NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **33**

ACQUISITION AND USE OF GEOTECHNICAL INFORMATION

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
CONSTRUCTION
EXPLORATION-CLASSIFICATION (SOILS)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1976

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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PREFACE

There exists a vast storehouse of information relating to nearly every subject of concern to highway administrators and engineers. Much of it resulted from research and much from successful application of the engineering ideas of men faced with problems in their day-to-day work. Because there has been a lack of systematic means for bringing such useful information together and making it available to the entire highway fraternity, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize the useful knowledge from all possible sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series attempts to report on the various practices without in fact making specific recommendations as would be found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available concerning those measures found to be the most successful in resolving specific problems. The extent to which they are utilized in this fashion will quite logically be tempered by the breadth of the user's knowledge in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis is recommended to soils engineers, materials engineers, design engineers, construction engineers, and others involved in the acquisition and use of geotechnical information in route selection, design, and construction of transportation facilities. Information is presented on current practice in such matters as planning, conducting, and presenting information from geotechnical investigations; the equipment, procedures, and selection of sampling locations for geotechnical investigations; and the structuring and positioning within the agency framework of the organization that must acquire and use geotechnical information. Standardized sampling and testing procedures available from textbooks and published standards are not treated.

Administrators, engineers and researchers are faced continually with many highway problems on which much information already exists either in documented form or in terms of undocumented experience and practice. Unfortunately, this information often is fragmented, scattered, and unevaluated. As a consequence, full information on what has been learned about a problem frequently is not assembled in seeking a solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem. In an effort to resolve this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of synthesizing and reporting on common highway problems—a synthesis being identified as a composition or combination of separate parts or elements so as to form a whole greater than the sum of the separate parts. Reports from this endeavor constitute an NCHRP report series that collects and assembles the various forms of information into single concise documents pertaining to specific highway problems or sets of closely related problems.

State highway and transportation agencies universally recognize the need for the application of geotechnical information in the processes of route selection, design, and construction of transportation facilities. The information is used in all of the several stages of project development, inclusive of corridor studies, route selection, preliminary and final design, advertising and bidding, and construction. The extent of use in any of the stages, however, varies widely among agencies. Wide variations also exist in the status and structure of the organizations that are assigned the responsibility for acquisition and use of geotechnical information. This report of the Transportation Research Board provides sufficient information on existing practices to allow comparison by highway and transportation agencies of their geotechnical information gathering and use practices with those of others to determine whether or not they are taking full advantage of the possibilities available to them.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from many state highway and transportation departments, contractor associations, and contractors. A topic advisory panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that which is now at hand.

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Valuable assistance in the preparation of this synthesis was provided by the Topic Advisory Panel, consisting of William A. Corn, President, Southwest Constructors & Engineers; Richard G. Elliott, Deputy District Director, System Operations, California Department of Transportation; David S. Gedney, Chief, Construction and Maintenance Division, Office of Highway Operations, U. S. Department of Transportation; John R. Kohnke, Assistant New York Area Manager, S. J. Groves & Sons Company; Clyde N. Laughter, Chief Soils Engineer, Wisconsin Department of Transportation; Wesley P. Moody, Associate Soils Engineer, New York State Department of Transportation; David L. Royster, Chief of Soils and Geological Engineering, Tennessee Department of Transportation; and John H. Williams, Assistant to Assistant Deputy, Highways, Michigan Department of State Highways and Transportation.

J. W. Guinnee, Engineer of Soils, Geology, and Foundations, Transportation Research Board, assisted the Special Projects staff and the Topic Advisory Panel.

Information on current practice was provided by many highway agencies and contractors. Their cooperation and assistance were most helpful.

ACQUISITION AND USE OF GEOTECHNICAL INFORMATION

SUMMARY

Transportation agencies recognize the importance of adequate geotechnical investigations as a prerequisite to route selection, design, and construction of transportation facilities. Such agencies generally do a good job in the acquisition and use of geotechnical information.

The organizational team responsible for acquiring and using geotechnical information is composed of individuals with a wide range of job classifications. Materials and research divisions of the various agencies are most commonly associated with geotechnical investigations. A few agencies have separately administered geotechnical engineering departments in responsible charge of all subsurface or geotechnical investigations.

Corridor studies, route selection, preliminary and final design, advertising and bidding, and construction are the generally accepted stages of development. The extent of geotechnical investigations undertaken in support of these stages varies considerably among the agencies. Although supportive information is required for the corridor and route selection stages, most agencies have their greatest involvement in geotechnical investigations in the preliminary design stage.

Upon completion of the geotechnical investigation program (including laboratory soil testing), soil survey reports, roadway soil profiles, structure site reports, or similar documents are prepared according to agency preference. Participating in this effort are draftsmen, technicians, geologists, and soils and foundation engineers, all primarily associated with and engaged in the geotechnical engineering discipline, as part of a materials and research department, or, in a few cases, as separate geotechnical engineering departments or soil mechanics bureaus.

Reports based on the geotechnical investigation are circulated to concerned individuals for review and discussion, and are ultimately adopted for use in planning, design and plan preparation, and construction. The geotechnical engineer (soil and foundation engineer, geologist, engineering geologist, materials engineer, and possibly other designations) is available for interpretation of the design recommendations and their application in plan development. The final plans and specifications are generally reviewed by the geotechnical engineer for compliance with his understanding of the general design intent and specific details originally adopted.

Agencies vary considerably in the presentation of information obtained in the geotechnical investigation. These variations reflect in some way the general philosophy of the agency regarding the purpose of such investigations. The predominant tendency is to direct the geotechnical investigation program toward acquisition of information required for project design. This information is then fashioned in a format suitable for geotechnical engineering study and design, and then used again as the official geotechnical investigation information at the time of bidding.

Some agencies prefer to show only the borings plotted to an elevation grid with appropriate symbolic legend or material call-out; others do not hesitate to show delineation of interpreted soil-rock stratification. A few agencies do not include any geotechnical investigation information in the plans, but make the boring logs available for inspection. Within the last few years several agencies have reoriented their

geotechnical investigation programs to obtain and present information considered more useful to the bidder, while providing what is required for project design as well.

Regardless of format, most agencies employ a standard disclaimer, intended to relieve the agency of any responsibility regarding accuracy or completeness of information and noting particularly that actual site conditions at time of construction may not be the same as reported. In addition to this disclaimer, there is usually a somewhat lengthy section of the Standard Specifications relating to the use or acceptance of geotechnical or subsurface information shown in the plans or made available by other means. The disclaimer is generally accepted by the agencies as serving a useful function. Contractors or bidders dislike disclaimers and believe agencies should take more responsibility for information provided.

A majority of bidders or construction contractors, where time permits, conduct independent geotechnical investigations prior to bidding. Some bidders will continue to do this; however, many would curtail or eliminate this added expense if the geotechnical investigation information included by agencies in the plans or made available in another format prior to bidding provided more of the type of information the bidder believes he needs in estimating the costs of performing the work.

Geotechnical engineers are usually available in the agency's central or district office to answer any questions raised by bidders during the bid preparation stage. The universal use of prebid conferences to provide geotechnical information to prospective bidders has been judged to be of questionable value in the bidding process. The current tendency is to have prebid conferences only for the larger, more difficult projects.

Resident engineers customarily assume control of the construction operations following contract award. For routine construction, the geotechnical engineer in the central or district offices will probably not be involved. Where there are special designs and construction techniques to be employed, the geotechnical engineer or his representative may be asked to participate in construction supervision. This participation may be limited to periodic site inspection and consultation with resident or district supervisory personnel, or to phone consultation. More often, however, the geotechnical engineer will be asked to participate only if problems arise that cannot be handled by resident or district construction personnel. A need for greater participation by geotechnical engineers in the solution of problems arising at the resident construction level is indicated.

It is common practice for the resident engineer to compile a final report for the construction contract. This report is intended to document the construction effort and to complement the as-built drawings. Distribution of these reports is apparently quite limited. Only a few agencies involve the key people in the geotechnical investigation and design stages in any postconstruction conferences. Other agencies could upgrade this element of their operation by placing geotechnical personnel in a position to examine the final results of their work and apply this knowledge to subsequent projects. Even a well-planned geotechnical investigation may not produce readily apparent benefits; however, a poor one can spell disaster.

CHAPTER ONE

INTRODUCTION

IMPORTANCE OF GEOTECHNICAL INVESTIGATIONS

Geotechnical investigations for transportation projects are conducted to provide surface and subsurface information relative to soil, rock, and water. This information is used in determining the proper location for the project and in making design decisions. It also provides information needed for estimates of construction costs, identifies and describes nearby sources of materials, and can be used to develop controls, when needed, for project construction. Geotechnical information provides input for both construction and for postconstruction evaluation (Fig. 1). Use of geotechnical information is not limited to the transportation agencies. Many agencies make much of this information available to the contractor preparing bids for the work.

In a study of the distribution of 1973 highway construction costs, 34 percent of all costs were for earthwork and subbase, 22 percent were for paving and shoulders, and 29 percent were for structures (Fig. 2). Because the characteristics of earth materials involved in construction are determined through geotechnical investigations, their importance is clearly evident.

When a geotechnical investigation for any project is properly planned, carried out, and utilized, its benefits will often go unnoticed. However, if the geotechnical investigation is improperly planned, inadequately carried out, or the results not used, numerous problems may be evident (Fig. 3). Some of these are:

- Cut slides.
- Embankment failures.
- Need to shift alignment.
- Construction delays.
- Higher construction costs.
- Excessive pavement maintenance.
- Pavement failure.
- Poor riding qualities.
- Structure settlement.
- Structure foundation failure.
- Slope sloughing.
- Frost heave or excessive erosion.

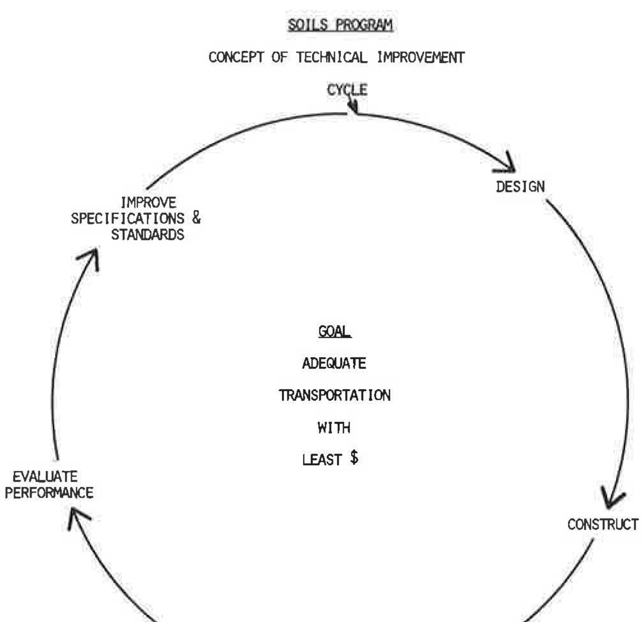


Figure 1. Concept of technical improvement through use of a well-designed soils program. (N.Y.)

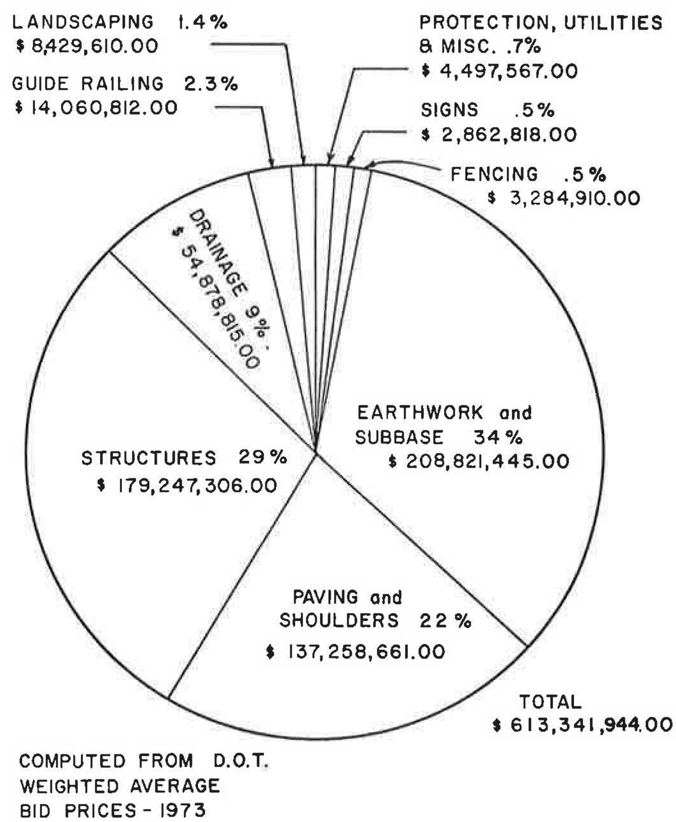


Figure 2. Distribution of 1973 highway construction costs.

Figure 3. Pavement damage resulting from subsurface failure.

Transportation agencies are generally aware of the importance of adequate geotechnical investigation and the transformation of the information collected into design recommendations, construction plans, and specifications. Practices and procedures followed by individual agencies vary widely. Specific areas where differences do occur involve the timing of the geotechnical investigation, extent of field reconnaissance and exploration work (drilling, sampling, and laboratory testing), type or classification of persons involved, and handling of information being made available to bidders.

The objective of this synthesis is to review the practices followed by transportation agencies in the acquisition and utilization of geotechnical information, to report these practices, and to provide recommendations wherever improvement is considered desirable. Agencies responding to a 1974 Transportation Research Board (TRB) survey are listed in Appendix B.

AVAILABILITY OF GEOTECHNICAL INFORMATION

Many agencies recognize that the planning, organization, and execution of a geotechnical investigation program, analysis of the information, and presentation of the resulting recommendations is a major effort, requiring numerous individuals with professional competence. (One example is shown in Appendix C.) The primary participants in this work may be identified by different titles within different agencies. Typical titles are: soils engineer, foundation engineer, geologist, engineering geologist, and materials engineer. Consistency in classification and qualification is desirable and the designation *geotechnical engineer* should be considered as an appropriate title.

It is generally accepted that transportation projects are developed through the following stages: (1) corridor study, (2) route selection, (3) preliminary design, (4) final design, (5) advertising and bidding, and (6) construction.

The use of the geotechnical investigation and the degree of participation by the various disciplines in these stages is not consistent. Those intimately concerned with geotechnical investigations (the soils and foundation engineer or geotechnical engineer or the engineering geologist) should be involved at the corridor study stage; however, based on the survey response, they may or may not be consulted. Their participation increases rapidly once a tentative alignment is selected and there are discussions of geotechnical investigations. This participation continues at a high level through the preliminary design stages and during the plan preparation, and declines through the bidding, construction, and postconstruction stages.

Some agencies associate their geotechnical investigations for the preliminary and final design stages with acquisition of information for project design only. Others will execute their geotechnical investigation programs with the dual purpose of providing design information as well as information for use by contractors in preparing bids, and by construction supervisors. In only a few agencies is there an attempt to emphasize the acquisition of geotechnical information for the contractor's use in the critical bidding stage.

Although most agencies make geotechnical investigation information available to potential bidders, a number of agencies take the approach that bidders are responsible for obtaining their own information for the development of bids. However, some information is usually furnished in the plans or upon special request.

For the most part, the presentation of geotechnical information in plans, or as otherwise made available to bidders, reflects agency use of information in project design and construction, agency experience regarding bidder acceptance and use of the information, and the concern for legal liability. The information may appear as a well-identified separate package of materials reports and boring logs; as an elevation plot of borings along the project baseline; or as a detailed soil profile with interpretation of stratification. One agency has developed its soil profile presentation in accordance with many of the desires or needs of contractors bidding on the work.

Most agencies retain some form of disclaimer with respect to responsibility for subsurface information presented in the plans or as a separate package (Appendix F). Although they are not necessarily convinced of the degree of effectiveness of the disclaimer, they feel it continues to serve some useful purpose. The use of the disclaimer is distasteful to bidders and many of them believe that the agencies should share the responsibility for any geotechnical information provided.

CHAPTER TWO

PLANNING AND ALTERNATE ROUTE LOCATION

CORRIDOR STUDY

The corridor study is the stage at which the choice of the best sites can be encouraged and poor sites discouraged. Frequently, this is when the geotechnical engineer can be of greatest over-all service. However, in a few agencies the geotechnical engineer has no assigned responsibilities with respect to the corridor study and may not even be aware that such a study is in progress.

In contrast, some agencies use a geotechnical engineer on the corridor study team. Soils, drainage, and geological maps, aerial photographs, field reconnaissance and, possibly, limited field explorations and testing are used to gain some acceptable measure of soils and geology information in each corridor. Past experience in the same area is frequently an important input. The engineering significance of problem sites can be pointed out by the geotechnical engineer to other members of the study team.

Environmental problems should also be recognized and resolved during the corridor study stage. Numerous cases can be cited in which failure to recognize subsurface problem areas or failure to take suitable courses of action when the problem areas were recognized resulted in considerable additional costs and long-delayed openings.

Office Review

Participation at the time of office review normally involves acquisition, assembly, and review of topographic base maps (United States Geological Survey quadrangle sheets or other), agricultural soils maps, geological literature, USGS water resource reports, test borings and soil test data from adjacent or local projects, review of known problem geological or soils and foundation conditions, and aerial photography (mosaics and stereo pairs and, less frequently, color photography and remote sensing). Review of this information with respect to the corridor under study is summarized in written reports and informal memoranda, and frequently supplemented by verbal discussions.

Field Reconnaissance

Nearly all agencies execute a field reconnaissance of the corridor under study. The reconnaissance may be performed individually by a division materials engineer, division location and design engineer, or chief geologist, or by a team composed of engineers of the planning, design, drainage, location, right-of-way, bridge, materials and research, geotechnical engineering, and possibly other sections. The magnitude and complexity of the proposed project determines the need for or extent of the reconnaissance and the composition of the team. It is accepted that valid reconnaissance by a geotechnical engineer requires that he occupy and inspect the site and walk the alignments under consideration.

Evaluation of Critical Requirements

The reconnaissance team, using information obtained from the office and field review, and the familiarity of individual team members with the area under consideration, provides as complete an assessment as possible of the following:

- Any critical right-of-way requirements.
- Environmental considerations.
- Areas of potential instability.
- Bearing capacity or consolidation considerations.
- Considerations for pavement design.
- Need for special construction sequences and techniques.
- Anticipated maintenance problems.

Materials Inventory

For any particular project there may be need for consideration of mineral rights for mineable materials and critical construction materials. Identification of common borrow areas may be a particular problem in urban areas and an even more difficult problem when granular materials are required.

At the time of the corridor study, most agencies consider it unnecessary to make any detailed inventory of required construction materials, or mineable materials that might enter into subsequent negotiations for property. This determination is more commonly made later in the design stage. A number of agencies have pre-mapped the material sources for their state, or have a continuing materials inventory program and have no need for a special inventory for any one project.

If critical problem areas are identified in the office and field reconnaissance, they are defined in a written report and distributed to those concerned (with follow-up verbal discussions as required). It is extremely important at this time that both technical and administrative levels be acutely aware of the need for adequate geotechnical information for public hearing requirements. Inadequate or erroneous information may result in unfortunate and irreversible situations, forcing new and more difficult public hearings.

Environmental Considerations

Members of the reconnaissance team have responsibility for identifying potential environmental problems that might ultimately be associated with access for surveys and the geotechnical investigation program, design, construction, and project performance. A few agencies have experienced no environmental problems associated with the geotechnical investigation itself, although others reported some experience with the following areas of special concern:

- Contamination of surface and groundwater.
- Denuding of slopes and temporary or permanent erosion control.
- Dust control.
- Leaving visible earth scars.
- Excessive drilling and sampling noise in urban areas.
- Interruption of surface drainage.
- Siltation.
- Lowering water level in ponds and small lakes by "breaking seal."
- Loss of water due to drawdown, by changes in wells.
- Disposal of drill and construction spoil.
- Disruption of marsh regimen.

ROUTE SELECTION

Geotechnical investigations for the route selection stage of project development vary from nonexistent to fairly comprehensive programs. The general tendency is to perform only the geotechnical investigations required for adequate evaluation of potential problem areas. It is the belief of several agencies that route selection is often predicated on considerations other than geotechnical (i.e., geometrics, economics, traffic patterns, politics, and local concerns), and, therefore, only limited investigations are required.

However, the information gathered during the corridor study can be supplemented with additional fieldwork where necessary to help tie down the final alignment. This stage is also crucial with respect to right-of-way and cost estimates; failure to consider all geotechnical factors can be costly in terms of funds and timely project completion.

During route selection, some attention is given to maximum heights for cuts and fills, subsurface drainage, and potential slide areas. Small changes in alignment often reduce the problem potential for little or no increase in cost.

The presence of major or minor subsurface problem areas may not be the deciding factor in the route location decision. However, many transportation agencies recognize the importance of good geotechnical data during this stage and consider this input before establishing the final alignment.

The geotechnical investigation may also supply adequate information so that the designer can establish grades, right-of-way widths, special cut sections, and other considerations. This information is also used to estimate earthwork quantities, write special provisions, and prepare plan notes.

Items of concern for the corridor study stage of development are of continuing concern in the route selection stage. Typical concerns are those expressed in "Outline for Corridor Reconnaissance Study—Engineering Geology Report," by the Georgia Department of Transportation, as follows:

I. Introduction
   - A. Scope of the report
   - B. Procedure followed
   - C. Limitations of the study

II. General Description of the Project
   - A. General geology of the area
   - B. Climatic conditions of the area
   - C. Drainage and general hydrology

III. Detailed Description of Centerline Conditions
   - A. Geology
     1. Bedrock type and formation
     2. Probable soil cover, type, and depth
     3. Geologic structure
     4. Suitability as aggregate or borrow
     5. Cut or fill stability
     6. Water table and groundwater seeps
     7. Structural problems
   - B. Land use
     1. Relative quantities of urban land
        - (a) Dwellings
        - (b) Commercial
     2. Rural area
        - (a) Woodlands, hardwoods, pines, forrested
        - (b) Farmlands, pasture, row crops
     3. Mineral deposits
        - (a) Potential
        - (b) Active

IV. Summary
- A. Cut and fill sections
  1. Hard rock excavation
  2. Rippable rock
  3. Availability of borrow
  4. Availability of local aggregate
  5. Stability of cut slopes
- B. Water crossings
  1. Depth and length
- C. Geologic comparison of lines considered
- D. Recommendation and consequence of line selected

A "Check List for Soil Surveys," prepared by the Georgia Department of Transportation, is as follows:

1. Location
2. Rock
3. Removal
4. Waste (III B)
5. Subgrade material
6. Slopes
7. Erosion—± formation factor
8. Shrinkage
9. Select grading
10. Groundwater
11. Drainage material
12. Pavement design values
13. Grade changes
14. Corrosion
15. Culverts
16. Existing pavement
17. Side borrow
18. Fill settlement
19. Springs and wells
20. Pavement design
21. Utilities
22. Special problems
23. Availability of base materials
24. Bench detail

Although the check list is rather comprehensive, and more specifically applicable to a preliminary or final design soil survey, many of the items listed must be addressed in detail at the route selection stage.

CHAPTER THREE

DESIGN

PRELIMINARY DESIGN

It is the general consensus of transportation agencies that the geotechnical investigations conducted for the preliminary design stage are the most extensive that would be undertaken for a project. With location of the project having been determined in previous stages, investigations at the time of the preliminary design offer the final opportunity to influence project design, including slopes, swamp area designs, pavement designs, and minor adjustments to avoid or minimize the over-all effect of problem areas.

Most agencies indicated that little additional geotechnical investigation work would be done later, unless problem areas were encountered or there were substantial changes in the vertical or horizontal alignments. Several agencies indicated they would make detailed geotechnical investigations only after they were reasonably sure there would be no further changes in alignment or grade. A few agencies make their most substantial geotechnical investigations in the final design stage. It appears there is an effort to maintain an open-door policy by the geotechnical engineer with respect to the planners, designers, and other interested disciplines using geotechnical input for the designs (Fig. 4).

Planning the Geotechnical Investigation

The responsibility for planning the preliminary design geotechnical investigation is a function of agency organization and thus varies considerably among agencies. Planning may be by the central headquarters office or at the district or regional office level.

In many agencies the work of the geotechnical engineer is handled within the materials division, in which case the materials and research engineer might have the responsibility for planning the investigations. In some agencies the work is planned by the district materials engineer, chief geologist, construction engineer, or design engineer. However, the responsibility for that portion of the geotechnical investigation relating to structures (bridges, retaining walls, drainage structures) often rests with the bridge design department. In only a few agencies is the planning of the preliminary design geotechnical investigation a direct responsibility of a geotechnical engineer, soils and foundation engineer, or engineering geologist. Figure 5 shows an organization chart for a geotechnical division in one agency.

The reconnaissance and planning of the geotechnical in-

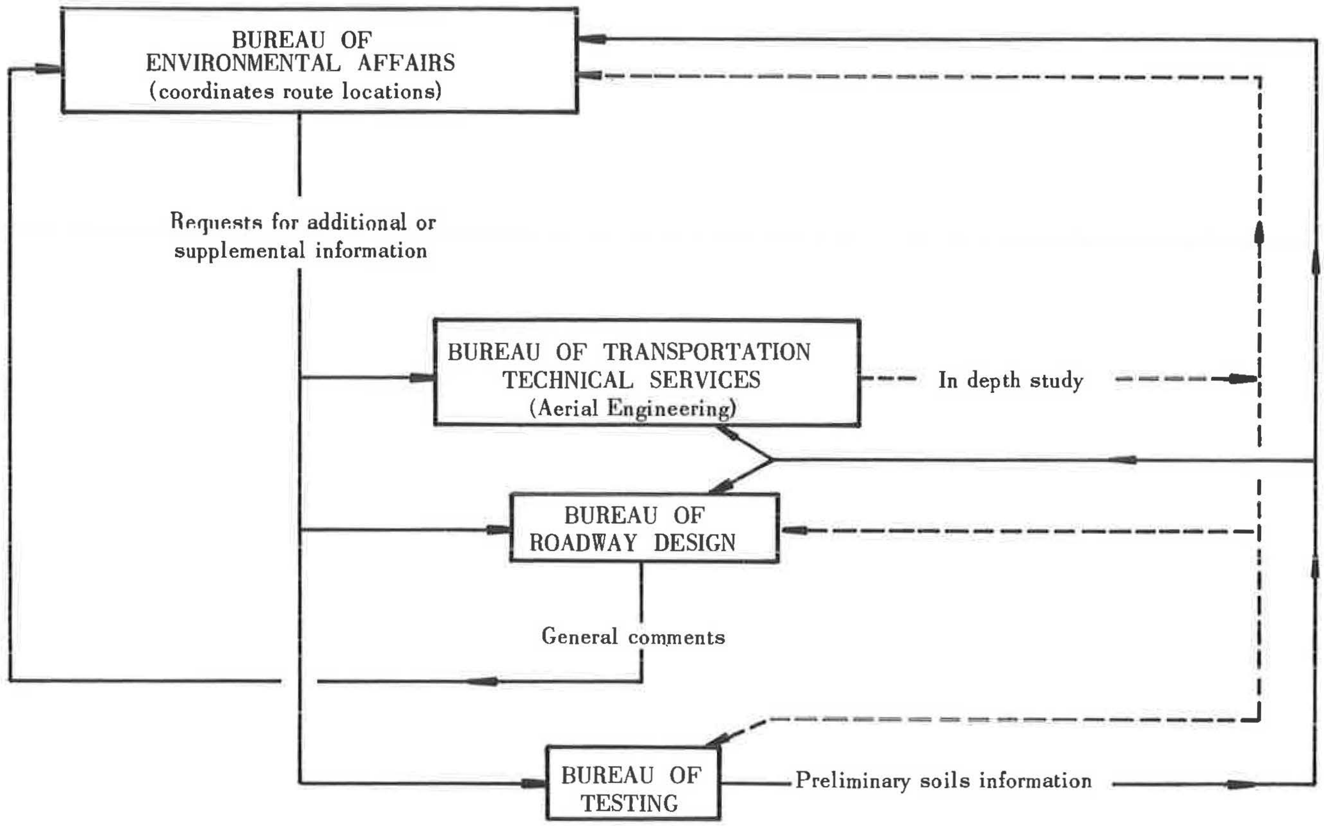
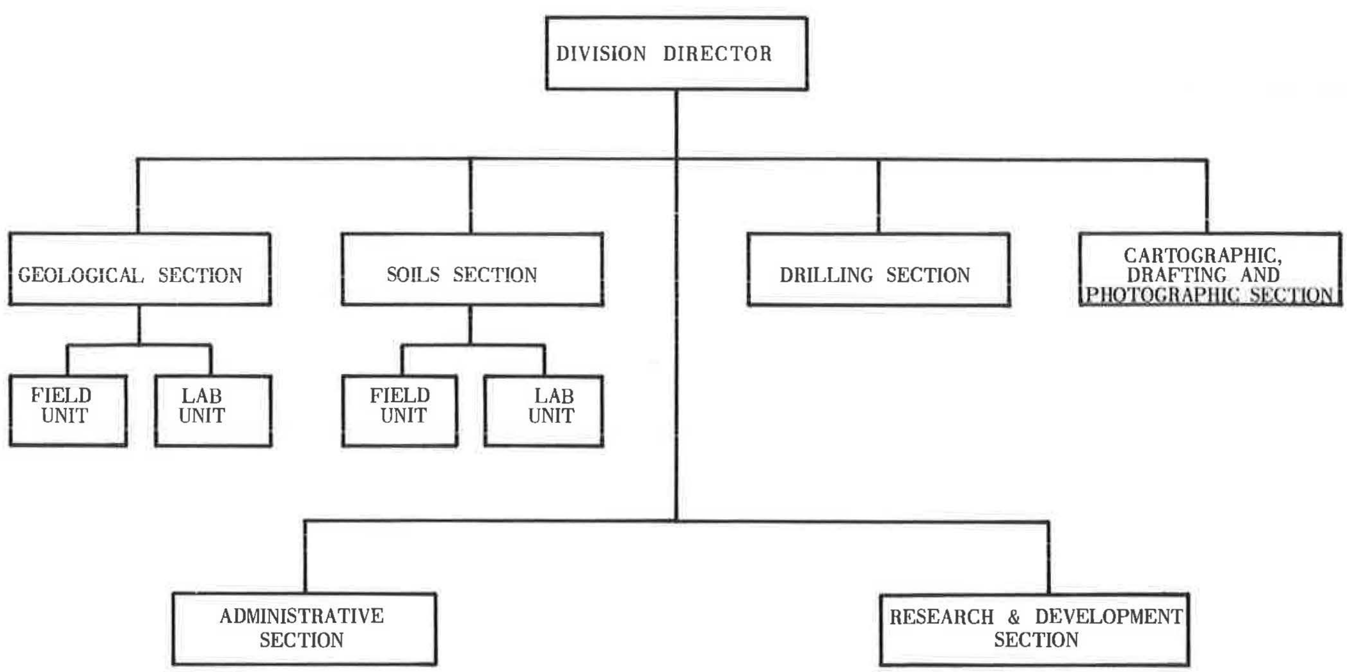


Figure 4. Flow of information for route investigation and preliminary design. (Ohio)



"It shall be the function of the Division of Soils and Geological Engineering to collect, process, interpret and report soils and geological information relevant to the planning, location, design, construction and maintenance of all state/federal roadways and structures within the State of Tennessee, and to serve as the principle advisory and coordinating authority with regard to the various plans and procedures developed from this information."

Figure 5. The organization of the geotechnical unit in one transportation agency. (Tenn.)

vestigation varies among agencies, but normally includes to varying degrees:

- Study of preliminary plans.
- Detailed on-the-ground inspection of terrain involved by the alignment, bridge, retaining walls, or other construction features.
- Appraisal of the extent to which natural soil conditions may influence design and construction or the extent to which construction may affect the natural state of stability of soil and rock masses involved.
- Ascertainment of the geologic origin of soil-rock masses involved.
- Development of the boring, sampling, and testing program.
- Preparation of an estimate of quantities of test borings, sampling, and field and laboratory soil testing work.

The criteria for location, spacing, depth of borings, type of sampling and coring, field testing, and laboratory testing are functions of the soil-bedrock geologic conditions, long-established agency customs, and the emphasis placed on providing information primarily in support of design or for design and estimating costs by the bidders.

Appendix D presents the generalized results from the TRB survey relating to the criteria and details of drilling, sampling, field testing, and laboratory soil testing used by the agencies.

As mentioned previously, a number of people may be involved in the planning of the geotechnical investigation. Generally those having the ultimate responsibility for use of the information obtained have an opportunity to participate in the investigation development, particularly where difficult or unusual situations are anticipated. Most agencies use an established geotechnical investigation procedure. The proposed program for geotechnical investigation (drilling, sampling, field and laboratory testing) goes directly to the department responsible for program execution. In some cases the work is let to subcontractors. In other agencies the program as recommended is specifically reviewed with key staff engineers in both the central and district offices, including the engineering geologist, highway design engineer, bridge engineer, materials engineer, construction engineer, and the consultant design engineer where applicable.

Display of Information

The format for display of the findings of the geotechnical investigation appears to be related to the agency philosophy regarding the purpose of the geotechnical investigation. There appear to be two basic approaches. The first assumes that the purpose of the geotechnical investigation is to provide information for design and agency costing of the project. The second approach assumes that the geotechnical investigation is to provide information for the design of the project *and* simultaneously, with little or no additional effort, permit a firm basis for bidders to estimate those portions of their costs relating to materials on the project. Examination of the survey responses and accompanying soil-rock profiles and other data indicates that most geotechnical investigations are, in actuality, oriented primarily toward acquisition of information for design use. It appears economically advantageous, from a production standpoint, that any roadway soil profile drawing, elevation plot of borings, or structure borings (Figs. 6 and 7) be assembled and presented in a format useful in design and also subsequently in the bidding and construction process.

Some agencies prefer to show plotted roadway borings along the project centerline or roadway baselines, in relation to existing natural ground and proposed profile grade. Borings plotted on selected, representative, or critical roadway cross sections may or may not be included. A symbolized legend or reference numbering system may be used in addition to call-out of material description or classification based on American Association of State Highway and Transportation Officials (AASHTO) classification or an independent system. Water levels encountered in borings at times of drilling, or subsequently, may or may not be shown. Appendix E demonstrates one technique for displaying geotechnical data.

Other agencies develop a soil profile (primarily for design purposes) indicating stratification of the soil-bedrock classification between borings. These interpretations are useful to the designer, aid in prescribing special treatments and corrective measures in the plans, and also are of use to the bidder in estimating costs and construction personnel for field supervision. Whether the information is shown as individual plotted borings or interpreted soil profile form, the sheets usually contain a note such as the following: "Information shown by this subgrade profile was obtained solely for use in establishing design controls. The State does not guarantee the accuracy of the data and they are not to be construed as part of the plans governing construction of this project."

Appendix F contains typical disclaimers that appear in connection with geotechnical information contained in construction plans or with other selected geotechnical investigation information to be made available to the bidder.

Borings for bridges and retaining wall structures are usually shown in graphic form with respect to an abbreviated elevation of the proposed bridge or wall.

Narrative reports often accompany the elevation plot of boring, soil profile, and structure boring presentations. They include detailed description and analysis of conditions, results of design analyses, and recommendation for design and preparation of plans. This type of report usually is readily available to agency personnel; it is sometimes made available to bidders free, or at a small cost.

In a few agencies roadway borings and test data are made available in-house in the form of materials reports, materials information reports, and foundation reports. Although this information is not routinely available later for contract bidding, the information is packaged and may be released to bidders on request. However, this is without any interpretation of the assembled information—interpretation being the responsibility of the bidder. In some of those same agencies, however, the logs of test borings for structures are plotted in elevation in a very detailed manner, but are not included in the bidding plans. These logs, used in design, might be of considerable value to bidders for structure work.

The time required for detailed plotting of geotechnical data on plan sheets is often a problem. Computer techniques are available that will perform this work automatically. However, time is required to prepare the data for the computer. The data may be recorded directly on the computer cards or tapes in the field, or may be taken from boring logs in the office.

Review and Use of Information

The steps involved in the review, adoption, and incorporation of geotechnical information in design, contract plans, and specifications vary considerably within agencies. The reviews are usually related directly to two categories: roadway soil profiles and structure borings.

In one agency, the soils survey data are used by the division materials engineer to construct a soil profile, which is then forwarded to the state materials engineer for review. Following review and correction, it is forwarded to the Bureau of Surveys and Plans for insertion in the plans. The division materials engineer also prepares a soil report containing results of all tests, results of material pit investigations, options on all borrow pits, and his recommendations for design of roadway structural courses. The recommendations are then reviewed by the state materials engineer and forwarded to the Bureau of Surveys and Plans for final design of base and pavement.

In this same agency, bridge foundation investigation results are assembled into a foundation report containing

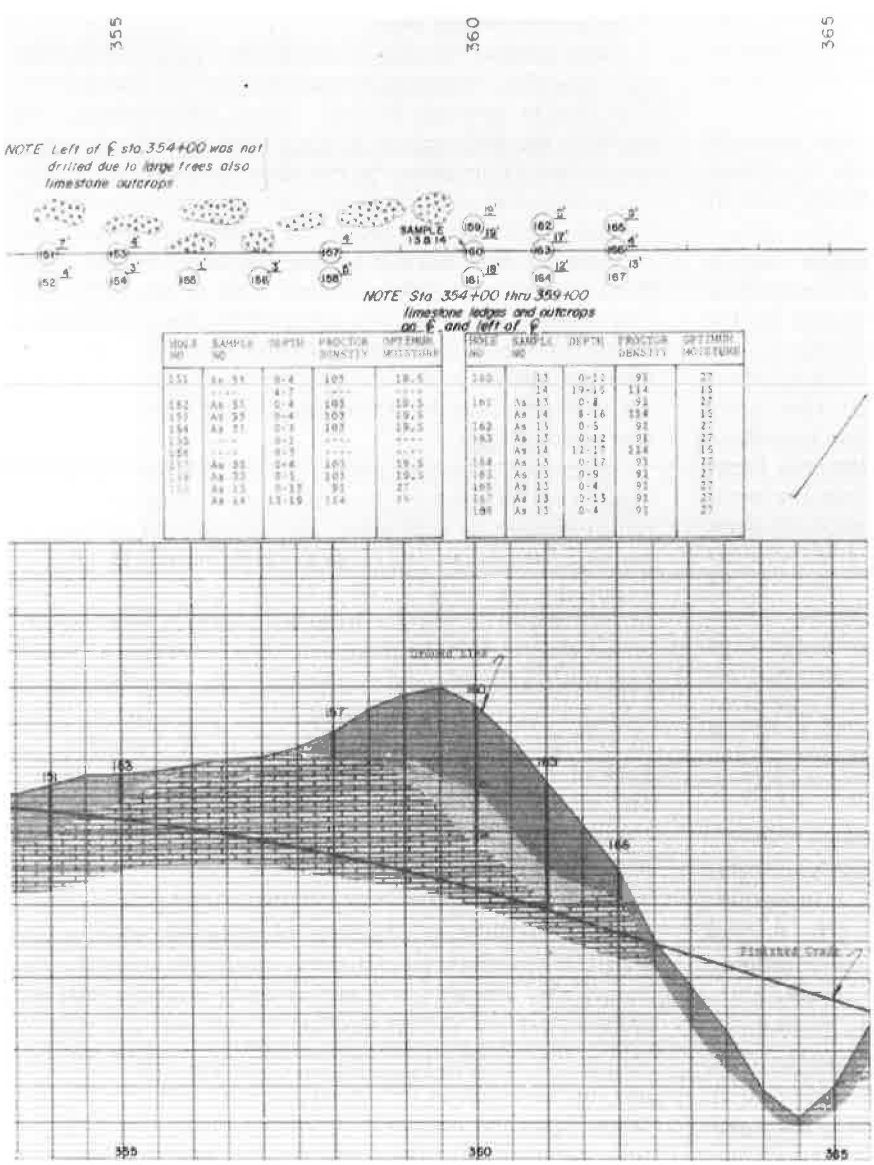


Figure 6. Centerline profile with geotechnical information.

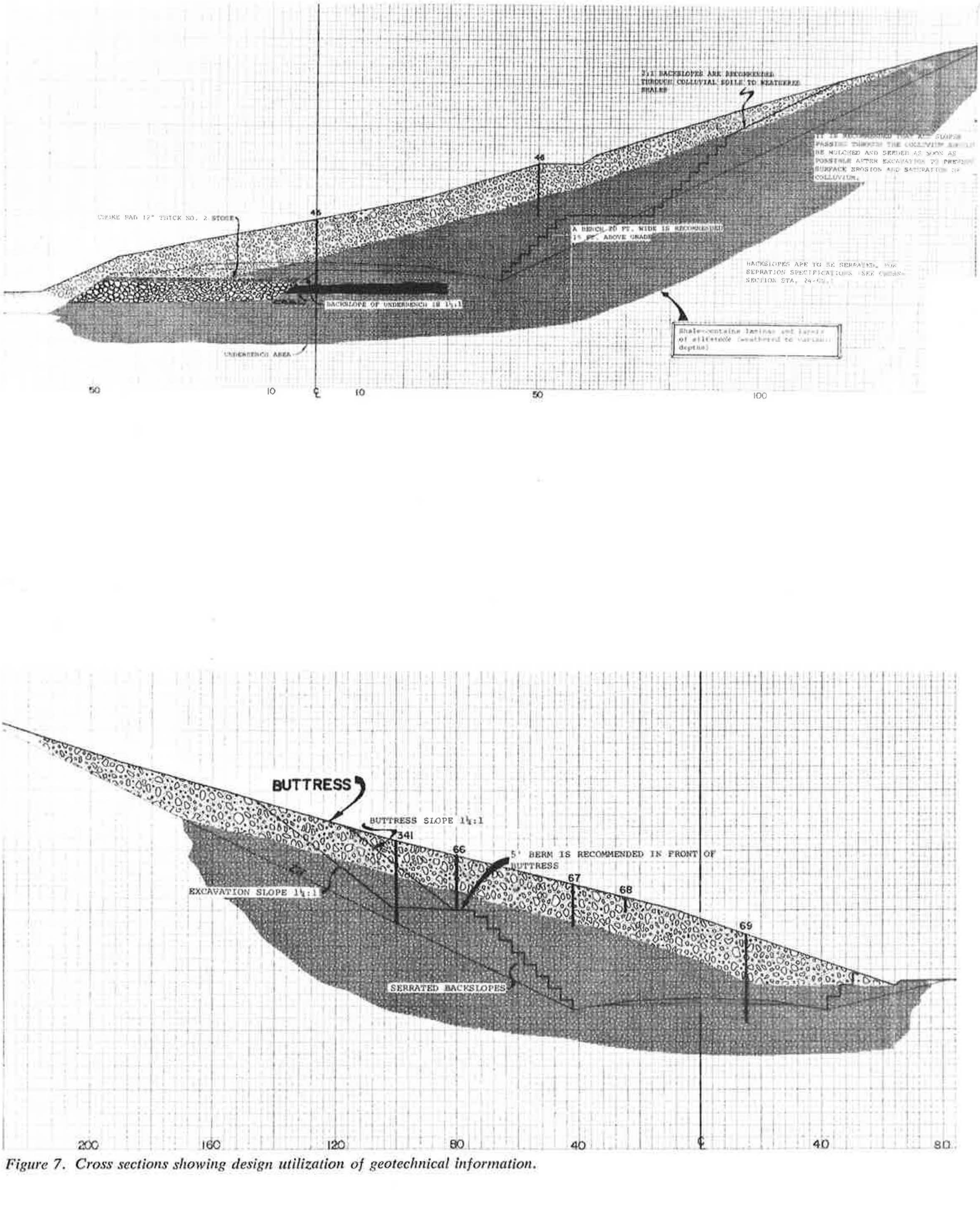


Figure 7. Cross sections showing design utilization of geotechnical information.

results of all tests, boring logs, and recommendations for foundation types. That report is discussed with the bridge engineers and used for final design of structures.

In another agency, the district soil report is reviewed by the district, then by a soils committee, and, when approved, is used in preparing roadway design plans. For structures, the borings are made by the district, reviewed by a soils and foundation engineer, and given to a bridge planner with foundation recommendations.

The flow of information in one agency is shown in Figure 8. Another agency indicated a more detailed approach, as follows:

1. Soil engineer completes subsurface investigation.
2. Recommendations suggested by soil engineer are reviewed and approved by the chief soil engineer.
3. A final soil meeting is held to discuss these recommendations. Representatives of construction, design, and materials attend this meeting and approve these recommendations.
4. A soil engineering report, including the soil profile and approved recommendations, is submitted to the divisions of design, construction, bridges, research, and maintenance.
5. Final joint inspection is held at the project site to review all plan notes, including soils. The soil construction engineer attends this meeting to ensure that all soil profile sheets, and specifications pertaining to soils, are included in the plans.

In another agency, requests for subsurface investigation are received by the division of soils and geological engineering directly from the roadway design division. These requests are usually accompanied by a plan and profile sheet and, in many cases, cross sections. The results of the soil and geological investigations are depicted graphically on the plan and profile sheets and returned to the design division, along with a narrative report that gives a station-to-station description of the alignment. The report also includes field logs and laboratory test data; however, all interpretations with regard to these data are made by the soils engineer or engineering geologist in the report. In most cases these recommendations are followed without question. Where there are problems with geometry, economics, etc., the designer will contact the soils engineer or engineering geologist who prepared the report, and the two will work out whatever alternatives are necessary. Where alternatives cannot be agreed upon readily, additional meetings that include the roadway design engineers and the chief of soils and geological engineering are held. Where necessary, the construction engineer and/or right-of-way engineer may also attend.

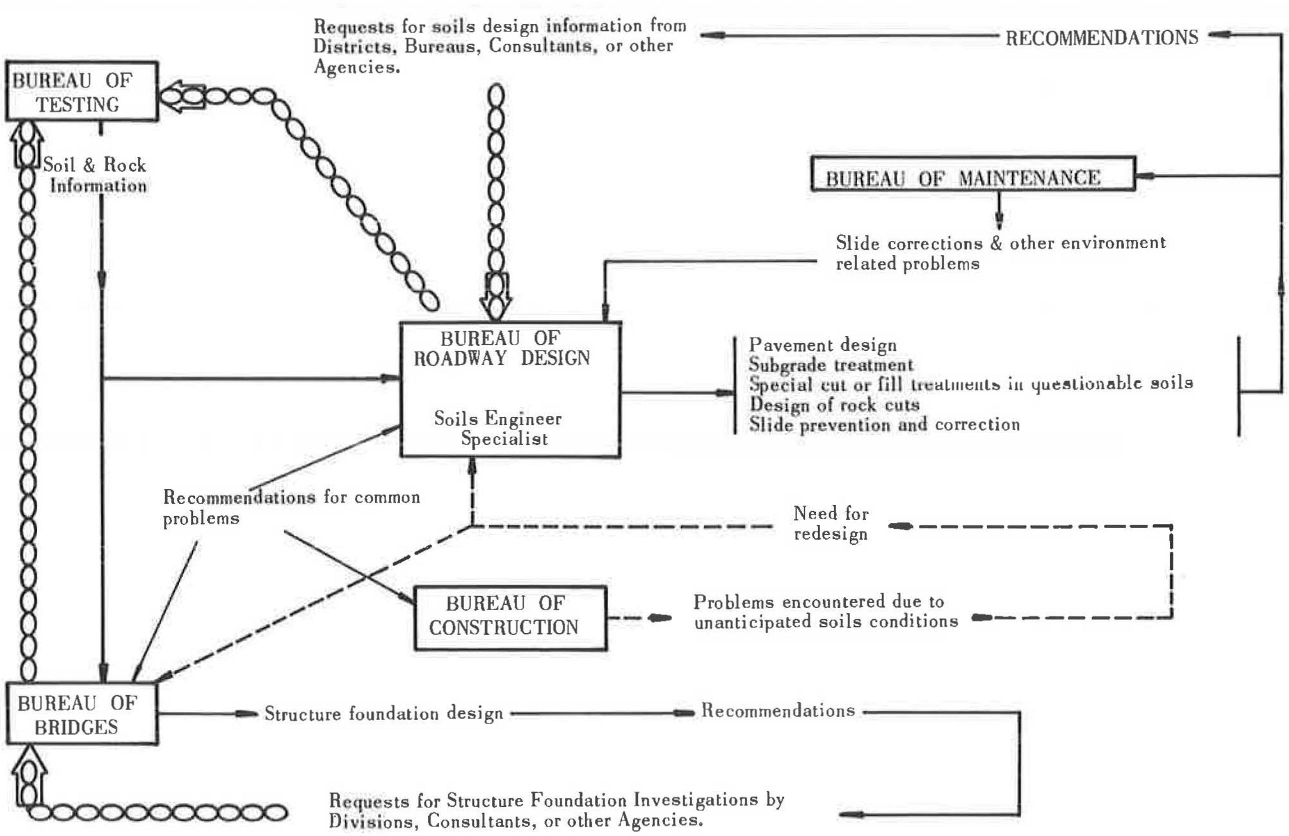


Figure 8. Flow of geotechnical information for design, construction, and maintenance. (Ohio)

In the agency discussed previously, approximately the same procedures are followed in foundation investigations except that the engineer of structures substitutes for the roadway design engineer.

FINAL DESIGN

Many of the agencies do little geotechnical investigation work in the final design stage. It is usually confined to obtaining information necessitated by changes or refinements in horizontal or vertical alignments to obtain borings for correlation with any seismic data obtained previously and to obtain additional undisturbed samples for laboratory testing in relation to documentation of design involving special foundation or cut slope treatments. Supplementary explorations may also be made for location changes for bridge substructure units or retaining wall relocations or additions.

A few agencies perform the bulk of all geotechnical investigations in the final design stage, including all disturbed and undisturbed sampling, laboratory testing, and additional geophysical work. A smaller proportion do not begin the geotechnical investigations until they are reasonably sure line, grade, and substructure locations are fixed.

Some final contract documents include drilling and sampling specifications to accomplish exploration work in previously inaccessible areas, or the agency will do the work with its own forces when it could be completed prior to the bidding date.

FINAL REVIEW OF DESIGN

One of the most important steps in the design procedure is the final review of the plans prior to advertising and bidding. Most agencies conduct plans, specifications, and cost estimates (P.S.&E.) reviews wherein appropriate members of the design team examine the plans in the field to confirm that all design features, requirements, and recommendations have been accomplished and included. A geotechnical engineering representative should participate in this review. Unfortunately, this review may sometimes be taken less seriously than it should be, with only a drive-by or "windshield" field examination in lieu of the actual walking of the area.

CHAPTER FOUR

ADVERTISING AND BIDDING

In some agencies the geotechnical information collected for the corridor study, route selection, and design stages may not be made readily available to the bidder. If the information is made available, there are conditions, disclaimers, or other releases from responsibility that may help destroy the confidence of the prospective bidder. There is some indication that the contractors perform less subsurface investigation when the agency makes all of its information available.

Agency procedures for advertising and receiving bids for construction projects are in accord with policy and planning provisions of the Federal Highway Administration, which, for routine projects, requires a three-week interval between date of advertisement and receipt of bids. Many contractors consider this to be inadequate time for proper prebid investigations of their own, particularly when they have a number of bids to prepare.

Formal prebid conferences to gain a better insight into project requirements before bidding have not been completely successful. Many contractors think that there could be improved centralization and indexing of all geotechnical information that is available for their use in preparing bids.

INFORMATION AVAILABLE TO BIDDERS

The attitude of agencies varies considerably with respect to what geotechnical investigation information should be made available to bidders. Many contractors or bidders contend that because public monies finance the geotechnical investigations, all results should be made readily available to bidders. Legal counsel for some agencies contend that full disclosure or release is not mandatory and arbitrarily restrict which information is actually released to the bidder.

The TRB questionnaire inquired as to what soil and rock test results were made available to bidders. Responses varied considerably. However, it is the consensus of the agency responses that all information obtained in the geotechnical investigation is made available, either voluntarily or on request. More generally, the agencies believed that the geotechnical information included on the plans and profile sheets was adequate. In one agency, test results were not routinely made available; however, the logs of borings were sold in two packages: structures and highways. Another agency has used photographs to represent subsurface conditions (Fig. 9).

A recent directive in one agency emphasizes that continuity be maintained throughout the agency in making the following information available to bidders:

1. Logs of all subsurface explorations made for project.
2. Tabulated results of probings.
3. Tabulated depth to bedrock as determined by geophysical investigations (seismic).
4. Logs showing laboratory description of soil samples.
5. Laboratory test data from soil samples (in summary form or included on the logs showing laboratory descriptions).
6. Rock outcrop maps (if prepared).
7. Granular materials resources, survey report (if prepared).
8. Terrain reconnaissance reports (if prepared).

PREBID CONFERENCE

Relatively few agencies have formal prebid conferences or conduct site visits with potential bidders. A few agencies indicated that such conferences were held in the past, but were discontinued when it was deemed they were unproductive and there was lack of interest on the part of the bidders. Bidders and agencies agree, however, that prebid conferences are desirable for the larger, more complex projects.

Many administrative and geotechnical engineers still consider the prebid conference to be an excellent way of informing bidders of any unique geotechnical or other special considerations that are a part of the construction. A very large construction company noted that they had good experience with agencies that, in addition to the prebid approach, left test pits open for inspection and even excavated trenches in the presence of the assembled bidders.

In the few agencies still having prebid conferences, the bidders are encouraged to ask questions. One agency indicated that any verbal briefing relating to geotechnical information was rare. Most agencies have available, at district or headquarters level, qualified personnel who can describe the geotechnical investigation, field and laboratory test results, and their applicability to the design, plans, and specifications.

BIDDER APPRAISAL OF INFORMATION

The personal interviews and questionnaire responses of individual contractors and contractor organizations indicated that the geotechnical information normally furnished them by agencies was sufficient in detail to reasonably assure an understanding of the geotechnical conditions and potential problems that might arise during construction. However, bidders generally consider the verbal presentation of geo-

Figure 9. Photographic and sectional display of subsurface information. (Tenn.)

technical information at a prebid meeting to be of limited or marginal value.

Many bidders believe, however, that the geotechnical investigation information provided by the agencies is generally inadequate for their use in working up their estimate of costs and bids. Some of the items of concern were:

A. Policy Items

- Inadequate lead time (i.e., information availability before bidding dates). A two- to three-week period seems standard. When a contractor is attempting to bid a number of jobs simultaneously, he cannot give the necessary investigation and study to all the projects on which he has the opportunity to bid.
- Variations in information presentation. This is usually between agencies and possibly is unavoidable.
- Interpretations, where given, are too general to be of use.
- Agency refusal to accept responsibility for subsurface investigation information shown in plans, reports, or otherwise.
- No general over-all attempt to maintain standardized nomenclature and material descriptions.
- Lack of simplicity in information presentation.
- Difficulty in finding geotechnical investigation information within the agency.
- Borings or soil-rock profile not usually shown on cut cross sections (excavation areas).

B. Technical Items

- Boring depth terminated above profile grade or lowest work area.
- Cores not taken to determine if boulder or bedrock.
- Insufficient borings in cut (excavation areas).
- Excessive borings in fill and/or swamp excavation areas.
- No groundwater elevation information.
- Incomplete boring location information and topography.
- Natural moisture contents and optimum moisture-density information not obtained or, if obtained, not shown.
- Rock type and soundness not indicated.
- Geological names of formations should be shown in certain geographical areas.
- Test data (soundness, abrasion, gradation) on granular and rock material in excavation that might be usable in construction as other specification items (select material, select base, etc.).

GEOTECHNICAL INVESTIGATIONS BY BIDDERS

The responding agencies indicated they have had a generally good experience with bidders reviewing and understanding the geotechnical information contained in the plans or presented in separate packages. The agency estimates of how many bidders make their own geotechnical investigations varied from zero to as high as 99 percent. Results showed that 15 to 25 percent of the bidders who make some kind of geotechnical investigation do it themselves. Bidders indicated that they believed additional investigations were necessary "to reduce bidding uncertainties." There appears to be no great distrust of the agency-furnished geotechnical information, but the bidders believe that the information routinely obtained by the agencies is primarily for design purposes. The bidders felt they must often make the additional field investigations to verify any information furnished with the bidding plans. They have no choice but to make their own geotechnical investigations when the agency provides no such information. Another reason for performing their own separate investigations, and perhaps the most important, is to permit the bidders to determine for themselves the nature of the materials to be excavated and the relation of the materials to their equipment parameters. In most instances they do not require highly sophisticated information. The natural moisture content, groundwater level, and the optimum moisture-density relationships will provide some idea of the manipulation and compactive effort required to meet specifications for soil excavation. In rock excavation the position of rock, presence of laminations, hardness and soundness, and seismic velocities will indicate the probable rippability or need for blasting.

Bidders specializing in structure work (bridges, retaining walls, tunnels) tend to have any necessary supplementary special deep borings drilled by commercial laboratories or geotechnical consultants providing drilling, sampling, and testing services. Bidders for grading projects most often provide their own equipment and analyses of information obtained. A description of equipment and procedures utilized by contractors in making supplemental geotechnical investigations included the following:

- Digging equipment (dozers, draglines, backhoes, etc.).
- Helical auger (hand or mechanical).
- Open cut examination.
- Core drill.
- Seismic surveys.
- Pneumatic drills.

CHAPTER FIVE

PRECONSTRUCTION, CONSTRUCTION, AND POSTCONSTRUCTION MONITORING

PRECONSTRUCTION GEOTECHNICAL CONFERENCE

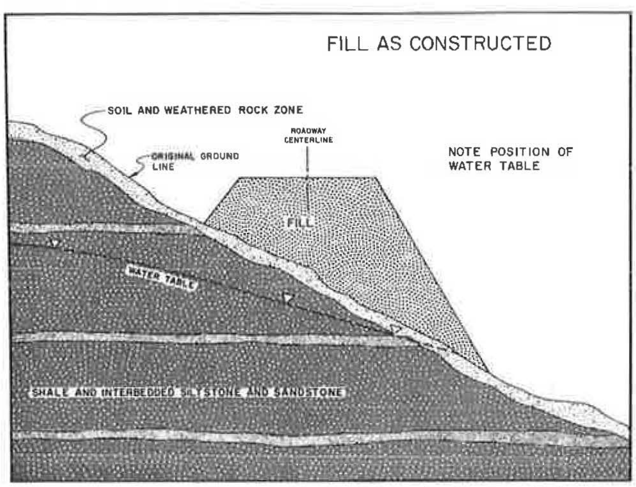
In at least one agency, when considerable geotechnical engineering involvement in construction is expected a conference is held after award of the construction contract but prior to the start of construction work. This conference is usually attended by the geotechnical engineers and construction monitors, and sometimes attended by resident engineers and design engineers for the purpose of discussing all earthwork-related items and problems, specifications and special provisions, special plan notes, and field control testing. For very complex earthwork projects, the bidder or contractor may also be invited to participate.

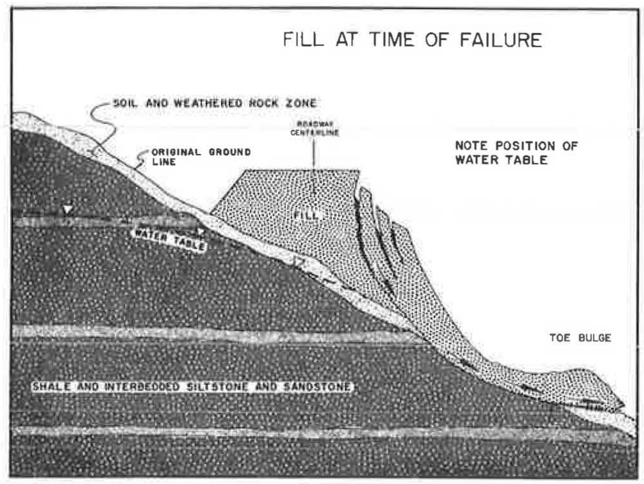
CONSTRUCTION MONITORING

In a few agencies, the geotechnical engineer makes official periodic visits to construction projects to observe and consult on the implementation of the plans or to aid in resolving geotechnical problems. This usually occurs when special testing or continuing analysis of foundation instrumentation is an acknowledged part of the contract work. Construction personnel appear to have direct access to geotechnical engineers in the district and central offices during construction. Most often, however, the geotechnical engineer is invited to the construction site only when a definite geology-, soils- or foundation-related problem arises during construction that can not be solved by resident construction personnel.

Embankment and cut stability problems that arise during and after construction often require design modifications to meet the changed or unforeseen condition. Geotechnical personnel usually provide additional field information to the designer and often assist with the construction inspection. One case involving an embankment failure that required special design and construction techniques is shown in Figures 10 and 11. A cut slide problem requiring special treatment is shown in Figure 12.

There is sometimes reluctance on the part of the district, division, or resident construction engineers to request geo-





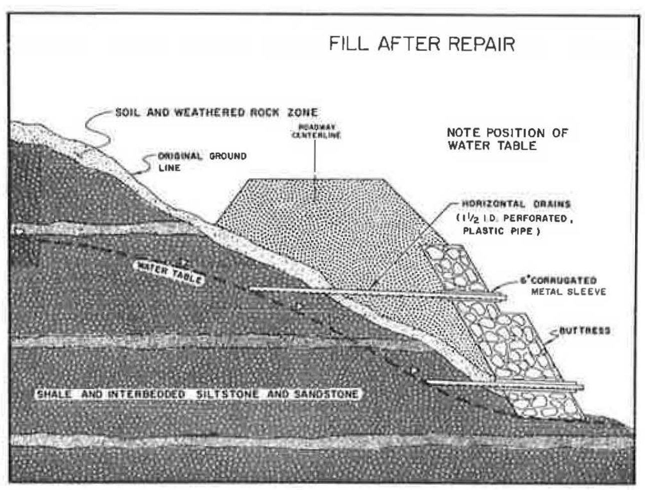
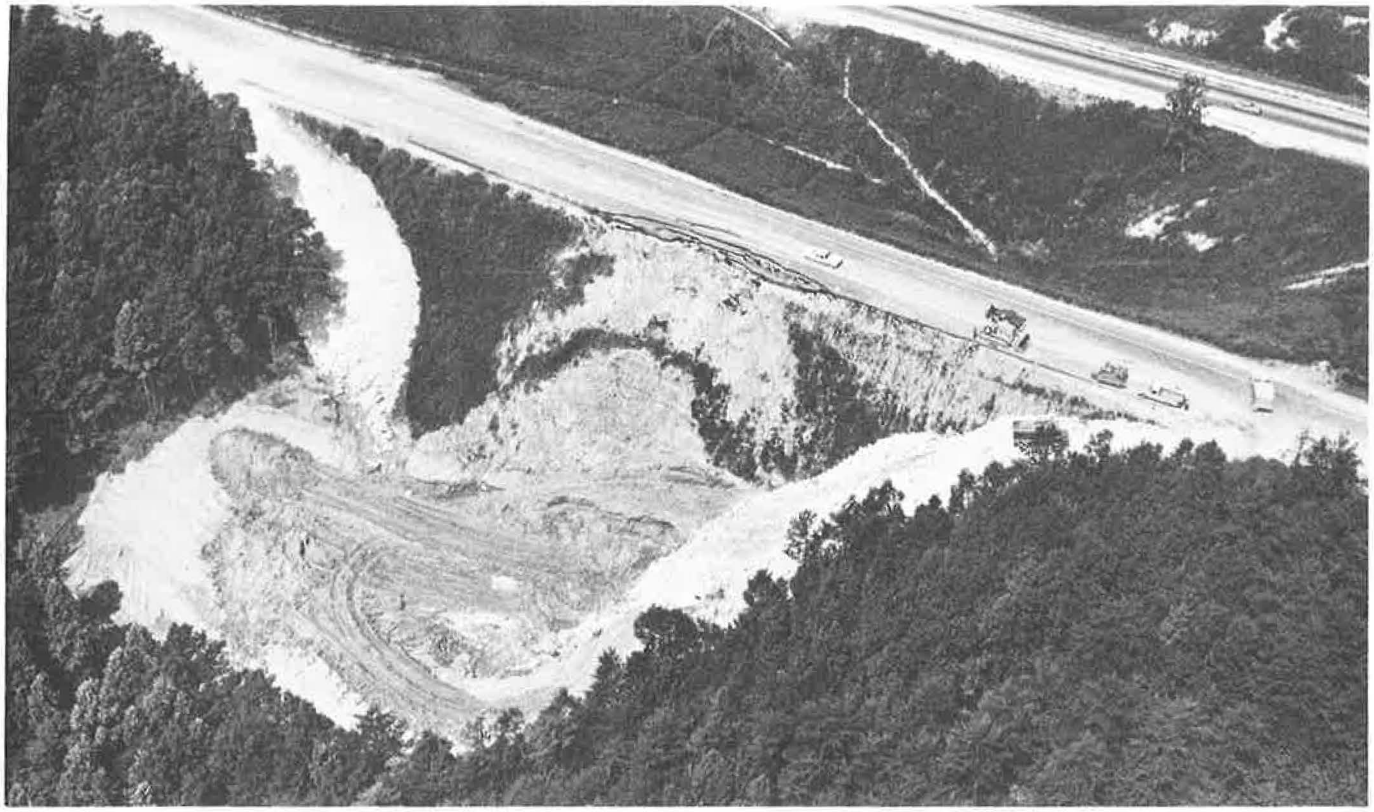


Figure 10. Sequence of events in an embankment failure and reconstruction. SOURCE: D. L. Royster, "Highway Landslide Problems Along the Cumberland Plateau in Tennessee." Assoc. of Engineering Geologists Bulletin. *Vol. 10, No. 4 (Fall 1973) pp. 255-287.*



a. During Reconstruction

b. After Completion of Work

Figure 11. Embankment shown in Figure 10.

technical personnel, particularly from the headquarters level. They prefer to solve their problems at the resident or district level. In some agencies this reluctance is lessening, particularly where there is a strong headquarters geotechnical section supported at the highest administration level. Resident engineers are finding that frequent consultations with geotechnical personnel often simplify their job. Actual participation of geotechnical engineering personnel in the construction monitoring effort is a function of agency organization.

Routine participation of geotechnical personnel in the monitoring effort is advantageous in that it broadens the background and experience of the individuals and better equips them to perform effectively in future work. More importantly, it permits desired contract changes to be made on the basis of direct evaluation of actual site conditions.

POSTCONSTRUCTION PERFORMANCE EVALUATION

Postconstruction performance evaluation as used in this synthesis includes an evaluation of the quality of the geotechnical investigations, project design, construction plans and specifications, and construction procedures following project completion, and also the longer-term evaluation of the performance of the project. This evaluation is enhanced by continued follow-up and feedback from construction and maintenance personnel. The primary objective is overall improvement in all stages of plan development with proper recognition of effective and possibly new exploration, design, and construction procedures and techniques.

When asked if these evaluations were held, most agencies indicated they were not. Some indicated there was unofficial voluntary feedback of information sufficient for their purposes. Others indicated such an evaluation would be a good idea.

Figure 12. Problem cut slope.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Transportation agencies generally recognize the importance of adequate geotechnical investigation with respect to corridor studies, route selection, and design of transportation facilities, and for the most part do a good job in the acquisition and use of geotechnical information.

The generally accepted stages of project development are: corridor studies, route selection, preliminary and final design, advertising and bidding, and construction. The extent of geotechnical investigations undertaken for these stages varies considerably among the agencies.

The organizational units responsible for planning, acquiring, and utilizing geotechnical information presently include a number of job classifications or titles, all commonly associated in the materials and research divisions of the agencies. Usual titles include: materials engineer, geologist, soils engineer, soils and foundation engineer, and engineering geologist.

There is considerable variation among the agencies in the format for presenting the information obtained in the geotechnical investigation. The general tendency is to make dual use of any displayed information as a design aid and also as a part of bidding and construction plans.

The use of geotechnical information in the agencies also varies considerably and is in accord with long-established local practice. Even though there are many processes and personnel categories involved, the analysis, use, and application of geotechnical information in construction plan development is generally adequate.

Information actually made available to the bidder for use in preparing his bid varies from practically no information to a considerable amount of useful information. The information applicable to structures is routinely more detailed and in a more acceptable format than information available for roadway grading projects.

Agencies are reluctant to release any interpretative information relating to geophysical investigations; however, they frequently release or sell all official logs of borings and soil test data. Seismic interpretations are not usually released, but top-of-rock determinations from those data may be given in tabular form.

Agencies routinely include on their drawings or in the specifications a standard disclaimer that relieves the agency of any responsibility regarding accuracy or completeness of geotechnical information, and noting that the actual site conditions at time of construction may not be the same as reported. The agencies believe the disclaimer serves a useful purpose. The contractors are definitely not in favor of the disclaimers.

Prebid conferences with bidders have declined in popularity and are rarely held. Lack of interest by bidders and the absence of noticeable results in bidding were given as the principal causes.

With gradual acceptance of the geotechnical engineering input into the exploration, design, bidding, and construction process, some agencies now include geotechnical participation in the field construction activities. Yet, there are many agencies where the geotechnical engineer is called to the construction site only after earthwork or foundation problems have developed.

Many agencies appear to have no well-organized effort to evaluate individual construction projects immediately after completion, and subsequently, to determine the good and bad aspects of the construction effort, as well as which procedures are desirable with respect to future plan development and construction. Agency budgeting does not normally include any postconstruction monitoring or evaluation.

RECOMMENDED PRACTICES

Organization

- A geotechnical engineering unit having staff level equivalent to conventional agency departments such as location and design, bridges, construction, and maintenance is suggested. This unit should be adequately staffed to have responsibility for planning and executing geotechnical investigations for all agency departments and should also be responsible for laboratory soil testing, geological work, soil mechanics and foundation analyses and design, and participation in construction and postconstruction follow-up.
- Geotechnical engineers should have increased involvement in all related stages of project development, with particular attention to their service in preparing and translating report data and recommendations into studies, plans, and specifications; review of plans prior to bidding; and participation in construction and postconstruction evaluations.
- Uniformity in job titles and responsibilities for those associated with geotechnical investigations should be attained. Soils engineers, soils and foundation engineers, engineering geologists, geologists, materials engineers, and bridge geologists are a few of the titles currently employed in this type of work. Use of the title *geotechnical engineer* is recommended.

Planning Geotechnical Investigations

- Responsibility for planning and developing geotechnical investigation programs should be assigned to geotechnical engineers who, by training and experience, have adequate exploration, analysis, design, and plan preparation experience to reasonably assure a suitable investigation program consistent with the particular stage of project development.

• Development of appropriate geotechnical investigation programs for any of the several stages of plan development requires that the site of the work be occupied and examined in the field by qualified personnel.

• The geotechnical engineer should be required to become involved at the earliest opportunity in the corridor study stage of plan development as it is at this time that he may render his greatest over-all service through careful analysis of options that usually decrease in number through subsequent stages.

• The environmental factors that can occur during execution of the geotechnical investigation, and those that may influence later stages of plan development, should be addressed early. These would include, but not be limited to, the following items:

(a) Possibility of contaminating surface and groundwater.
(b) Denuding of slopes and temporary or permanent erosion control.
(c) Leaving visible earth scars.
(d) Dust control.
(e) Excessive drilling and construction noise in urban areas.
(f) Interruption of water regimen.
(g) Siltation.
(h) Disposal of construction spoils.
(i) Disruption of marsh regimen.

• The intent or purpose of geotechnical investigations should be revised or expanded beyond concern primarily for information acquisition for design, to equal concern for the needs of contractors in preparing bids and field personnel in constructing the project. Items requiring attention include:

(a) Lead time (availability of geotechnical information in advance of bidding date).
(b) Improved coordination among the agencies in the presentation of geotechnical information.
(c) Use of standardized nomenclature and material description and classification.
(d) Simplification of information presentation.
(e) Information readily available to bidders in a format that will aid in their pricing the work and submitting a bid. Indication of precisely where all geotechnical information relating to a project can be found within an agency.
(f) Adequate location of test excavations or measured sections, and boring information shown, using detailed topographic base maps.
(g) Sufficient borings in cut (excavation) areas, taken well below the anticipated lowest working area.
(h) Display of groundwater information as obtained at time of drilling, boring, or excavating trenches.
(i) Adequate cores obtained to establish boulder or bedrock conditions.
(j) Indication of rock type and soundness.
(k) Geological names of formations or members included in certain geographical areas.
(l) Provision of all test data on granular or rock material in excavation, so that its potential use as other specification items (base or select material) may be evaluated.
(m) Inclusion of cut soil moisture and optimum moisture-density information.

Design

• The geotechnical engineering unit should have coordinated participation in all related stages of project development, including: initial occupancy of the proposed work site; field and laboratory functions of the geotechnical investigation; close liaison with design engineers; soil and rock mechanics analyses and design; and preparation and assembly of information to be made available to bidders.

Prebid Information, Advertising, and Bidding

• The geotechnical engineering unit should have considerable responsibility in organizing, displaying, and answering inquiries relating to all geotechnical information made available prior to and at the time of bidding.

• A prebid conference should be considered when the type, size, and anticipated complexity of a project indicate that some benefit may be derived through formal participation by representatives of the design, construction, and geotechnical engineering departments.

• For large or complex projects the customary three-week interval between advertising and receipt of bids is inadequate for independent geotechnical investigations by the potential bidders. This lead time should be increased for such projects, depending on the complexity and anticipated bidding interest.

Construction

• Geotechnical engineers should be involved to a much greater extent in all phases of construction. They must recognize their support role and contribution to the over-all effort without sacrifice of the authority of the resident engineer. The resident engineer and his field inspectors should recognize the expertise available within the geotechnical engineering unit and use it to its fullest advantage.

• An in-house conference should be held on earthwork and related activities for certain projects, with the geotechnical engineer, resident construction engineers, and inspection staffs in attendance. Attendance by the construction contractor may be desirable on certain complex projects.

Postconstruction Performance Evaluations

• Postconstruction evaluations should be conducted on many projects and would involve those responsible for originating the geotechnical investigation, project design, bidding, plan and specifications development, construction monitoring, and, possibly, maintenance.

• The initial evaluation would include determination of desirable and undesirable design and construction aspects for deletion, application, or reinforcement in subsequent projects.

• With the comments of the maintenance engineer, and continued surveillance by the geotechnical engineer over a longer period of time following construction, performance records can be used to augment new or improved designs.

APPENDIX A

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APPENDIX B

AGENCIES AND ORGANIZATIONS RESPONDING TO TRB SURVEY OR TO INTERVIEWS

TRANSPORTATION AGENCIES

Alabama
Arizona
California
Connecticut
D.C.
Florida
Georgia
Hawaii
Idaho
Illinois
Iowa
Kansas
Kentucky
Louisiana
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
New Mexico
New York
North Carolina
North Dakota
Ohio
Oregon
Pennsylvania
South Carolina
South Dakota
Tennessee
Texas
Virginia
Washington
West Virginia
Wisconsin

CONTRACTOR ASSOCIATIONS

Associated General Contractors, New York
Associated Pennsylvania Contractors
California Association General Contractors
Carolinas Branch, ARBA
Kansas Contractors Association
Kentucky Road Builders Association
Michigan Road Builders Association
New England Road Builders
Tennessee Road Builders Association
Utah Chapter, Associated General Contractors
Wisconsin Road Builders Association

CONTRACTORS

Amino Brothers Company, Inc.
Bayer Construction Company, Inc.
Bemis Construction, Inc.
Brasfield Construction, Inc.
Broce Construction Company, Inc.
Bushman Construction Company
Burns & Baker, Inc.
C. A. Hull Company
Clark Brothers, Contractors
D. W. Winkleman Company
Greenfield Construction Company
Guy F. Atkinson Company
Kasler Corporation
List & Clark Construction Company
Malone Construction Company
Michael Construction Company
Oman Construction Company
Reno Construction Company, Inc.
Rhoades Construction Company, Inc.
Russell Ralph Company, Inc.
Shore & Sons, Inc.
The Lane Construction Company
Thompson Construction Company
Torrington Construction Company
United Construction Company, Inc.
William Givens Construction Company, Inc.

APPENDIX C

NEW YORK STATE SOIL PROGRAM

The responsibilities of the New York State Department of Transportation Soils Mechanics Bureau have been developed over a number of years and are clearly defined in the *Highway Design Manual,* Vol. 1, Facilities Design Subdivision (1972). The state is divided into ten regions. Each region office has a regional soils section that provides geotechnical services to all region program areas, including planning, design, construction, and maintenance.

ORGANIZATION		PLANNING
REGIONAL PLANNING GROUP		REGIONAL PLANNING ENGINEER PROVIDES – Regional Soils Engineer with Corridor Location Plan – Completion Deadline for Report RECEIVES Terrain Reconnaissance Report
SOILS PROGRAM	REGIONAL SOILS SECTIONS	PREPARES TERRAIN RECONNAISSANCE REPORT 1. Identify major soil and rock deposits in each corridor. Evaluate engineering significance of major deposits that could affect highway performance and construction costs. Occasionally, right-of-way considerations may be influenced by soil and rock deposits. A. Field Reconnaissance (1) Performance of nearby facilities B. Survey of existing soil data (1) Agricultural soil maps (2) Geologic literature (3) Previous explorations in area (4) Analysis of air photos C. Preliminary subsurface explorations if needed for major problem evaluation.
	SOIL MECHANICS BUREAU	PROVIDES technical assistance to Region where required. A. Terrain Reconnaissance Reports Reports for major projects on new location when requested by Region B. Assistance to Regional Soils Section in preparation of reports. C. Determines Present Serviceability Index (PRI) for resurfacing projects.

<table>
<tr><th colspan="2">ORGANIZATION</th><th>ALTERNATE DESIGN</th></tr>
<tr><td colspan="2">REGIONAL DESIGN GROUP</td><td>REGIONAL DESIGN ENGINEER

PROVIDES
– Regional Soils Engineer with plans, profiles and typical sections of alternate designs.

RECEIVES
Phase I Soils Report</td></tr>
<tr><td rowspan="2">SOILS PROGRAM</td><td>REGIONAL SOILS SECTION</td><td>PREPARES SOILS REPORT FOR PHASE I DESIGN REPORT
1. Identify major soil and rock deposits for each alternate design.
2. Determine engineering significance of major deposits that could affect highway performance, construction costs, influence of soil and rock deposits on right-of-way considerations, and appearance of completed project.

A. Field Reconnaissance
(1) Performance of nearby facilities
B. Survey of Existing Soil Data
C. Preliminary subsurface explorations in major problem areas for feasibility studies and evaluation of economic considerations.</td></tr>
<tr><td>SOIL MECHANICS BUREAU</td><td>PROVIDES technical assistance to Region where required.</td></tr>
</table>

ORGANIZATION		ADVANCE DETAIL
REGIONAL DESIGN GROUP		REGIONAL DESIGN ENGINEER PROVIDES – Regional Soils Engineer with plans, profiles and generalized typical sections – All plan and profile changes in design development – Completion deadline for report RECEIVES Soils Report for Advance Detail Plans
S O I L S P R O G R A M	REGIONAL SOILS SECTIONS	PREPARES SOILS REPORT FOR PHASE V – ADVANCE DETAIL PLANS 1. Recommendations to provide designers all necessary information to prepare quantity and cost estimates for earthwork items. 2. Advises on additional ROW requirements determined by soil and rock conditions. 3. Recommendations for treatment of all embankment foundation problems and cut slopes. 4. Evaluates existing shoulder and pavement structure for resurfacing projects. A. Sufficient subsurface explorations, lab testing, and analysis to determine all subsurface information for design and construction considerations, including embankment foundations, cut slope design, top of slope ditches, structure foundations (including Region design), subsurface drainage, unsuitable material removal, undercutting unstable soils, granular construction lifts, granular slope protection treatment, subbase design, topsoil sources, granular material sources, earthwork factors and earthwork consideration influencing typical sections, soil considerations for bank and channel protection, recharge basin design.
	SOIL MECHANICS BUREAU	PROVIDES technical services and technical assistance to Regions where required. A. Geophysical Surveys – Seismic Explorations to determine depth to rock surface for cut slope design and earthwork quantity estimates. B. Rock Outcrop Mapping – Preparation of rock outcrop map to aid designers in determination of rock surface for earthwork quantity estimates. C. Borehole Camera Survey – Evaluation of rock structure in drill holes. D. Geologic Surveys – Rock Cut Slopes Recommendations for rock cut slope treatment. E. Roadway Foundation Design – Recommendation for treatment of embankment foundation soils in critical areas. F. Earth Cut Slope Design – Recommendation in critical soil and groundwater seepage areas. G. Retaining Walls Designed by Regions Recommendations for vertical and lateral earth pressure considerations. H. Roadway Design – General Assistance to Regional Soils Engineer where required. I. Pipe Design – Unusual problems involving earth pressures and jacking procedures. J. Channel Slope Protection Problems involving rip-rap, gabions, and fabriform treatments and filter designs, except in the vicinity of structures. K. Subsurface Explorations – Provides special equipment, technical advisory service, and prepares drilling contracts. L. Provides data for recharge basin design.

ORGANIZATION		FINAL DESIGN
REGIONAL DESIGN GROUP		REGIONAL DESIGN ENGINEER PROVIDES – Regional Soils Engineer with plans, profiles, and earthwork specifications – Completion deadline for report RECEIVES Final Soils Report
SOILS PROGRAM	REGIONAL SOILS SECTION	PREPARES SOILS REPORT FOR FINAL P.S. & E. 1. Detailed recommendations on previously reported treatments sufficient for preparation of final quantity estimates. 2. Special earthwork specifications, if required. 3. Provides accurate location of all subsurface exploration data for plotting on plans. 4. Special typical sections, if required. 5. Package of all soils data for examination by bidders
	SOIL MECHANICS BUREAU	PROVIDES technical services and technical assistance to Regions where required.

ORGANIZATION	CONSTRUCTION

REGIONAL PLANNING GROUP

REGIONAL CONSTRUCTION ENGINEER

ADVISES
- Regional Soils Engineer of earthwork problems requiring soil and rock investigation
- Date of pre-construction soils meeting if required.

RECEIVES
Recommendations from Regional Soils Engineer

SOILS PROGRAM

REGIONAL SOILS SECTION

PROVIDES services to the Regional Construction Supervisor on all construction problems involving earth and rock.

1. Pre-Construction Soils Meeting
   Reviews with Regional Construction Engineer and Project Engineer, details of all embankment foundation and cut slope designs, special earthwork specifications and anticipated earthwork problems.
2. Conducts sampling and testing of granular material items for acceptance.
3. Advises on problems involving unsuitable material excavation, undercutting, stabilized shoulders and compaction.
4. Advises on need for quantity changes in earthwork items.
5. Trains earthwork inspectors, provides project labs with testing equipment.
6. Conducts investigations for redesign caused by unanticipated soil and rock conditions.

SOIL MECHANICS BUREAU

PROVIDES technical services and technical assistance to Region where required.

A. Roadway foundation design – redesigns needed in construction.
B. Roadway inspection – stone filling and rip-rap. Formal program for field inspection and approval for suitability of material.
C. Roadway inspection – rock cut slopes Advisory service for presplitting and fragmentation and inspection of completed slopes for scaling and rock bolting needs.
D. Monitoring Vibrations – special equipment for monitoring vibrations caused by blasting or pile driving.
E. Testing of topsoil from borrow for acceptance.
F. Testing for proper mixes of stabilized shoulders, and advisory service on field mixing. Includes bituminous, cement and lime stabilization.
G. Testing granular materials for acceptance.
H. Construction control devices – Assistance and inspection service for installation of special monitoring devices (piezometers, settlement measurement) for foundation treatments.
I. Provides field services on difficult earthwork compaction problems.
J. Evaluation of design recommendations for improvement of design criteria.
K. Advisory service – Influence of construction on groundwater supplies for wells & ponds.

ORGANIZATION		POST CONSTRUCTION
REGIONAL PLANNING GROUP		REGIONAL DIRECTOR may initiate evaluation of earth-work specifications and standards through Design and Construction Division.
SOILS PROGRAM	REGIONAL SOILS SECTION	CONDUCTS performance evaluation and data collection for improvement of specifications and standards involving earthwork.
	SOIL MECHANICS BUREAU	EVALUATES construction specifications and design and construction standards and procedures involving earthwork to improve economy, performance and efficiency.

APPENDIX D

METHODS, EQUIPMENT, AND BORING CRITERIA UTILIZED IN PERFORMING GEOTECHNICAL INVESTIGATIONS

The Transportation Research Board sent a questionnaire to all state transportation agencies to ascertain the relative frequency of use of conventional and special methods and equipment currently used in performing geotechnical investigations. Agencies responding are listed in Appendix B. In the summary of results presented hereinafter, every attempt was made to incorporate broad, general descriptions of equipment, with the recognition that local descriptions of identical equipment may vary.

The location, spacing, type, and depths of borings and/or excavations comprising a geotechnical investigation are usually determined on the basis of design considerations and reconnaissance observations for development of maximum subsurface information utilizing a minimum number of borings. Topography, geologic origin of materials, and surface manifestation of soil and rock conditions are of vital concern. As boring and sampling progresses in the field and subsurface conditions become more evident, the locations, spacing, depths, and types of explorations are reviewed and the extent of explorations increased or decreased as considered necessary.

Although it is recognized that flexibility in the subsurface explorations program is necessary and desirable, and reflects good engineering practice, most agencies nevertheless have a more or less standard criterion for conducting geotechnical investigation programs. The following abbreviated summary of criteria is intended to show the approximate extent of investigations completed for design of structures and roadways.

DRILLING

TYPE	NUMBER OF AGENCIES: ROUTINELY USING	INFREQUENTLY USING	NEVER USING
ROTARY:			
Fishtail Bit	19	12	4
Rock Roller Bit	26	6	4
Drag Bit	2	-	-
PERCUSSION:			
Cable Tool	1	3	31
Hammer	12	5	18
AUGER-Mechanical:			
Spoon	3	5	25
Hinged	-	4	28
Disk	-	6	21
Continuous Helical	33	3	1
Hollow Stem	25	6	5
WASH BORING	15	16	7
CONTINUOUS SAMPLE	15	17	1
BORING STABILIZATION:			
Water	29	6	-
Natural Slurry	13	12	10
Artificial Slurry	17	15	6
Air	3	-	-
Freezing	-	1	35
Grouting	-	21	13
Casing	30	7	-

GROUND WATER OBSERVATIONS

FOR DESIGN	NUMBER OF AGENCIES: ROUTINELY USING	INFREQUENTLY USING	NEVER USING
FREE GROUNDWATER LEVEL:			
Uncased Borings	32	4	-
Cased Borings	23	9	2
Well Point			
Well Screen	5	13	15
Porous Tube	5	11	17
Perforated Pipe	1	-	-
PORE PRESSURE:			
Standpipe Piezometer	12	16	9
Closed Hydraulic Piez.	3	12	21
Vibrating Wire Strain Gauge Piezometer	-	5	30
Pneumatic Piezometer	5	11	18
FOR CONSTRUCTION:			
Standpipe Piezometer	12	17	8
Closed Hydraulic Piez.	3	12	19
Vibrating Wire Strain Gauge Piezometer	-	3	31
Pneumatic Piezometer	6	12	18

SAMPLING

TYPE	NUMBER OF AGENCIES ROUTINELY USING	INFREQUENTLY USING	NEVER USING
PENETRATION TESTS:			
Split Barrel	33	2	2
Split Barrel w/liner	5	17	14
Large Diameter Split Barrel w/liner	1	14	21
Solid Barrel	1	6	22
Solid Point	1	-	-
THIN WALL TUBE:			
Shelby Tube	31	6	-
Fixed Piston	7	11	16
Pitcher Sampler	2	7	26
WASH	10	15	11
RETRACTABLE PLUG	6	7	20
PEAT SAMPLER	7	6	21
ROCK CORING:			
Size EX	2	1	4
Size AX	10	3	-
Size BX	9	1	1
Size NX	20	1	-
CORE BARRELS:			
Single Tube	10	12	11
Double Tube	30	4	2
Wire Line	2	4	26
Denison	1	4	-
CORE BITS:			
Diamond	34	2	-
Hardened Surface	18	23	2
HOLE ORIENTATION:			
Vertical	32	3	-
Horizontal	-	1	-
Angle	4	13	18
BORE HOLE CAMERA	1	3	32
ACCESSIBLE EXPLORATIONS:			
Test Pits	9	17	11
Test Trenches	4	24	7
Caissons	-	14	-
Accessible Borings	17	4	10

FIELD TESTS

	NUMBER OF AGENCIES ROUTINELY USING	INFREQUENTLY USING	NEVER USING
DYNAMIC:			
Standard Penetration Test	34	1	1
Cone Penetrometer	5	8	23
Driven Probe	5	11	19
Driven Casing	11	10	13
Drive Rod	1	-	-
STATIC:			
Cone Penetrometer	2	5	31
Field CBR	2	8	25
Plate Bearing Test	1	20	13
Lateral Bearing Test	1	-	-
IN-PLACE-VANE	8	18	15
PRESSUREMETER	1	4	20
PERMEABILITY:			
Falling Head	6	18	12
Pumped-In	-	11	23
Pumped Well	-	1	-
IN-PLACE SOIL DENSITY			
Sand Cone	1	5	9
Rubber Ballon	-	4	7
Nuclear	2	4	9
Drive Cylinder	1	2	6
Shelby Tube	-	1	2
Ring Sampler	-	1	1

GEOPHYSICAL

	NUMBER OF AGENCIES ROUTINELY USING	INFREQUENTLY USING	NEVER USING
ELECTRICAL:			
Resistivity	11	15	10
RADIATION:			
Natural Gamma Ray	3	2	29
Gamma-Gamma Ray	-	2	28
Neutron	3	2	28
ACOUSTICAL			
Velocity (porosity)	-	1	35
Amplitude (Location of fracture zones)	-	1	35
SEISMIC			
Standard Refraction Survey	11	10	13
Sonar Continuous Seismic Profiling			
Boomer Probe	-	1	35
Pinger Probe	-	1	34
Standard Reflection Survey	-	7	29

LABORATORY SOIL TESTING

TEST	NUMBER OF AGENCIES INVESTIGATION STAGE: CORRIDOR STUDY	PRELIMINARY DESIGN	FINAL DESIGN
PARTICLE SIZE ANALYSIS:			
Sieve	10	29	24
Hydrometer	3	21	20
ATTERBERG LIMITS:			
Liquid	10	30	22
Plastic	9	29	19
Shrinkage	1	14	14
MOISTURE CONTENT	8	31	23
ORGANIC CONTENT	4	12	15
SPECIFIC GRAVITY	3	22	21
COMPACTION:			
Standard	1	19	21
Modified	1	9	12
RELATIVE DENSITY	1	9	5
PERMEABILITY:			
Constant Head	-	7	8
Falling Head	-	10	10
CONSOLIDATION:			
Permeability	1	13	10
Hysteresis (Double)	1	8	4
UNCONFINED COMPRESSION	2	23	20
DIRECT SHEAR, DRAINED	1	10	14
TRIAXIAL COMPRESSION:			
Q-Test, (Unconsolidated-Undrained)	2	19	18
R-Test, (Consolidated-Undrained)	1	12	14
$\bar{R}$-Test, (Consolidated-Undrained w/ Pore Pressure Measurements)	1	10	10
S-Test, (Consolidated-Drained)	1	14	9
MINIATURE VANE:			
Laboratory Vane	-	4	3
Manual Vane	-	1	3

CONSTRUCTION MONITORING INSTRUMENTATION

INSTRUMENT	NUMBER OF AGENCIES: ROUTINELY USING	INFREQUENTLY USING	NEVER USING
INCLINOMETERS	11	16	9
SHEAR STRIP	-	-	34
SETTLEMENT PLATES	14	17	5
PIEZOMETERS:			
Standpipe	13	17	6
Closed Hydraulic	3	12	20
Vibrating Wire			
Strain Gauge	1	1	29
Pneumatic	7	8	18
DISPLACEMENT STAKES	12	15	9
TELLTALES	4	5	23
EARTH PRESSURE CELLS	-	10	25
STRAIN GAUGES	1	6	29
ROCK BOLT LOAD CELLS	-	2	30

ABBREVIATED SUMMARY

ROADWAY BORING CRITERIA

SITUATION	BORING SPACING	BORING LOCATION	MINIMUM DEPTH	BORING TYPE	MINIMUM NUMBER BORING OR CROSS-SECTIONS
EMBANKMENTS - Roadway:	1 per fill to 1 each 400-500 ft	Centerline or Ditchline	(Emb Ht +10') (2/3 Emb Ht.) (Firm Material) (10' into firm material)	Auger, Undist. Samples, Backhoe	1 to 5
CUTS Roadway:	25' to 400'	Centerline or Ditchline	(2' to 10' below grad) (Firm Material)	Auger, Backhoe	1 to 5
CUT-FILL	(Same as above)				
SPECIAL INVESTIGATIONS Cut Slope Stability	(25' to 300') (1 per cut)	Midpoint Top & Toe Slope	(5' to 70') (variable) (10' into stable soil)	Auger, Continuous Samples	2 to 3
Emb.-Found. Stability	(approximately same as above)				
Settlement Studies	(50' to 300')	Centerline	Refusal or Hard Layer	Auger, *SPT, Continuous Samples	
CONSTRUCTION MATERIAL Borrow Sources	50' to 500'	Grid	Variable	Auger, to Pit Excavations	Varies

*SPT - Standard Penetration Test - ASTM D 1586-67

ABBREVIATED SUMMARY

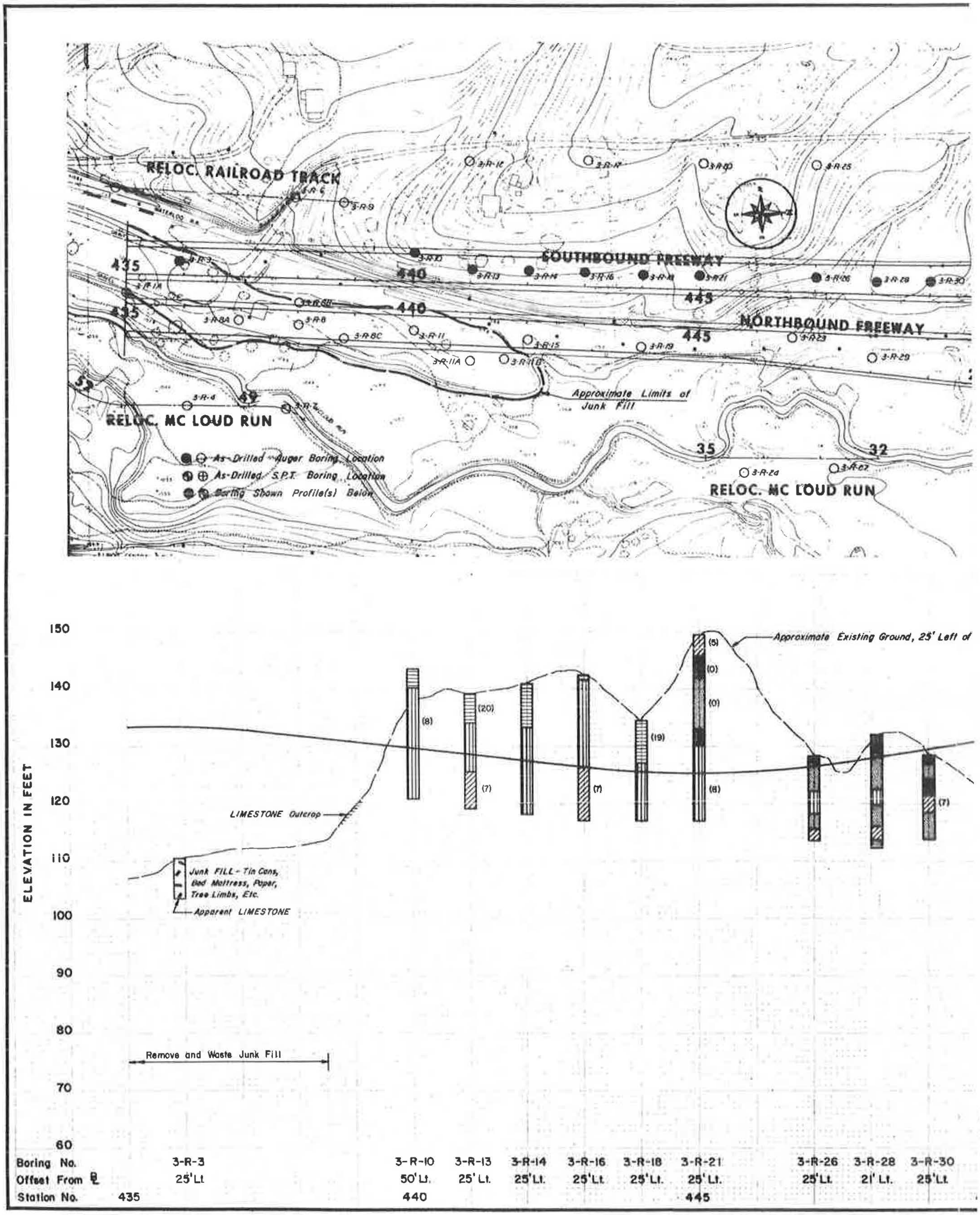
STRUCTURE BORING CRITERIA

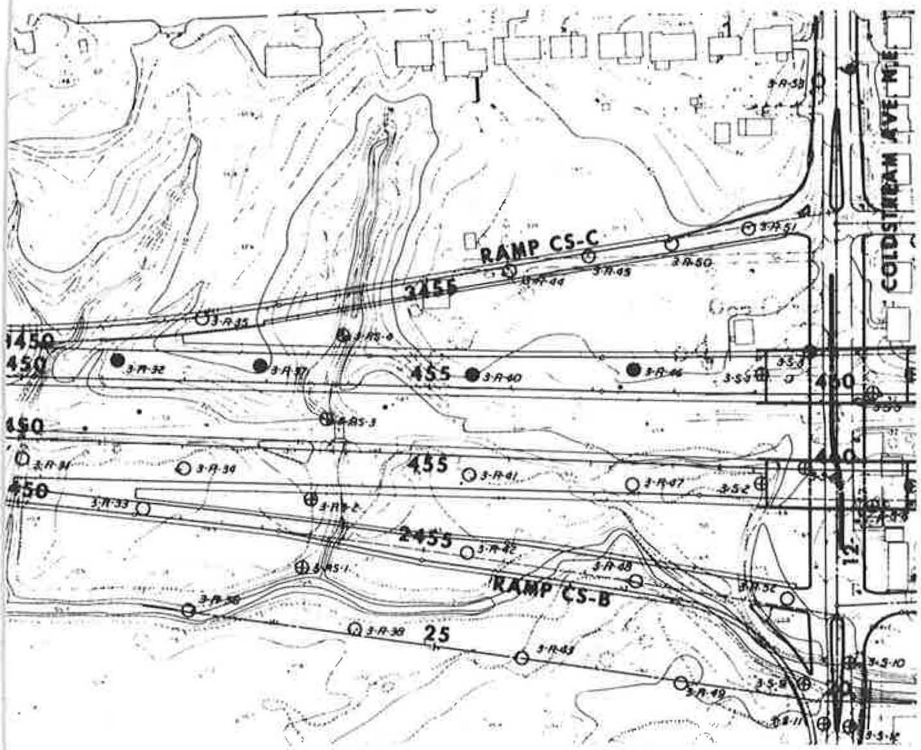
STRUCTURE TYPE	# OF BORINGS PER SUBSTRUCTURE UNIT	MINIMUM DEPTH OF BORINGS	BORING TYPES	USUAL LOCATION OF BORINGS
MAJOR STREAM CROSSINGS: Land Units	1 to 6	10' to 120' (Preset formula or to rock)	Auger, SPT, Rock Core	Centerline of Units or at ends
Water Units	(Generally same as Land, but with increase in depth)			
GRADE SEPARATIONS	(Generally same as Land Units)			
RAILROAD BRIDGES	(Generally same as Land Units)			
SIGN BRIDGES	1 or 2 (20%± seldom investigate)	10' to 20'	Auger	Centerline
TUNNELS	1 per 100± Length	Below proposed tunnel	SPT & Rock Core	Centerline or along side
CULVERTS	0 to 6	2' to 30' into Hard Material Depends on Height of fill	SPT, Auger Backhoe	Centerline or @ Wingwalls
HIGH LIGHT TOWERS	1	20' to 25'	SPT, Auger	Centerline Footing and at Anchors

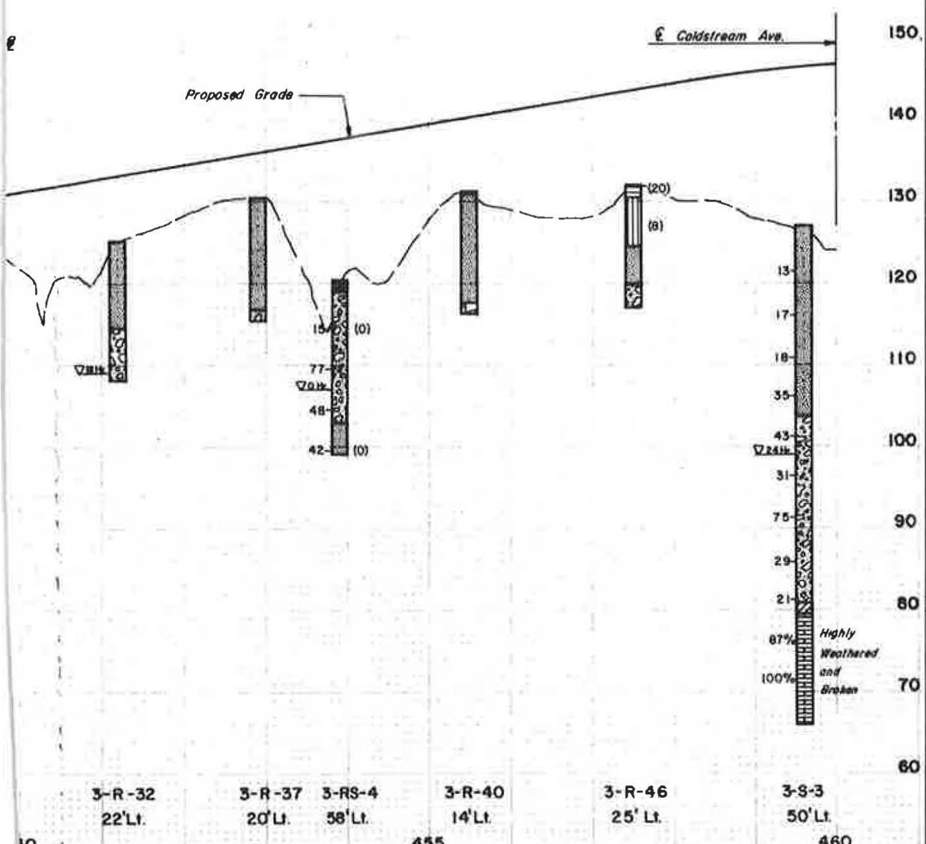
APPENDIX E

PRESENTATION OF SUBSURFACE INFORMATION

Transportation agencies do not follow any single format in the presentation of geotechnical information on plan sheets. Each agency has its standardized method for showing data, using its own symbols and display techniques. Although the difficulty in offering a representative set of individual agency plan sheets is recognized, the plans used in this appendix were prepared to illustrate generally accepted practices for showing geotechnical information.


RELOC. RAILROAD TRACK
SOUTHBOUND FREEWAY
NORTHBOUND FREEWAY
RELOC. MC LOUD RUN
Approximate Limits of Junk Fill
RELOC. MC LOUD RUN
As-Drilled Auger Boring Location
As-Drilled S.P.T. Boring Location
Boring Shown Profile(s) Below
Approximate Existing Ground, 25' Left of
ELEVATION IN FEET
LIMESTONE Outcrop
Junk FILL - Tin Cans, Bed Mattress, Paper, Tree Limbs, Etc.
Apparent LIMESTONE
Remove and Waste Junk Fill
Boring No. 3-R-3 3-R-10 3-R-13 3-R-14 3-R-16 3-R-18 3-R-21 3-R-26 3-R-28 3-R-30
Offset From ℄ 25'Lt 50'Lt. 25'Lt. 25'Lt. 25'Lt. 25'Lt. 25'Lt. 25'Lt. 21'Lt. 25'Lt.
Station No. 435 440 445

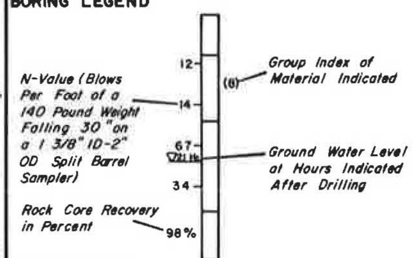




MATERIAL LEGEND

SYMBOL	AASHTO	VERBAL DESCRIPTION
	A-1-a	*Stone Fragments or Gravel, with or without binder of fine material*
	A-1-b	*Coarse Sand, with or without soil binder*
	A-3	*Fine Sand, clean*
	A-2-4	*Silty Sands or Gravel, nonplastic to moderately plastic*
	A-2-5	*Silty Sands or Gravel, may be highly elastic*
	A-2-6	*Clayey Sands or Gravel, plastic, may be subject to high volume change*
	A-2-7	*Clayey Sands or Gravel, highly elastic, subject to high volume change*
	A-4	*Silty Soils, nonplastic to moderately plastic*
	A-5	*Silty Soils, highly elastic*
	A-6	*Clayey Soils, plastic, may be subject to high volume change*
	A-7-5	*Clayey Soils, highly elastic, subject to considerable volume change*
	A-7-6	*Clayey Soils, highly elastic, subject to extremely high volume change*
		Peat or Muck
		Miscellaneous Fill
		Limestone
		Sandstone
		Shale

BORING LEGEND



GENERAL NOTES

1. *Borings were drilled by ____________ between September 17, and October 2, 1974.*
2. *Elevations shown are project datum, 200.00= 862.75 USGS.*
3. *Ground water levels shown were recorded during the exploration program. Porosity of soil strata, time of year, weather conditions, site topography, etc., may cause changes in these levels.*
4. *Logs of Borings and Laboratory Test Results are available for inspection at ____________*
5. *Subsurface information shown on this drawing was obtained solely for use in establishing design controls for the project. The accuracy of this information is not guaranteed and it is not to be construed as part of the plans governing the construction of this project.*
6. *The alignment and/or proposed grade (s) shown were developed prior to completion of final design and may vary slightly from final plans.*

LOG OF BORING

BORING NO.	A-1
SHEET	OF
PROJECT	
EXPLORATION CONTRACTOR	
ENGINEERS REP.	
LOGGED BY	
STATION	0 + 35
OFFSET	85' Right
STARTED	10-3-74
COMPLETED	10-3-74

GROUND WATER: ENCOUNTERED DURING DRILLING AT ___; ___ HOURS AFTER DRILLING ___; ___ HOURS AFTER DRILLING ___; ___ HOURS AFTER DRILLING ___; Caved in at 13'

BORING METHOD: HAND AUGER; HOLLOW STEM AUGER; CONTINUOUS FLIGHT AUGER; DRIVING CASING; ROTARY (MUD) DRILLING; 0.0 DEPTH MUD STARTED

SAMPLER TYPE AND DATA: SPLIT BARREL 1-3/8" I.D.; UNDISTURBED SAMPLE 3" O.D.; AUGER; ROCK CORE

Soil Classification System: ASTM Unified. ELEV. DATUM U.S.C. & G.S. ELEV. 854.3

DEPTH BELOW SURFACE	SAMPLE NUMBER	RECOVERY (IN.)	0-6	6-12	12-18	BPF	POCKET PENETROMETER (P) or TORVANE (T) (TSF)	SOIL DESCRIPTION (Color, Consistency, Modifier, MATERIAL, Moisture, Classification)	ELEV.
3.5	J-1	5"	2	4	7	11	2.2P	Gray Brown, Very Stiff, Silty, CLAY, Moist, CL	
5.0									849.3
10.0	J-2	9"	3	4	4	8		Gray Brown, Loose, Fine to Medium, SAND, trace of Silt, Wet, SP	
20.0	J-3	14"	3	4	8	12		Gray, Medium Dense, Fine to Medium, SAND, Wet, SP	
30.0	J-4	10"	6	5	5	10		Gray, Medium Dense, Fine to Coarse, SAND, with Clay Pockets, wet, SP	
40.0	J-5	12"	7	10	11	21		Gray, Medium Dense, Fine to Medium, SAND, trace of Lignite, Wet, SP	
45.0									809.3
50.0	J-6	14"	12	15	13	28		Gray, Medium Dense, Fine to Coarse, SAND, trace of Gravel and Lignite, Wet, SW/SP	
60.0	J-7	14	15	18	19	37		Gray, Dense, Fine to Coarse, SAND, trace of Gravel & Lignite, Wet SW/SP	
61.5									792.8
								Bottom of Boring at 61.5'	
								Boring backfilled 10-15-74	

LOG OF BORING

BORING NO.	A-3
SHEET	OF
PROJECT	
EXPLORATION CONTRACTOR	
ENGINEERS REP.	
LOGGED BY	
STATION	0 + 35
OFFSET	110' Left
STARTED	10-3-74
COMPLETED	10-3-74

GROUND WATER: ENCOUNTERED DURING DRILLING AT ___; 1/2 HOURS AFTER DRILLING 18'; ___ HOURS AFTER DRILLING ___; ___ HOURS AFTER DRILLING ___

BORING METHOD: HAND AUGER; HOLLOW STEM AUGER; CONTINUOUS FLIGHT AUGER; DRIVING CASING; ROTARY (MUD) DRILLING; 0.0 DEPTH MUD STARTED

SAMPLER TYPE AND DATA: SPLIT BARREL 1-3/8" I.D.; UNDISTURBED SAMPLE 3" O.D.; AUGER; ROCK CORE

Soil Classification System: ASTM Unified. ELEV. DATUM U.S.C. & G.S. ELEV. 854.2

DEPTH BELOW SURFACE	SAMPLE NUMBER	RECOVERY (IN.)	0-6	6-12	12-18	BPF	POCKET PENETROMETER (P) or TORVANE (T) (TSF)	SOIL DESCRIPTION (Color, Consistency, Modifier, MATERIAL, Moisture, Classification)	ELEV.
2.5	U-1 J-1	14"						Light Brown, Fine to Medium, SAND, Moist, SP	
10.0	J-2	9"	3	5	6	11		Light Brown, Medium Dense, Fine to Medium, SAND, Trace of Silt, Wet SP	
20.0	J-3	4"	7	8	7	15		Light Brown, Medium Dense, Fine, SAND, Trace of Silt, Wet, SP	
25.0									829.2
30.0	J-4	10"	3	4	6	10		Light Brown, Medium Dense, Fine to Coarse, SAND, Wet, SW/SP	
35.0									819.2
40.0	J-5 J-6	13"	11	22	44	66		Light Brown, Very Dense, Fine to Medium, SAND, Trace of Clay and Gravel, Wet, SP	
41.0								Gray, Very Dense, Fine to Medium SAND, Wet, SP	813.2
50.0	J-7 J-8	6"	10	11	18	29		Gray Medium Dense, Fine to Medium, SAND, Wet, SP	
51.0								Gray Medium Dense, Fine to Coarse, Sand, Trace of Clay, Wet, SP	803.2
55.0									799.2
60.0	J-9	9"	8	10	11	21		Gray Brown, Medium Dense, Fine to Coarse, SAND, Wet, SW/SP	
68.0									786.2
70.0	J-10	15"	10	17	23	40	7.0P	Gray, Hard, Clayey, SILT, Moist, ML	
80.0	J-11	14"	8	11	21	32	3.75P	Gray, Very Stiff, Clayey, SILT, Trace of Sand, Moist, ML	
85.0								Trace of Gravel at 85'	
87.5									766.7
90.0	J-12	8"	24	90	50/1"		9.0P	Gray, Moderately Hard, SHALE, Trace of Sand and Mica, Dry	
100.0									754.2
								Bottom of Boring at 100.0'	
								Boring Backfilled 10-15-74	

LOG OF BORING

BORING NO. S-1
SHEET OF

PROJECT
EXPLORATION CONTRACTOR
ENGINEERS REP
LOGGED BY
STATION 8 + 98
OFFSET 45' Right
STARTED 10-5-74
COMPLETED 10-5-74

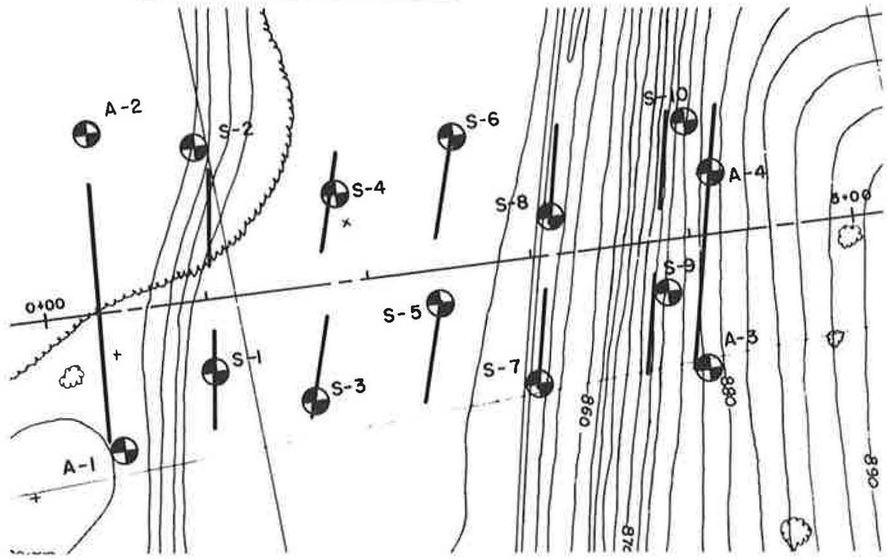
GROUND WATER
ENCOUNTERED DURING DRILLING AT
HOURS AFTER DRILLING
HOURS AFTER DRILLING
HOURS AFTER DRILLING
Caved at 3'

BORING METHOD
HAND AUGER
HOLLOW STEM AUGER
CONTINUOUS FLIGHT AUGER
D DRIVING CASING
R ROTARY (MUD) DRILLING
0.0 DEPTH MUD STARTED

SAMPLER TYPE AND DATA
S SPLIT BARREL 1-3/8" I.D.
U UNDISTURBED SAMPLE
A AUGER
C ROCK CORE 2-1/8"NX

DEPTH BELOW SURFACE	SAMPLE: INTERVAL AND TYPE	SAMPLE: NUMBER	SAMPLE: RECOVERY (IN.)	SPT (Blows per 6 inches) 0-6	6-12	12-18	BPF "N"	POCKET PENETROMETER (P) or TORVANE (T)	SOIL DESCRIPTION (Color, Consistency, Modifier MATERIAL, Moisture, Classification) Soil Classification System ASTM Unified		ELEV. DATUM U.S.C. & G.S. ELEV. 855.8
									Light Brown Silty Fine SAND, Moist, SM	1.0	854.8
2.5	S	J-1	5"	2	3	3	6	2.25P	Brown Mottled Gray, Very Stiff, Sandy, Silty, CLAY, Moist, CL	5.0	850.8
7.5	X										
10.0	S	J-2	13"	3	4	7	11		Gray Brown, Medium Dense, Silty, Fine, SAND, Wet, SM	15.0	840.8
15.0	X										
20.0	S	J-3	12"	4	4	9	13		Gray Brown, Medium Dense, Fine to Medium, SAND, Trace of Silt, Wet, SP		
25.0	X										
30.0	S	J-4	12"	4	11	10	21		Gray, Medium Dense, Fine to Medium, SAND, Trace of Lignite, Wet, SP		
35.0	X										
40.0	S	J-5	10"	28	34	31	65		Gray, Very Dense, Fine to Medium, SAND, Wet, SP		
45.0	X										
50.0	S	J-6	12"	35	38	62/3"			Gray, Very Dense, Fine to Medium, SAND, Wet, SP	55.0	800.8
55.0	X								Trace of Gravel at 55'		
60.0	S	J-7	11"	12	20	24	44		Gray Brown, Dense, Fine to Coarse, SAND, Wet, SW/SP		
65.0	X									69.0	786.8
70.0	S	J-8	18"	14	20	24	44	7.5P	Gray, Hard, Clayey,SILT, Moist, ML		
75.0	X										
80.0	S	J-9	16"	10	14	20	34	3.5P	Gray, Very Stiff, Clayey,SILT, Moist, ML		
85.0	X										
90.0	X								Gravelly from 87' - 91'	91.0	764.8
95.0	W A S										
100.0–110.0	C	C-1	C-1 100.0 - 110.0 Rec. 100% RQD 46%						Gray, Hard, SHALE, Thinly Laminated, Varved, Trace of Fine Sand, Dry	110.0	745.8
									Bottom of Boring at 110.0' Boring backfilled 10-15-74		

BORING LOCATION SKETCH



GENERAL NOTES

1. Borings were Drilled by ______________ Between October 3, 1974 and October 15, 1974.
2. Elevation datum is USC&GS referred to mean sea level.
3. Legend of Boring Logs:

(A) Standard Penetration Test – Driving a 2" O.D., 1 3/8" I.D. sampler a distance of 1.0 foot into undisturbed soil with a 140 lb. hammer free falling a distance of 30.0 inches. It is customary to drive the sampler 6.0 inches to seat it into undisturbed soil, then perform the test. The number of blows required to seat the sampler and take the test are recorded for each 6.0 inches of penetration (Example: 6-8-9). The standard penetation test results, N-Value, is obtained by adding the last two figures (8+9=17 blows per foot). Refusal is defined as 100 blows for less than 12" penetration and is indicated by blows / penetration (100 / 2").

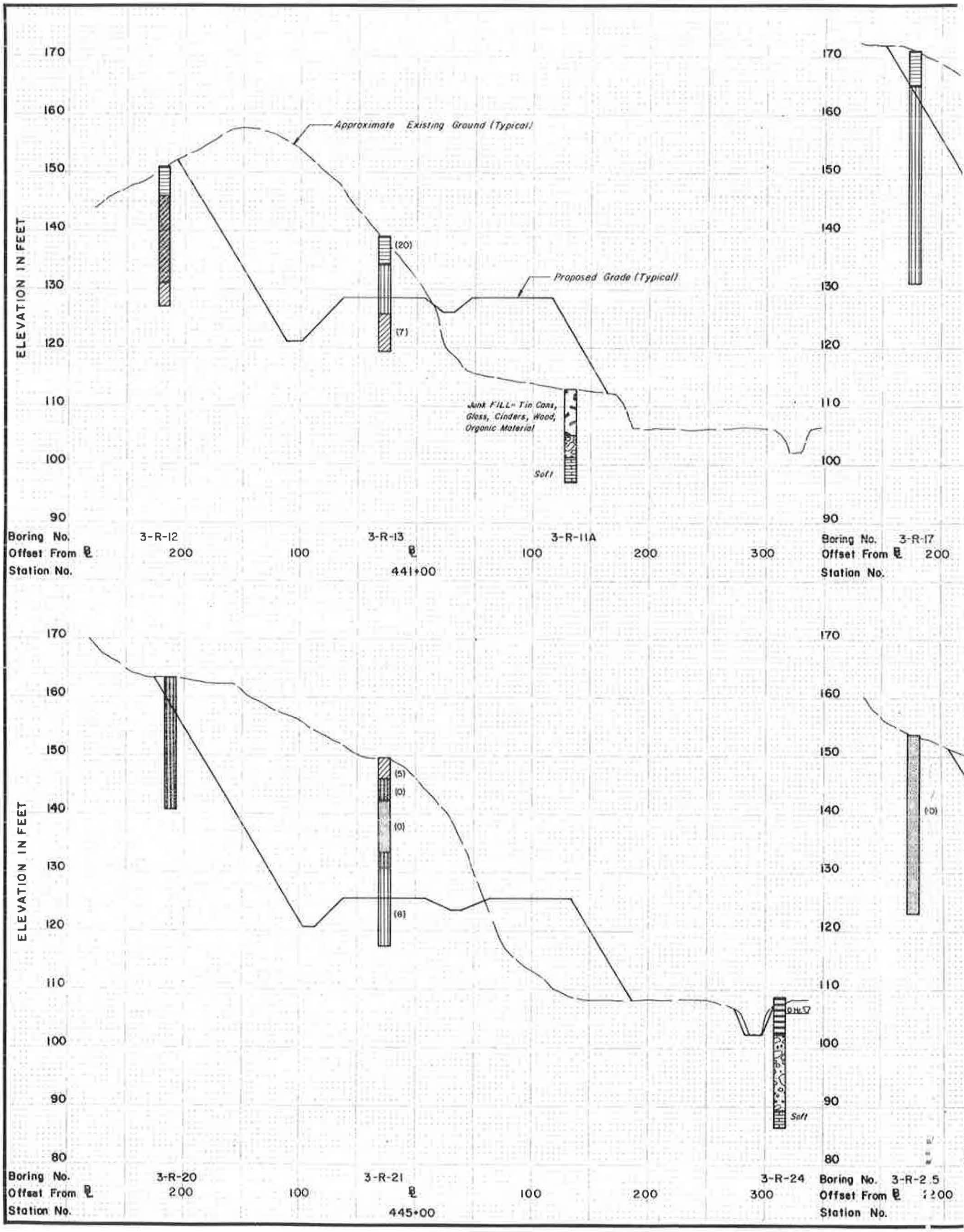
(B) Rock Coring – A 2 1/8" diameter core sample was obtained through the use of a double tube core barrel. Core recovery is designated in per cent. RQD (Rock Quality Designation) is designated in per cent and is a modified core recovery procedure used as an index to rock quality.

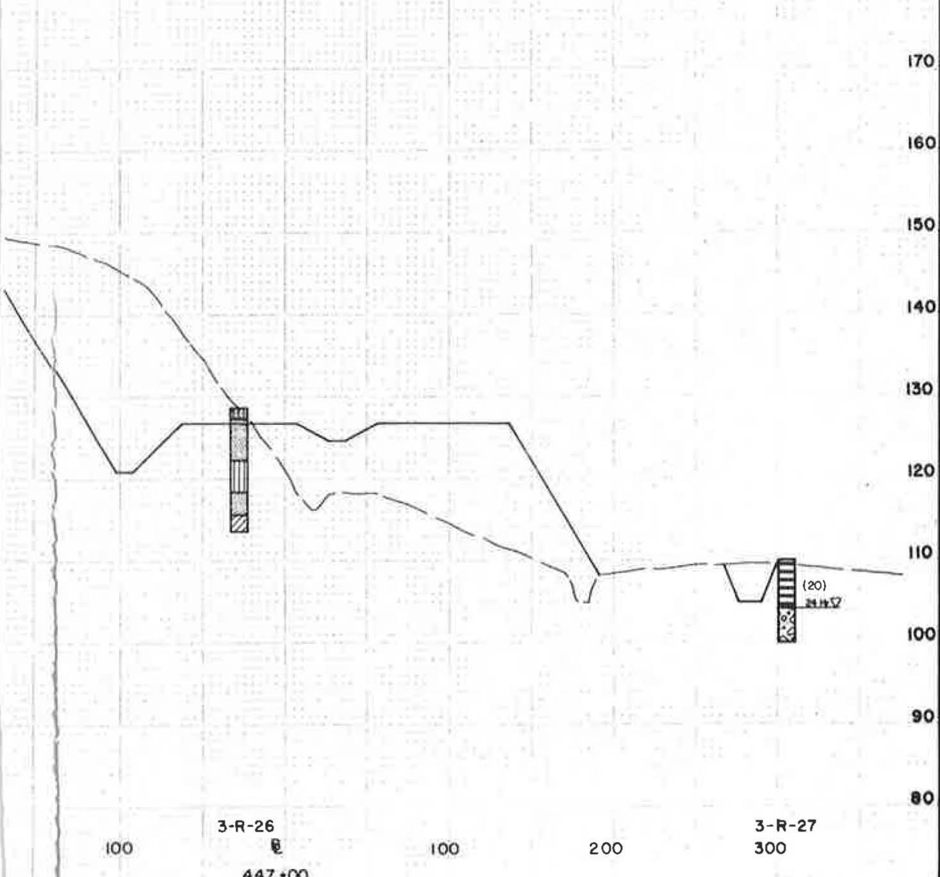
RQD (%)	Description of Rock Quality
0-25	Very Poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

(C) Undisturbed Sample – A 3" O.D. thin wall (Shelby) tube was pushed 18" into undisturbed soil to obtain the undisturbed sample.

(D) Ground water observations were made at the time of drilling. Porosity of soil strata, weather conditions, seasonal changes, site topography, etc., may cause changes in the water levels as reported on the boring logs.

NOTE: *Subsurface information shown on this drawing was obtained solely for use in establishing design controls for the project. The accuracy of this information is not guaranteed and it is not to be construed as part of the plans governing construction of the project.*

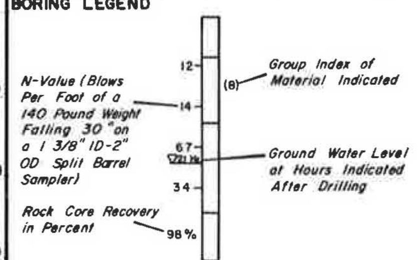

ELEVATION IN FEET
Approximate Existing Ground (Typical)
Proposed Grade (Typical)
(20)
(7)
Junk FILL- Tin Cans, Glass, Cinders, Wood, Organic Material
Soft
Boring No. 3-R-12 3-R-13 3-R-11A
Offset From ℄ 200 100 ℄ 100 200 300
Station No. 441+00
Boring No. 3-R-17
Offset From ℄ 200
Station No.
ELEVATION IN FEET
(5)
(0)
(0)
(8)
Soft
Boring No. 3-R-20 3-R-21 3-R-24
Offset From ℄ 200 100 ℄ 100 200 300
Station No. 445+00
(0)
Boring No. 3-R-25
Offset From ℄ 200
Station No.



MATERIAL LEGEND

SYMBOL	AASHTO	VERBAL DESCRIPTION
	A-1-a	*Stone Fragments or Gravel, with or without binder of fine material*
	A-1-b	*Coarse Sand, with or without soil binder*
	A-3	*Fine Sand, clean*
	A-2-4	*Silty Sands or Gravel, nonplastic to moderately plastic*
	A-2-5	*Silty Sands or Gravel, may be highly elastic*
	A-2-6	*Clayey Sands or Gravel, plastic, may be subject to high volume change*
	A-2-7	*Clayey Sands or Gravel, highly elastic, subject to high volume change*
	A-4	*Silty Soils, nonplastic to moderately plastic*
	A-5	*Silty Soils, highly elastic*
	A-6	*Clayey Soils, plastic, may be subject to high volume change*
	A-7-5	*Clayey Soils, highly elastic, subject to considerable volume change*
	A-7-6	*Clayey Soils, highly elastic, subject to extremely high volume change*
		Peat or Muck
		Miscellaneous Fill
		Limestone
		Sandstone
		Shale

BORING LEGEND



GENERAL NOTES

1. *Borings were drilled by __________ between September 17, and October 2, 1974.*
2. *Elevations shown are project datum, 200.00= 862.75 USGS.*
3. *Ground water levels shown were recorded during the exploration program. Porosity of soil strata, time of year, weather conditions, site topography, etc., may cause changes in these levels.*
4. *Logs of Borings and Laboratory Test Results are available for inspection at __________*
5. *Subsurface information shown on this drawing was obtained solely for use in establishing design controls for the project. The accuracy of this information is not guaranteed and it is not to be construed as part of the plans governing the construction of this project.*
6. *The alignment and/or proposed grade (s) shown were developed prior to completion of final design and may vary slightly from final plans.*

APPENDIX F

TYPICAL DISCLAIMERS

Disclaimer notes are generally used by agencies in connection with the display of subsurface investigation data in connection with construction plans. Although it is believed that disclaimers serve some useful purpose, it is not the intent of this synthesis to select or designate a preferred disclaimer. Variation in wording is illustrated by the following selected disclaimers.

The borings as logged on the plans represent the character of the subsoil at the locations indicated. No guarantee is made that subsoil conditions vary uniformly between or outside the given locations shown.

While subsurface investigations will have been performed with reasonable care, there is no warranty or guaranty, either expressed or implied, that they will disclose the actual conditions which will be encountered during the progress of the work.

Any interpretation or evaluation of the State's subsurface investigation record made by the bidder as to the types, characteristics, quantity or quality of any subsurface material or condition shall be at the sole risk of the bidder.

The data shown in the individual log of each test boring apply only to that particular boring taken on the date indicated and are not intended to be conclusive as to the character of any material or conditions between or around test borings at the time of examination of the site.

Sounding and test boring data shown on plans were accumulated for designing and estimating purposes. Their appearance on the plan does not constitute a guarantee that conditions other than those indicated will not be encountered.

Without regard to the materials encountered, all roadway and drainage excavation shall be unclassified and shall be designated as "Roadway excavation." It is distinctly understood that any reference to rock, earth, or any other material on plans or cross sections, whether in numbers, words, letters or lines, is solely for the Department's information, and is not to be taken as an indication of classified excavation or the quantity of either rock, earth, or any other materials involved.

The bidder must draw his own conclusion as to the conditions to be encountered. The Department does not give any guarantee as to the accuracy of the data and no claim will be considered for additional compensation if the materials encountered are not in accord with the classification shown.

The character of all materials and the extent thereof as shown by borings has been obtained by methods and from sources believed to be reliable. The exactness of this information is, however, in no case guaranteed.

We, the undersigned, do hereby agree that any interpretation of the State's subsurface investigation records as to the types, characteristics, quantity or quality of any subsurface material or condition shall be at our sole risk.

The State Highway Department does not assume any responsibility for any variation or misinterpretation of the classes of materials, and adjustment in bid prices will not be made if the materials found do not agree with those shown in the log of borings.

Bidder	Representative	Date

The within information is furnished the bidder at his request. This information was obtained by the State Highway Commission for its use for cut classification and for estimation of quantities for the purpose of bid comparison. Any other subsurface information which the Commission has can be inspected at the Commission's District Office upon request. The Commission makes no representation as to the accuracy of the logs or other subsurface information, since the accuracy is limited by the equipment used and the personal judgment of the persons making the investigation, and the logs indicate conditions encountered only at the locations shown. The furnishing of this information is not to be considered as a representation of actual conditions to be encountered during construction and does not relieve the bidder from the responsibility for making his own investigations of conditions to be encountered and basing his bid on information obtained from his investigation.

The information contained herein is not implied or guaranteed by the Board of Transportation as being accurate, nor is it considered to be a part of the plans, specifications, or contract for the project. By having requested this information the contractor specifically waives any claim for increased compensation or extension of time based on differences between the conditions indicated herein and the actual conditions at the project site.

Subsurface information shown on these drawings was obtained solely for use in establishing design controls for the project. The accuracy of this information is not guaranteed and it is not to be construed as part of the plans governing construction of the project.