propose and commit to realistic schedule for data collection, or identify and document the risks if investigations are delayed or eliminated. This TM will be the basis for the next milestone documents, the Geologic Design Data Report from the field and the Engineering Geology Considerations for Conceptual Design TM.

Exploration requirements will be prepared on Bureau of Reclamation Form 7-2145 "ACER Field Exploration Request" or appropriate modified forms. Figure 8-1, a modified version of this form is provided for reference. Specific instructions concerning the program also should be included. Exploration programs may include requirements in the following areas: geological and construction record searches, geological mapping, dozer or backhoe trenching, seepage monitoring drilling and test pitting, sampling, in situ testing, instrumentation, and field laboratory testing. In addition, data provided by these programs must receive appropriate distribution in the Denver Office and any samples obtained must be properly selected, stored, handled, and shipped by appropriate methods. Agreed upon data requirements, priorities, and procedures to obtain these data are to be listed on the form(s).

Intermediate decision points, interim submittals and final submittal dates are to be identified as well, especially for staged exploration programs.

The form usually will be prepared by the leader of the exploration team. Each member of the team will initial this form to signify that the program meets initial requirements. If the designated exploration team field geologist is not present to initial the form, he or she will be contacted for concurrence with the exploration request, and their initials added after approval by phone or letter. A brief transmittal memorandum will be prepared and routed with the TM and the ACER Field Exploration Request through the appropriate branches for surnaming. The ACER coordinating Branch Chief will sign the transmittal memorandum. Modifications or supplements to the initial program will be prepared and transmitted in the same manner.

GEOLOGIC DESIGN DATA REPORT

Interim submittals of drill hole logs, analyses, drawings and other data are encouraged throughout the design process. These submittals may be informal "blue envelope" submittals for the design team to use during monitoring of the data collection process, or they may be formal submittals specified by ACER Field Exploration Requests, ACER Project Plans or Project Management Team Schedules. These interim submittals are not to take the place of a Geologic Design Data Report.

The Geologic Design Data Report(s) shall be prepared in the Project or Regional Office. It is to be submitted in accordance with *Reclamation Instructions, 133.4.1,* Design Data Requirements, the Field Exploration Requests, team memorandums, and the standards presented in the *Engineering Geology Office Manual.* Generally, it is due at the same time or before design data submittal. For Denver Office specifications designs, this will be at least one month prior to the CONCEPTC flag shown on the Denver Office Schedules and/or ACER Project Plan unless delayed submittal has been agreed to. For other studies or evaluations such as Modification Decision Analyses, Corrective Action Studies, and planning reports, submittal dates will be established by separate schedules or memorandums. Preparation of the report, submittal dates, and review procedures are discussed in subsection, Geologic Design Data Review Memorandum(s) and in Chapter 9.

The data report shall address regional and site geology, reservoir geology (if applicable), analyses and conclusions, and geotechnical considerations. The report shall include interpretative drawings and tabular data which are the results of analyses, logs, and other data. Geotechnical considerations shall be addressed for each conceptual layout and each structure. A format for discussion of the pertinent issues is shown in the suggested outline in Chapter 9. The outline is a guide; organization, content and format may be at the discretion of the individual geologist(s) to accomodate site-specific geologic conditions or design concepts. The field geologist and Principal Geologist (design team) shall agree on the format and content during the data collection process. When required, the report shall specify the need for additional geologic studies and geologic design data. A supplemental or series of supplemental reports, or a revised, amended Geologic Design Data Report is required for any additional or delayed data or studies. The revised, final report and identified supplements are to be completed approximately one month prior to the DESIGNC flag for Denver Office specifications designs.

Whether geological design data is submitted in interim submittals and one final report, or the final report and a supplement(s), all submittals should be in final form. Data contained in the report(s) should have been reviewed, include the most current and complete information, and be suitable as legal contract documents. Although specifications and contract documents formally supersede previous data reports, these reports normally are referenced in the specifications and are available to the Contractor. These reports are expected to be of the highest quality.

GEOLOGIC DESIGN DATA REVIEW MEMORANDUM(S)

Data reports often are used as legal contract documents. The field office is responsible for required format, completeness and editing as a final Reclamation product. The Denver Office review will be primarily for technical accuracy and content. After receipt of the geologic design data, review of the data should be completed prior to analysis or use for final text or drawings. The Principal Geologist shall review the report to determine whether it is complete, satisfies the data requirements set forth in *Reclamation Instructions* and the design team technical memorandum prepared prior to exploration, specifically addresses design requirements, and that it is technically adequate for initiation or continuation of design. All data, including descriptions, conclusions, interpretations, analyses, drawings, and logs of exploration are reviewed for Reclamation standards. Designers and other exploration and design team members review the report. Appropriate comments are incorporated into the responding review letter. Revisions, additional data collection or analyses requirements, inadequate data or failure to meet standards should be identified if significant. The report requires approval by the Principal Geologist and the Geology Branch Chief, and concurrence by the Principal Designer and Division Chief. Discrepancies must be corrected before final approval is made.

The review memorandum is prepared in internal-letter format by the Principal Geologist for the Chief, Division of Geotechnical Engineering and Geology signature, and addressed to the originator of the data report. Generally, the response is due 10 working days after receipt of the report for minor structures, and 20 working days after receipt for major structures. Content and format may vary depending upon results of the review, and originator/ACER correspondence practices. If there are significant comments they should be stated in the review memorandum. If there are numerous comments, the preferred practice is a cover letter with an enclosure which addresses specific comments. Minor comments or suggestions should be handled informally.

Close coordination by geology staffs is encouraged to preclude oversights, inadequate data, or nonconformance with required standards. Informal reviews whether piecemeal, or as a draft of the report, are preferable to the unreviewed formal submittal of a final report. Informal submittals of a draft report allows detailed review, constructive comments, and cooperative interpretations, and should eliminate the need for detailed and/or any "unfavorable" review memorandums.

ENGINEERING GEOLOGY CONSIDERATIONS FOR CONCEPTUAL DESIGN TECHNICAL MEMORANDUM

An Engineering Geology Considerations for Conceptual Design TM, will be written by the Principal Geologist for specifications prepared in the Denver Office which require geologic investigations, geologic design input to designers, or geologic paragraphs and drawings. It will be completed during the CONCEPT stage as soon as practicable after the receipt of the geologic design data report, and unless waived, completed at least five working days prior to the CONCEPTC flag. If the geologic design data report has not been received prior to CONCEPTC, the TM will be completed using data and interpretations available. The requirement for the memorandum may be waived upon recommendation of the Branch Chief, and concurrence of the Division Chief and by the Principal Designer. Justification for waiving the requirement may be due to one or more of the following:

Insufficient lead time or resources are available between acceptance of the job and CONCEPTC, such as unscheduled or emergency specifications.

When a Design Team Decision or Technical Memorandum for Data Collection includes all of the geology considerations known and no additional data are available.

The specifications are part of a phased construction program where no or limited investigations are required for the second or later phase.

Specifications are for very minor construction, the geologic input is not significant, or where no or limited investigations are required.

This TM will identify those engineering geology issues pertinent to the conceptual designs. It will reference or summarize data and interpretations available to select the conceptual design, address those design and construction considerations which may have affected the selection, identify the need for additional analyses, data collection, or sampling and testing, and provide the designers with engineering geology issues to be considered or resolved as the design process continues.

GEOLOGY FOR DESIGN SUMMARY AND CONSTRUCTION CONSIDERATIONS MEMORANDUM

A design summary is prepared for Denver Office final designs. Geological considerations and other geological design documentation are provided to the coordinating design branch by memorandum. If geotechnical considerations are not presented in the specifications this memorandum shall be expanded into two parts: "Geology for Design Summary" and "Geology for Construction Considerations." The geotechnical considerations will be incorporated into the Design Summary for that feature by the Principal Designer.

The second part of this memorandum will be included in the printed "Construction Considerations" for a given specifications. The ACER Project Plan usually will specify when the design summary and construction considerations are to be furnished by the Branch coordinators. If not identified, this memorandum shall be written by the Principal Geologist and be in final form at the SPECD date and signed by the Division Chief no later than SPECB. A draft of this memorandum is required at SPECG for use by designers, review by the field geologists, and for preparing the final Design Summary and Construction Considerations.

Geologic considerations presented in both parts of this memorandum shall be discussed for each structure. A suggested outline for these discussions follows. Format and organization are at the discretion of the individual geologist(s) to accomodate site-specific geological conditions and design concepts. The "Geology for Design Summary" part shall document the sources of the geologic and seismotectonic data utilized in the design process, summarize or reference other geologic reports or data describing the known geologic conditions, and present or reference the final geologic considerations used for design and construction of the feature(s). Detailed descriptions are not necessary, nor are they desired, if they were adequately described in the Geologic Design Data Report and specifications paragraphs. However, if descriptions are necessary to substantiate or clarify geologic considerations, they are permissible. If required, the "Geology for Construction Considerations" part shall discuss the geologic implications for construction.

Part I—Geology for Design Summary

A. Introduction
   (1) Describe features being constructed.
   (2) Provide sources of geologic and seismotectonic data. Provide a list of reports, memorandums, etc. used for specifications paragraphs—reference specifications paragraphs or reports

for more detailed discussions. State that this memorandum documents what has been discussed with designers and documents those considerations reflected in the design and/or specifications paragraphs.

B. Regional Geology—Provide a *short* summary, not a repeat of specifications paragraphs.

C. Site Geology—Briefly describe geology, but be much less specific than specifications paragraphs, summarize only enough information to understand the implication of geology for the design and construction considerations. Regional geology and site geology sections may be combined under "Geologic Setting" (for example) when applicable.

D. Seismicity—Indicate what was used for design of structure(s). Reference Algermissen et. al. or Seismotectonic (D-1630) technical memorandum.

E. Geological Hazards Considerations.—If there no other significant geological hazards, this section may be combined with titled "Seismicity" and Geologic Hazards Considerations."

F. Engineering Considerations used for design or constructability considerations in specifications—geomechanical, geologic fluids, and geochemical and geothermal elements.

(1) Geomechanical (stability and deformability)—Specific engineering geology issues—discussed by feature(s) or topics, such as:

Excavation classification and/or excavation methods—controlled blasting, overbreak, special cleanup for mapping; stability—temporary and permanent cutslopes, excavation support, waste materials, etc.; deformability—differential settlement, overexcavation, etc.; and special conditions—monitoring, protection for slaking, heave, treatment.

(2) Geologic fluids element—Discuss groundwater occurrence and behavior—unwatering and/or dewatering, water testing, permeability, grouting, seepage, monitoring; and if present, describe other fluids, gasoline, toxic wastes.

(3) Geochemical and geothermal elements—Describe conditions such as corrosion, leaching of cementation, solutioning, and slaking (if not covered above).

G. Environmental Considerations—Degradation and aggradation of downstream channels, mud and dust, and environmental aspects of construction such as pollution of aquifers or running water by construction activities.

Part II—Geologic Construction Considerations

Considerations are addressed to the (project) construction engineer and staff. These considerations generally deal with effects of geology on construction, construction monitoring, safety, changed conditions, and geologic data collection or reporting.

A. Geologic Requirements During Construction

(1) Mapping, photographs, reporting in L-29, special reports or other required documents.

(2) Requirements for geologic monitoring or instrumentation of slides, cutslopes, or ground water.

(3) Notification of design team members for potential changed conditions or differences in design intent.

(4) Geologic or laboratory testing, sampling, or exploration.

B. Geologic Implications for Construction

(1) Potential geologic conditions that could affect stability, deformability, or conditions different than anticipated which would have to be evaluated, or determination of acceptable foundation conditions.

(2) Blasting, special excavation, trimming or protective measures required.

(3) Special mapping or need to inform others if specific conditions are found.

(4) Special foundation cleanup, inspections, or procedures required for geologic conditions.

(5) Above all do not ask the construction staff to require the contractor to do something in these considerations that has not been required in the specifications.

ENGINEERING GEOLOGY CONSIDERATIONS FOR DESIGN AND CONSTRUCTION TECHNICAL MEMORANDUM

This memorandum(s) documents the geological activities and considerations for design and construction used during the Design, Draft Spec, Review, and Final Spec stages of the total design process. The TM provides the resolution of issues identified by the Engineering Geology Considerations for Conceptual Design TM; documents additional data, analyses, or interpretations developed or reconsidered during later design processes; documents geotechnical considerations presented to designers and recommended solutions; and identifies geotechnical considerations to be discussed in the specifications, and may assist the designers and specifications writers preparing specifications documents.

The TM will be prepared by the Principal Geologist during the Design stage. In most cases, this will be a rewrite, in greater detail and certainty, of the earlier TM prepared prior to CONCEPTC. The memorandum must reflect the most current design parameters, and documents or summarizes all geological data and interpretations used for final design. The draft of this TM should be furnished to the Design Team, Branch Chief and field geologists for review and use no later than 10 days prior to DESIGNC. It is to be signed through the "prepared" signature on the TM cover sheet by DESIGNC. The final draft of the TM is due, signed through "technical approval" at SPECG. The memorandum should be signed through "submitted" by REVIEWC and "approved" by SPECB.

The content of this TM is similar to that for Part I of the Geology for Design Summary and Construction Considerations Memorandum.

SPECIFICATIONS PARAGRAPHS AND DRAWINGS

Geological portions of the specifications for Denver Office designs shall be written and prepared by the Principal Geologist and reviewed by the Regional and Project Geologist and other field office personnel. The review by field geologists may be either formal during the REVIEW stage and/or informal if the REVIEW stage is waived. Also, the total design process uses an internal Denver Office review process by the design team. Signatory approval of the paragraphs and drawings will follow the instructions contained in Chapter 7 and appropriate field office or Denver Office directives.

Unless otherwise identified and agreed to in the ACER Project Plan, a draft of the specifications paragraphs and drawings is to be furnished to the coordinating specifications section (D-263 or D-270A) on or before the SPECG date (5 weeks prior to SPECD). A hard copy of the paragraphs and a copy of a COMPUCORP disk are provided with drawings signed through technical approval. At an agreed upon number of days prior to the SPECD flag any revised paragraphs and a specified number of prints and/or reproducibles of the geologic drawings are to be provided to the field offices for formal review.

After the Review stage, the drawings and paragraphs are revised as necessary, submitted for approval, and forwarded to D-263 or D-270A prior to SPECB.

The format of the specifications paragraphs may vary greatly depending upon number, size and type of structure(s), quantity and quality of data available, geologic complexity and type of solicitation such as advertised or negotiated, and Construction Specifications Institute (CSI) or Federal Acquisition Regulations (FAR) format.

Reclamation is responsible for determining the type, quality, and amount of design data necessary to produce adequate designs and to define construction. The meaning and significances of the geologic data are to be interpreted in preparing the designs and specifications. These interpretations, their significance, and associated geotechnical implications for construction, should be presented in the specifications. Specifications can be prepared which reflect our knowledge and understanding of site conditions and how they may impact construction, and which convey to the bidders, the contractor, and our construction personnel, the known and anticipated conditions and work requirements. Also, they can define those areas where uncertainties exist that may require changes during construction.

To improve the quality of Reclamation specifications and clarify the intent, the use of disclaimers and "as directed" clauses is being reduced and interpretation of geologic data and the conditions expected to be encountered during construction are being provided in the specifications. The use of "as directed" and disclaimer statements should be avoided whenever possible. "As directed" provisions allow for work under the contract that cannot be fully specified until the work is underway. Excessive use of these statements can infer greater unknowns and contractor risk than appropriate, resulting in higher bids. Whenever possible, work requirements conditions and desired sequencing should be fully specified. If this is not possible until the actual site conditions are disclosed, the specifications should describe the conditions that will establish a basis for determining the work requirements. Specifications language disclaiming responsibility for data presented in the specifications should not be included.

When the specifications are prepared in this manner, a Construction Considerations document need not be prepared. Prior to construction, the Design Team should brief the construction staff on design intent, construction considerations, and specifications provisions.

An example of a possible format for specifications is:

Division 1—Geologic Investigations (Narrative)
- A. General—"Boilerplate"
- B. Geologic Description
  - (1) Regional Geology (Very brief summary or can be combined with site geology as "geologic setting")
  - (2) Investigations—Explorations
  - (3) Site Geology (Alignment Geology)
    - a. General (May include terminology and description of units or geologic structures and refer to drawings)
    - b. By structure or portion of an alignment (This may be part of other divisions in the specifications)
  - (4) Ground Water and/or Water Occurrence and Behavior
  - (5) Special Conditions (Caliche, oversize, gasses, caving, saving of certain instrumentation or observation holes, seismicity [only included where pertinent to construction if significant seismic hazards are present])

(6) Testing and Sampling (References summaries of physical properties or other special testing)
(7) Construction Materials
C. Geotechnical Considerations (Included in Division 1 unless covered in other divisions such as Excavation, Control of Water, Grouting).

Division ____ — Records of Subsurface Investigations (Different format by type of structure, includes Logs of Exploration, Geophysical Surveys, Photographs, Summaries of Physical Properties, Test Results and Geologic Drawings.)

The Records of Geologic and Subsurface Investigations and Records of Construction Materials and Foundation Materials Test Data divisions are provided for if large quantities of data accumulated during the investigation and design process are determined to be of potential value to the bidders. The Principal Geologist, Materials Specialist and Principal Designer, with input and concurrence from the line organization, will determine whether these divisions are added. Drawing lists for Denver Office specifications/solicitations shall be prepared in accordance with ACER Memorandum No. 31, and *Contents Guide for Construction and Supply Solicitations / Specifications.*

GEOLOGIC REQUIREMENTS DURING CONSTRUCTION MEMORANDUM

The Geologic Requirements During Construction Memorandum is to be prepared by the Principal Geologist for the Chief, Division of Construction's signature. The memorandum will set forth those geologic requirements during construction, such as necessary documentation, mapping, analyses, notification, and monitoring. These discussions should elaborate on the general requirements presented in *Reclamation Instructions, 171.6,* but not repeat them. It shall define for the Contracting Officer's representative(s) at the site the geologic requirements during construction, the reasons for and the requirements for any cleanup, mapping, additional exploration, interim report submittals, monitoring of geological instrumentation, miscellaneous documentation, concerns for safety or changed conditions, and final report requirements (if any). Construction geology programs are a continuation of the total design process, and should be completed to the extent necessary for the type of structure, complexity of geology, and available resources. Preparation of this memorandum by the Principal Geologist should be the final product of discussions with the field geology staff and design team. The memorandum is to be transmitted as early as possible after SPECB, and in all cases at least 2 months prior to the AWARD date.

FOUNDATION ACCEPTANCE REPORTS

Foundation acceptance for structures other than dams is delegated to the field construction office unless otherwise agreed upon at the REVIEWC briefing. In such cases, the project construction staff will inspect and document foundation conditions, and immediately communicate unexpected or questionable conditions to the Design Team.

Reclamation Instructions requires Design Team acceptance of foundations for dams. Design Team representatives involved in foundation approval may include the Principal Designer, the Principal Geologist, and engineers involved in foundation or structure design. Dam foundation acceptance by Design Team representatives should be based on first-hand knowledge, and therefore, cannot be delegated.

After a significant portion of the foundation is exposed, geologically mapped, and prepared for fill or concrete placement, appropriate Design Team representative are to thoroughly examine the foundation for conformance with design intent. The team will prepare a Foundation Acceptance Decision Memorandum on foundation acceptance referencing available drawings, photographs, tabular data and/or video tapes. If required, this memorandum should contain stipulations concerning additional work that must be completed prior to fill or concrete placement.

The foundation acceptance process shall incorporate areas as large as practicable to reduce travel and paperwork, but shall be repeated as often as necessary to ensure that the design intent is accomplished for the entire foundation. Each foundation acceptance will be documented by a Decision Memorandum signed by the Design Team members who are accepting the foundation. The PCE or designated representative also will sign the Decision Memorandum, concurring that the foundation has been prepared in accordance with the specifications and that additional work identified by the Design Team will be performed. If the acceptance of a foundation area is by telephone, the Foundation Acceptance Decision Memorandum will be the same except PCE concurrence will be obtained by telephone and so noted.

The Decision Memorandum shall be prepared before the Design Team leaves the project or immediately after foundation acceptance by telephone, and distributed to all interested parties within 2 working days. Copies will be sent to all involved Design Team members, the PCE, the RD, and ACER, technical review, and involved ACER Division and Branch Chiefs. Those who receive copies of the acceptance reports should bring their concerns to the attention of the Design Team immediately.

After acceptance of the entire foundation for a dam, the PD will prepare a Foundation Acceptance Summary Memorandum which will summarize data from all Foundation Acceptance Decision Memorandums and verify completion of the foundation acceptance process.

CONSTRUCTION GEOLOGY REPORTS

This report shall be written by Project or Regional Geologists in accordance with *Reclamation Instructions, 171.6*. The Principal Geologist shall review, approve, and prepare a written response to the originating office within 20 working days after receipt of the report.

MISCELLANEOUS GEOLOGICAL REPORTS

Geological data requirements for Denver Office specifications are transmitted formally by the final Geologic Design Data Report. Field offices are responsible also for the preparation of various geological reports for MDA (Modification Decision Analysis) investigations, CAS (Corrective Action Studies) investigations, and various levels of planning or special studies. It is recommended that these reports generally be similar in format and content to the Geologic Design Data Report, as described in Chapter 9. However, depending on the scope of the investigations, the time frame, and monetary and staff resources involved, especially if adequate data reports or construction geology reports are available, the content of MDA and CAS reports should be evaluated by the Principal Geologist and field geologist(s) to reduce or eliminate redundant information, or information that is not pertinent to the MDA or CAS issues.

This method will be more cost effective in both time and monies. Data previously identified and distributed should be referenced or very briefly summarized. However, if the latest investigations alter previous conclusions or refine geological conditions, revised drawings and descriptions are to be provided.

Chapter 9

GEOLOGIC DESIGN DATA REPORTS

OBJECTIVES OF THE GEOLOGIC DESIGN DATA REPORT

This chapter sets forth the guidelines to be used in the preparation of the Geologic Design Data Report for specifications. This report is a prerequisite to initiating designs for specification as stated in *Reclamation Instructions, 133.3 and 133.4,* Design Data Requirements and the Total Design Process. Because the report must be approved by ACER for Denver Office designs, it is in the best interest of both the originating office and the Principal Geologist to coordinate and cooperate continually during data collection and report preparation so that omissions of required data or last minute problems do not arise that might delay submittal or approval and subsequently delay specifications preparation. Input to the report must be sought from all involved.

The intent of the Geologic Design Data Report is to: (1) formalize the submittal of geologic design data; (2) furnish geologic information to the Design Team at the start of design; (3) provide geologic design and construction considerations; and (4) submit the geologic design data to a review process to ensure technical adequacy. The formal submittal of the report is not to be construed as the only geologic data submittal. Interim transmittals of data during the exploration program are necessary to evaluate continually the progress and potential revision to exploration programs and early analysis of design concepts, but these interim submittals do not substitute for a final Geologic Design Data Report.

SUBMITTAL OF THE REPORT

The Geologic Design Data Report is due on an agreed upon date, usually one month prior to the CONCEPTC flag on the Denver Office Specifications Schedule. This date should coincide with the "Geology" date on the region's Design Program Data Sheet. By necessity, and in accordance with the Total Design Process, several interim data transmittals with geologic drawings and logs, with or without extensive narrative descriptions, normally will be submitted, early in the process. However, for some designs the collection of geologic design data will continue well into the design (SPEC) phase. If explorations are incomplete, a Geologic Design Data Report submitted at the CONCEPTC date and a Supplement to the Geologic Design Data Report or an Amended Geologic Design Data Report are required at a later date as discussed below.

If agreement is reached that both an original and amended report(s) are required, the reports must be submitted to the review process. Also, they must be complete and address all the required geologic design data, data collections, conclusions, and geologic considerations as of the date of their submittal. If the initial report is submitted on the CONCEPTC date, then the amended report or supplement will be due as agreed upon by the Design Team and the appropriate field offices. The use of supplements is discouraged. However, if special studies or additional exploration occur after the amended report has been prepared, subsequent exploration data would be submitted by supplements. These procedures will allow the report(s) to discuss results of exploration for final designs rather than feasibility or preliminary design concepts, and would eliminate the discussion of additional studies and renumbering of stations on logs of exploration due to changes of alignment.

Early scheduling of the geologic investigations program and the early delegation of responsibilities for the preparation of the Geologic Design Data Report will greatly facilitate the timely completion of the program and ensure proper participation (Chapter 8). Every attempt should be made to complete all or a significant portion of geologic explorations prior to the CONCEPTC date. If it becomes apparent during the exploration program that the investigations will not be completed according to the schedule, the Principal Geologist and/or ACER contact shown on the ACER Field Exploration Request should be notified so that the Design Team can assign priorities to the remaining investigations, if necessary. Data collected prior to submittal of the Geologic Design Data Report may be transmitted officially or informally to the Principal Geologist.

Data submitted informally or officially in "preliminary" form must still be resubmitted in the formal submittal of the Geologic Design Data Report. If additional investigations are to be performed during the design phase, they should be directed to answering specific engineering geology issues or to specific explorations and should be accomplished in time to meet the Design Team's needs. These later investigations should be defined in the report. If the additional work cannot be clearly stated or defined, or the investigations have not proceeded to a point where a meaningful report can be prepared, the CONCEPTC or PRELIMC date(s) may have to be slipped. The impact of this slippage upon the other schedule dates will be evaluated by the Design Team and/or Project Management Team. They either recommend slippage of the subsequent flag dates or proceed with the designs without the required data.

A construction materials report may be submitted separately from a Geologic Design Data Report. However, construction materials data relevant to the geologic data should be included as part of the geologic design data. The construction materials report can be submitted as an appendix to the Geologic Design Data Report if the Design Team and project or regional offices agree it is appropriate. The geologic content of the materials report will then be subject to the same approval process as the geologic design data.

Review of the Geologic Design Data Report by the Principal Geologist and the Regional or Project Geologist should take place prior to the submittal date. This review must take place early enough before the due date to incorporate any changes or revisions. This review may consist of round-table discussions for the more complex geological settings. Approval of the report will be by memorandum. For ACER designs, sufficient copies (three to seven as determined by the needs of the Denver Office and conveyed to the originating office by the Principal Geologist) of the approved report should be transmitted for distribution.

The geologic specifications paragraphs, drawings, and Records of Subsurface Investigations will be prepared by the Principal Geologist from data presented in the approved Geologic Design Data Report.

GENERAL COMMENTS ON THE REPORT

Content of the Report

The Geologic Design Data Report should contain all the necessary geologic information and evaluations required to design all the features and to prepare specifications for bidding and constructing a facility. Other chapters of this manual discuss or provide guidelines for terminology, description, collection, and presentation of geologic information. The information contained in the report must represent established geologic concepts and be capable of being substantiated by sound geologic reasoning. Geologic evaluations and interpretations are necessary in engineering geology and should be well developed and used in the report to address adequately the geologic conditions and engineering geology issues at the site. However, these evaluations and interpretations should not be stated or represented as an established geologic fact.

The authors of the report and a geologist from the region who is familiar with the job should provide critical review of the narrative, the logs of explorations, the drawings, and any test data sheets for content, adequacy, and consistency in terms and numbers.

Drawings

Drawings should be prepared as standard-size drawings to facilitate their incorporation in or adaptation to the specifications. Oversize drawings may be used during the data collection phase if necessary; however, if used for specifications, they usually will be cut to standard size, using match lines. The set of geologic drawings should include a drawing title "General Geologic Legend, Explanation and Notes," which is the major reference for the other geologic drawings. Appropriate symbols and explanations or notes should be used to portray and qualify subsurface geology to properly represent interpretations.

All plan and section drawings should be prepared in accordance with Chapter 7, interpretation and presentation of Geologic Design Data which includes the drafting standards and symbols for geologic drawings, and current *Reclamation Instructions* for drafting standards, Series 130, Part 134.

General Outline

A general outline for a Geologic Design Data Report follows. This outline may vary from site to site because of type of structure (e.g., dams, tunnels, canals) or geology. Therefore, judgment and discretion must be exercised in the preparation and formulation of the report.

Title page
Approval page
Preface
Table of contents
- List of plates, photographs, drawings, drill logs, material test data

Introduction
- Purpose
- Location
- Proposed structures
- Topographical data base

Geologic investigations and data base
- Previous investigations
- Current investigations
- Testing and sampling

Regional geology
- Stratigraphy
- Structure
- Regional ground water

Seismicity and other natural geologic hazards
Reservoir geology
- Catchment area
- Geology
- Water-holding capability
- Known landslides and rim stability

Site geology
- Stratigraphy
- Structure
- Geomorphology
- Ground water

Geologic considerations
- Engineering
- Geologic hazards

- Environmental
- Economic
- Operation and Maintenance

Additional investigations
References
Appendixes

- Testing and sampling data
- Exploration logs
- Drawing
- Photographs

Comments on General Outline

Title Page.—See example at the end of this chapter.

Approval Page.—The approval page provides signatory approval by the author(s) and, depending upon regional policies and delegation authority, by the Project Geologist, Project Construction Engineer, Regional Geologist, or others (see example at the end of this chapter). Additional signatory approval will completed by the Denver Office either by insertion of the approval memorandum or signatures and titles.

Preface.—A preface is a statement written by the author giving credits and acknowledgements, and the names of the geologists who contributed to the report.

Table of Contents.—A table of contents lists the heading appearing in the report with the relative rank of heading indicated by indentation. Under the table of contents list all photographs, figures, drawings, drill logs (with photographs if included), logs of other explorations, materials test data, and other test and geophysical data. Anything interspersed in the text or included in an appendix must be listed, including a complete log.

Introduction.—The introduction should state the purpose of the report and the location of the site and proposed structures. The introduction should also include a project location map showing the features and, if available aerial photographs showing the general area. The source, scale, detail, and feature adequacy of the topographic and geologic maps used for the program should be mentioned in the introduction.

Geologic Investigations and Data Base.—This section should include reasons for conducting all geologic investigations such as drilling, testing, mapping, and geophysics, whether performed by Reclamation, other agencies, or individuals and any previous construction work pertinent to the area under consideration. A statement that other data about the site from previous reports are included in the report. Reference also should be made to selected reports pertaining to the geology of the area prepared by other organizations or persons. Include descriptions of all geologic or geophysical field testing, sampling, and other studies done pertinent to the site. The raw data should be included in the appendix.

If a report by the Division of Research and Laboratory Services or other laboratory has been or will be prepared on some or all of the testing and sampling, the report(s) should be referenced by all of the information not duplicated in the Geologic Design Data Report.

Regional Geology.—Knowledge of the regional geology is of value as it helps provide a conceptual model to assist in interpreting the results of an exploratory program and in extrapolating from known data. It also provides a basis for comparison with other similar sites. It also is helpful when the project exploration is developed initially.

The regional geology should be written in succinct paragraphs that are relevant to the site. Illustrations and references should be cited as appropriate.

Seismicity.—For critical structures, the Seismotectonics and Geophysics Section at the Denver Office will prepare an earthquake hazards evaluation of the site. The need for scheduling a separate seismotectonic report will be determined at the start of the design data collection. In the Geologic Design Data Report, mention should be made that this work has been completed or is scheduled for completion by a certain date (usually the CONCEPTC or PRELIMC date).

For noncritical structures, a description of the historical earthquakes and related ground motions which have affected the site or project area should be presented. Discussions should include historical movement on faults, historical seismicity in the vicinity of the site, and any known geologic evidence pertaining to ages of fault displacement. Also, indicate the level and probability of ground shaking at the site from *Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States* [1]. An excellent reference for historical earthquakes is *Earthquake History of the United States* [2].

Reservoir Geology.—If appropriate, reservoir site study should be included and should be conducted in accordance with Chapter 10, Reservoir Site Geologic Studies. This section should describe the catchment area, geology, water-holding capability, and rim stability.

Site Geology.—Site geology is the recognition and delineation of specific geology in the area of the particular features to be constructed. Separate sections may be written for the various features. The site geology includes a description of the local stratigraphy and structure which will be encountered during construction and the quality and characteristics of the foundation materials. This should include discussions of detrimental qualities or planes of weakness such as joints, faults, and shear zones; weathering; surficial deposits to be encountered, excavated, stockpiled, or wasted; ground water; and any special conditions such as landslides, expansive or dispersive materials, subsidence, presence of oil or gas, and mineral extractions. In the discussion, refer specifically to geologic drawings (plans and sections), logs, test data, tables and photographs of particular geologic conditions, all of which should be included in the report. Avoid ambiguous words, such as *probable, any, maybe, perhaps, apparent, can, should* and *could be*. Terms should be defined and consistent between the narrative and supporting data. The liberal use of photographs is encouraged.

Geologic opinions, interpretations, or conclusions used to influence the designs are to be provided in the report. They must be defensible. Supportive documents include text books, technical papers, training, mapping, and photographs. The geologist must continually conceptualize and hypothesize the subsurface conditions to better comprehend and describe the impact of geology upon the design and construction of the features and to better direct the investigation effort.

If ground water or other special considerations, such as landslides, faulting, or subsidence, are considered to be of particular significance, they may warrant a main heading and complete discussion. For example, under the heading, "ground water," describe the nature of the aquifer(s) indicating any perched, artesian, or seasonal water tables and water-level fluctuations. Refer to percolation or permeability tests, water-level readings, hydrographs, or related charts of information. If water-level measurements were obtained at completion of drilling, indicate whether or not the hole was bailed prior to measuring. Ideally, these measurements should be made over a significant time period to determine seasonal fluctuations.

Geologic Considerations.—The intent of this section is to discuss separately all the geologic issues pertinent to the design and construction of the engineering features and to present an evaluation of the issues. The geologist should address the geologic condition to be encountered, stressing identifiable problems, presenting solutions or recommendations and the need for monitoring or verification, particularly during construction. Generally, the discussion of issues should be on a structure-by-structure basis. Chapter 6 provides a checklist for the more common issues. In the discussion of each issue, one should note if particular statements or information regarding any aspect of an issue should be included in the specifications to clarity the geologic conditions or emphasize potential construction problems for the bidders. These discussions will constitute a major portion of the report.

For most major structures, the Principal Geologist will prepare a final memorandum describing the geologic design and construction considerations after all design concepts and criteria are known. This memorandum will reference all geologic data used in the design including the Seismotectonic Report and the Geologic Design Data Report.

Cooperation between all involved offices in the preparation of the geologic design and construction considerations is essential, and issues should be defined and resolved as early as possible.

Additional Investigations.—Any geologic investigations which are to be performed after preparation of the Geologic Design Data Report should be discussed.

References or Bibliography.—Pertinent references or a bibliography should be included.

Appendixes.—Appendixes should include all supportive data not included in the body of the report.

OTHER GEOLOGIC DESIGN DATA SUBMITTALS

Interim Geologic Specifications Data Submittals

Usually, data requirements, exploration requirements, and flag dates for various formal interim submittals are established by the appropriate Design Team. Format and content for interim reports may be very abridged, or they may be similar to the format and content of the Geologic Design Data Report. Regardless of how they are structured, all of the preliminary data and conclusions must be finalized in a data report. All concerned must be cognizant that the final product, or products, are a matter of record for construction contracts. Previous interpretations or geologic considerations presented in interim reports must be appropriately referenced, revised, or superseded by the Geologic Design Data Report or supplement.

Geologic Design Data for Nonspecification Designs or Studies

Geologic data may be submitted as a part of the "engineering data" package, as an appendix to it, or as a separate report depending upon the agreed upon requirements of the Site Review or Design Team, and the quantity of available data.

The previous discussions pertaining to the report format and submittal requirements are established for geologic studies and exploration programs conducted for producing contract specifications. Similar format and content may also be pertinent to planning reports. Although exploration may be limited, is no longer state-of-the-art, or is nonexistent, the content of the report should be developed, as well as possible, and similar format is desirable. Interpretative drawings and engineering geology conclusions for proposed design concepts or construction should be developed and discussed if sufficient data are available.

Exploration programs conducted for various SEED/SOD or O&M investigations also may be structured similar to the specifications, Geologic Design Data Report. Appropriate additional discussions, or the omission of some items not relevant, may be necessary depending on the scope of the investigations and quality of known geologic data available.

BIBLIOGRAPHY

[1] Algermissen, S. T., D. M. Perkins, P. C. Thenhaus, S. L. Hanson, and B. L. Bender, *Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States*, Open-File Report 82-1033, United States Geological Survey, 1982.

[2] *Earthquake History of the United States*, Publication 41-1, rev. ed. through 1970, National Oceanic and Atmospheric Administration, 1973, and the 1971-1976 Supplement, 1979.

GEOLOGIC DATA REPORT
(Appropriate title for scope of study)

for

(FEATURE)

(PROJECT)

(STATE)

(AUTHOR)

(DATE)

United States
Department of the Interior
Bureau of Reclamation
(Office)

Figure 9-1. – Sample title page.

Bureau of Reclamation
(Office)

Figure 9-2. – Sample photograph of job site page.

This Geologic Design Data Report was prepared in the ____(Office)____ by:

____(Name)____ **____(Name)____**
(Title) **(Title)**

____(Name)____
(Title)

Field approval by:* ____(Name)____ **____(Date)____**
(Title)
(PCE/Regional Geologist, etc.)

(Lower half of the page blank for entries by Office of the ACER)

*** Field approval per Regional policy.**

Figure 9-3. – Sample approval page.

Chapter 10

RESERVOIR SITE GEOLOGIC STUDIES

GENERAL

The geologic adequacy of a proposed reservoir site is as important as the adequacy of a damsite foundation; reservoir-wide investigations must be planned with comparable care. Concurrent study of both reservoir and damsite(s) is best. If a major defect is uncovered in one or the other, investigations can be reoriented or stopped before a disproportionately large exploration investment accrues on a site which might or must be abandoned.

In evaluating and exploring the reservoir geology, attention must be given to all factors which affect reservoir adequacy or use. Principal factors are rim stability, water-holding capability, lateral ground-water storage, and potential sources of pollution. In addition, geologically related problems of relocation of highway, railroad, and other physical facilities must be considered. The degree of attention given to each of the several problems should be appropriate to its importance and to the stage of planning. The detailed character of investigations will, of course, be determined by the purpose of each specific reservoir. A geologic and topographic description of the reservoir catchment area also provides valuable information on runoff characteristics, stream sediment and bedload, and water quality.

Reservoirs are classified by function as:

- Storage reservoirs;
- Flood-control reservoirs;
- Evaporation reservoirs; and
- Infiltration reservoirs (percolation ponds).

A **storage reservoir** holds water for future use and the loss of water must be kept within acceptable limits.

A **flood-control reservoir** temporarily stores floodwater. Water losses are not important if structural or human safety are not endangered.

An **evaporation reservoir** holds water, e.g., saltwater, wastewater, for evaporation and is normally watertight.

An **infiltration reservoir** recharges the ground-water system, and seepage is encouraged if a safety hazard is not created.

The intended use of a reservoir must be kept in mind when evaluating its water-holding capability. A site which is not suitable for a storage reservoir may be entirely satisfactory as a flood-control reservoir.

Reservoirs may be classified hydrologically into three major categories:

- Perched reservoir;
- Semiperched reservoir; and
- Confined reservoir.

This classification is very basic, and any given reservoir may incorporate more than one type and may be classified from one to another because of the geology, hydrology, and topography of the reservoir area.

The floor of a perched reservoir is above the normal ground-water table. The water-holding capability of the reservoir depends upon the reservoir floor and rim being impervious or the permeability of the bedrock and surficial deposits beneath the reservoir being low enough to enable a ground-water mound to build up beneath the reservoir. This reservoir condition is common in many climates. The amount of seepage from the reservoir necessary to build and maintain the ground-water mound must be evaluated as a water loss.

The floor of a semiperched reservoir is adjacent to the original ground-water table. The ground-water table may slope gently away from or toward the valley. Again, like the perched reservoir, the water-holding capability of this type reservoir depends upon the reservoir floor and rim to impede the flow of water away from the reservoir. Semiperched reservoirs are common in the arid regions of the Western United States.

A confined reservoir occurs when the reservoir lies entirely within a depression of the ground-water table, except in the vicinity of the valley barrier (dam). The original ground-water table rises above the reservoir rim and provides a natural barrier to the movement of the impounded water away from the reservoir.

The reservoir bank storage should be discussed in the Geologic Design Data Report, the Design Summary and Construction Considerations.

GEOLOGIC STUDIES FOR RESERVOIRS

Basic Requirements for Reservoir Geologic Maps and Studies

On geology maps prepared for engineering and related geologic studies, the range of data to be shown and the scale to be used will be determined by: (1) the purpose of the investigations; (2) the detail that can be shown; and (3) the extent to which quantitative data must be presented or derived from the map such as distances, volumes of potential slide masses, thickness of formations, differences in elevation, or details of formation or outcrop boundaries. Choice of a suitable scale is important since it influences details shown and legibility of the map.

In large-scale regional or project maps, the principal objective is to present a graphic picture of the general distribution of major site conditions; these may be geologic as well as existing manmade features such as highways and railroads, proposed dams, tunnels, or other engineering structures. In contrast, small-scale or site maps are detailed representations of geologic features. In the two types of maps, scales may range from 1 inch equals 10 miles (small scale) to 1 inch equals 20 feet (large scale). The usual reservoir map scale ranges from about 1 inch equals 2,000 feet to 1 inch equals 400 feet.

The reservoir geologic map(s) may not be restricted to the immediate area of the proposed reservoir. It must be supplemented by a regional-type map which will demonstrate the reservoir position, elevation, and distance to adjacent valleys. As a minimum, this map should show ridge and valley outlines with elevations.

The reservoir geologic map may be supplemented by several specialized maps or overlays and/or by larger scale inserts or separate maps showing detailed geologic conditions in critical areas of potential seepage or landslides. Similarly, small-scale skeleton inserts may be used to show gross relations of topographic saddles and adjacent drainages. Supplemental maps, charts, or graphs portraying regional ground-water contours or data (estimated if necessary) are desirable, particularly if potential leakage or anomalous ground-water conditions exist. Geologic sections and overlays showing generalized geologic structure, landslides, faults, and buried channels, also should be prepared.

The basic reservoir mapping, at least on a reconnaissance basis, must extend above the maximum reservoir level to characterize the geologic environment and facilitate evaluation of reservoir-rim stability and water-holding capability. In local areas of the reservoir, more detailed mapping may be necessary to define landslide or leakage problems. In many cases, this will be required only in critical areas.

Only in certain types of terrain will the entire reservoir require detailed mapping and study. Commonly, the study and detailed mapping will be accomplished only as needed to establish the geologic adequacy and principle defects.

Methods of Investigations

Field examinations and air photograph interpretation are the basic methods by which geologic data are secured and collated on map(s) and section(s) for study and interpretation. The reservoir geologic map is the initial and principal medium through which geologic studies are planned or conducted and by which the nature and scope of reservoir defects are recognized and evaluated.

The map may range from a sketch presenting the composite mental concept developed by a geologist during early reconnaissance and appraisal field studies, to a complete, detailed delineation of lithologic and structural features for advanced planning and final design. Whatever the stage, the product is a combination of fact and interpretation which, from an engineering geologic viewpoint, defines the geologic environment and aids in recognizing geologic defects or issues. Direct subsurface investigations such as drilling and trenching may or may not be a part of the overall study. Hydrogeologic conditions must be considered and defined. Thus, an effective reservoir map is more than a representation of surface information. It also should show selected subsurface interpretations of geologic and ground-water conditions which characterize the reservoir site.

A variety of techniques or investigation approaches can be used in conducting reservoir studies. The annotated outline which follows is presented simply as a checklist of principal techniques which will assist even an experienced geologist in recalling or selecting the several investigation methods which will be most effective in conducting a specific reservoir site study.

Geomorphic Interpretations.—Stream patterns, topographic and geologic maps, and aerial photographs can provide information such as:

- Geologic features and structure, regional and local joint patterns, location of geologic contacts, sinkholes, and subterranean drainage;
- Glacial, fluvial, and aeolian deposits;
- Aggrading and degrading stream history;
- Sources for embankment materials;
- Ground-water conditions; reservoir leakage potential; and
- Existing and potential landslides.

Hydrogeologic Studies.—Hydrogeologic studies yield information or require analyses such as:

- Fundamental ground-water conditions, i.e., whether water bodies are perched, confined (artesian), unconfined;
- Ground-water velocities, direction of flow, elevations, and contours of static and piezometric

water levels, which can be determined using methods such as borehole water level measuring devices, down hole flowmeters, dye and radioisotape tagging, and water sampling and analysis;

- Ground-water ages (relative) as determined by tritium, carbon dioxide, or dissolved oxygen content;

- Differentiation of ground-water bodies and evaluation of water quality by chemical analyses (analyze graphically by Stiff diagrams), conductivity, pH, and temperature studies;

- Flow estimates or measurements of springs and small watercourses. Data such as spring flow and volume, and ground-water levels in drill holes may be essential to define changes in the original ground-water conditions due to reservoir leakage. Data collection must be started and completed in advance of reservoir filling to establish the character of normal prereservoir conditions. Measurements of hydrostatic head may be necessary to judge whether spring flow may be reversed when subject to reservoir head.

- Estimates of reservoir bank storage and inflow and outflow seepage rates.

Subsurface Investigations.—Subsurface investigations may include geophysical tests. Bailing tests in drill holes are performed as need to determine water-table elevations and movement. Water pressure testing using packers and pump-out tests are performed to estimate permeability. Exploration drilling may be performed to obtain landslide thickness (slide plane data), as well as the depth and nature of surficial material in saddles, location of buried channels.

Collection and Presentation of Data

In the following discussions are some geologic conditions which must be considered in field examinations and mapping for the average reservoir. Those conditions actually selected for investigation or, because of their bearing on reservoir problems, for presentation on specific reservoir geologic maps will depend on a variety of factors, some of which were outlined in previous paragraphs.

Distribution of Bedrock and Surficial Deposits.—Studies should differentiate between major areas or surficial deposits such as talus, slope wash, alluvium, and glacial deposits. Particular attention should be given to differentiating and mapping those units which will have different or adverse engineering properties. Areas or materials which will be susceptible to erosion by wave action are to be delineated.

Discontinuities and Structural Features.—Regional joint systems and localized joint patterns should be determined. Their attitudes as well as those of bedding or foliation are to be described and shown on maps, particularly in areas of proposed construction and in the vicinity of existing or potential landslides.

Stress relief joints, fractures patterns, and major structural features are significant and are to be shown.

Major faults, shear zones, and lineaments should be identified early in the data collection process. Relative ages and structural relationships are to be noted so that seismotectonic evaluations may be performed early in the design process.

Ground-water Occurrence and Behavior.—Artesian wells, pumped wells, springs, seeps, swamps, and ephemeral lakes are to be located.

Mineral Resources.—Mineral prospects and claims; active and inactive drifts; mines and quarries; sand and gravel pits; oil and gas wells; waste dumps; and other resource development or potential development are to be discussed and features identified on the reservoir map(s).

Observed and Potential Geologic Hazards.—Observed and potential subsidence, settlement, and reactivation of faults resulting from man's activities, such as hydrocarbon and ground-water withdrawals, or reservoir-induced effects, are to be addressed.

Landslide and Rim Stability.—Identify existing and potential landslides, state whether active or inactive, and show boundaries. Describe slide debris, estimated slide depth, and site geologic conditions. Estimate depths and volumes for use in judging right-of-way requirements, freeboard requirements, and locations of other features. Provide recommendations regarding treatment, stabilization or removal.

Reservoir Integrity and Potential Leakage.—Ridges and saddles between the reservoir basin and adjacent valleys and drainage ways should be examined. Physical properties of the materials and geologic structure in these areas should be determined. This includes the position of permeable or soluble formations or joint systems which will be exposed to reservoir water and which bypass the damsite and grout curtain or extend into adjacent valleys. Saddles frequently indicate faulting and should be investigated thoroughly for potential leakage.

Buried channels that may bypass the damsite or lead out of the reservoir basin should be identified.

Anomalous ground-water levels may be an indicator of potential reservoir leakage paths. Therefore, static water level measurements are essential for the determination of reservoir leakage.

Sources of Contamination of Reservoir Water.—The potential for contamination of reservoir waters by soluble materials such as halite, gypsum, alunite or arsenic-bearing ores, mill tailings and mine dumps, acidic mine water, oilfield brines, industrial waters, selenium and animal waste should be ascertained.

GPO 857-040