PROCEDURAL MANUAL FOR PRELIMINARY SOIL SURVEY

DIVISION OF HIGHWAYS
STATE OF COLORADO

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ILLUSTRATIONS

December

1974

INTRODUCTION

This set of guidelines generally follows current practice in the Division for obtaining soil profiles and is intended to establish standardized procedures for use by the District Materials Sections in the performance of uniform and adequate soils investigations. It is not a design manual. The recommendations presented herein are oriented toward the solution of such problems as pavement design, slope design, slope appearance, cost, landslides, embankment subsidence and settlement, excavation characteristics, expansive materials, drainage, and compaction characteristics. All of these problems are directly related to the character and distribution of soil and rock bodies both inside and outside of the right-of-way, and to the influence of surface and sub-surface water on these materials. With the proper amount and kind of samples and field information, the designers are provided with data denoting the types of materials to be encountered, the vertical and horizontal boundaries of the changes in these materials, and their strength and deformation characteristics. Adequate preliminary investigation will help prevent uneconomical overdesign and unforseen failure resulting from underdesign.

Proper investigations to achieve these goals cannot be dictated by a rigidly prescribed set of procedures, although certain basic requirements must be satisfied in each investigation. Both the detail and extent of the investigations will vary depending on the individual problem, the nature of the project under consideration, and the allowable risk of failure.

There may be certain projects in special problem areas or in areas of rough terrain which will require detailed investigations which go beyond the scope of the minimum recommendations presented herein for the usual soil profile taken by District engineers and technicians. These latter studies may be especially recommended for high-speed, multi-lane facilities in rough terrain. These studies will be conducted by the District Geologist and/or the Denver Engineering Geology Unit or by outside consultants.

Soil surveys may be classified as reconnaissance or preliminary, depending upon the type of information developed and the stage of project development during which each is performed.

1.1 Reconnaissance Soil Surveys

Reconnaissance surveys are general in nature and are performed during Phase II (Corridor Location Study) of project development under the CDH Action Plan. The information developed during these surveys is used in preparation of Environmental Impact Statements for proposed projects. These surveys are performed only if the necessary information cannot be obtained from existing data, such as soil maps, test reports from previous projects in the area, etc.

The information required from reconnaissance surveys consists of AASHTO classification of all major soil types present in the corridor, identification of landforms or geologic formations with which each is associated, and description of specific engineering problems associated with each. This information will be included in the soils and geology reconnaissance report prepared for each project and should be developed through joint effort of District Materials personnel and the geologist assigned to the project.

The field survey, if required, will consist only of identifying the major soils present and obtaining representative bulk samples of each. Usually, no line will have been established at this point in the project development and sample locations may be selected without regard for line and grade. Samples may be taken by the most convenient method available. The primary considerations in sampling will be that the samples are representative of the major soil types and large enough to permit accurate laboratory classification. The survey may be performed either by District Materials personnel or by the geologist concerned, as determined by mutual agreement.

1.2 Preliminary Soil Surveys

Preliminary soil surveys are performed during Phase III (Preliminary Design) of project development under the CDH Action Plan. The information developed during these surveys is used in project design and preparation of cost estimates and must therefore be as accurate as possible. These surveys are performed on all new alignments and most widening projects.

The information required from preliminary soil surveys is described in detail in Sections 2.1 through 2.12 of these guidelines, together with recommended procedures for obtaining the information.

One of the most important items to be determined during the survey is the relationship between soil boundaries and the line and grade of the proposed project. If soil survey personnel do not know the location of line and grade at the time of the investigation, they cannot be certain that the soil conditions encountered in the test holes represent conditions to be encountered during construction. In particular, they cannot be sure that the soil conditions have been sampled to below finished grade if they do not know where finished grade will be located. Consequently, it is essential that soil survey parties be provided with a ground line profile and a proposed grade line prior to the initiation of any preliminary soil survey. Top hole elevations for all test holes should be determined from the ground line profile if the hole is on centerline, or measured from a centerline station elevation with a hand level and rod if the hole is offset. If the grade is subsequently changed, the resulting changes in the relationship of soil boundaries to grade line can be easily determined if the soil profile is plotted on the line and grade sheet. If additional information is then required, the locations for additional testing will be immediately apparent.

Data obtained during the preliminary soil survey should be reported on DOH Form 107 and 107-1. Examples of a completed DOH Form 107 and 107-1 are attached as Appendix A.

THE SOIL SURVEY

2.1 Soil and Rock Classification and Description

Soil and rock materials encountered in test holes or surface outcrops should be identified and described as indicated in Appendices B through D of these Guidelines. Accurate descriptions of soil or rock encountered in the field will provide information which will be helpful in the economic design of the project. Complicated descriptions not relevant to design or construction problems are to be avoided.

2.2 Sampling Methods

Test holes can be drilled or dug by hand, power auger, power rotary drill, backhoe, or any other practical method. In any case, it is of the utmost importance that the method be used which will absolutely insure the attainment of representative, uncontaminated samples whether bulk samples, undisturbed samples, core samples, drill cutting samples, or split-spoon samples. Care should be taken to make sure that loose, sloughed soil or rock in the bottom of the test holes is not mixed in with samples representing the given depth. Where uncertainty exists as to the reliability of a sample, it is better that it be discarded.

In the paragraphs that follow, the term "drilled" is used to mean any appropriate method for advancing a test hole.

2.3 Horizontal Distribution of Test Holes

Test holes will be spaced no farther apart than 500 feet in continuous cut sections and no farther apart than 1000 feet under any circumstances. In addition test holes should be drilled wherever there is any variation in soil or geological conditions, base gravels, and/or pavement thicknesses. Time should be taken to obtain a sufficient number of test holes to outline subsurface complexities. If during the design phase of the project it is determined that additional data or samples are needed, such will be obtained and a supplemental report submitted.

2.3.1 Proposed Widening Projects

On roadway widening projects, holes along the edge of the pavement will usually yield sufficient information. However, if the widening is to be such that different soils conditions are anticipated or cuts are to be made, the applicable directions under Subsection 2.3.2 should be followed.

Since there is, at times, considerable lag between the time of the preliminary soil profile and actual construction, holes drilled through the existing pavement should be held to a minimum. Such holes present maintenance problems, and excessive drilling in the traffic flow presents needless hazards. Test holes can usually be drilled on the shoulder of the present road close enough to the pavement to obtain thickness measurements and required samples.

When taking soil surveys on proposed widening jobs, attention should be given to areas where CMP, RCCP, or box culverts may be extended, replaced, or added. Quite often these areas will require muck removal. Such requirement for muck excavation should be reported with respect to stationing, distance from survey line, and approximate depth. If it is not practical to drill test holes in the muck, it may be possible to get a rough estimate of depth by probing with a bar or rod.

2.3.2 Proposed New Line and/or Grade

For cut sections, test holes should be spaced as shown in Figure 1. At locations 1 and 3, test holes should be drilled on proposed outside shoulder line (edge of oil) at the daylight line between cut and fill. An additional test hole should be drilled at location 2 (highest elevation of terrain on center line). For embankments whose maximum height will be more than 20 feet, test holes should be drilled on center line as shown in Figure 2.

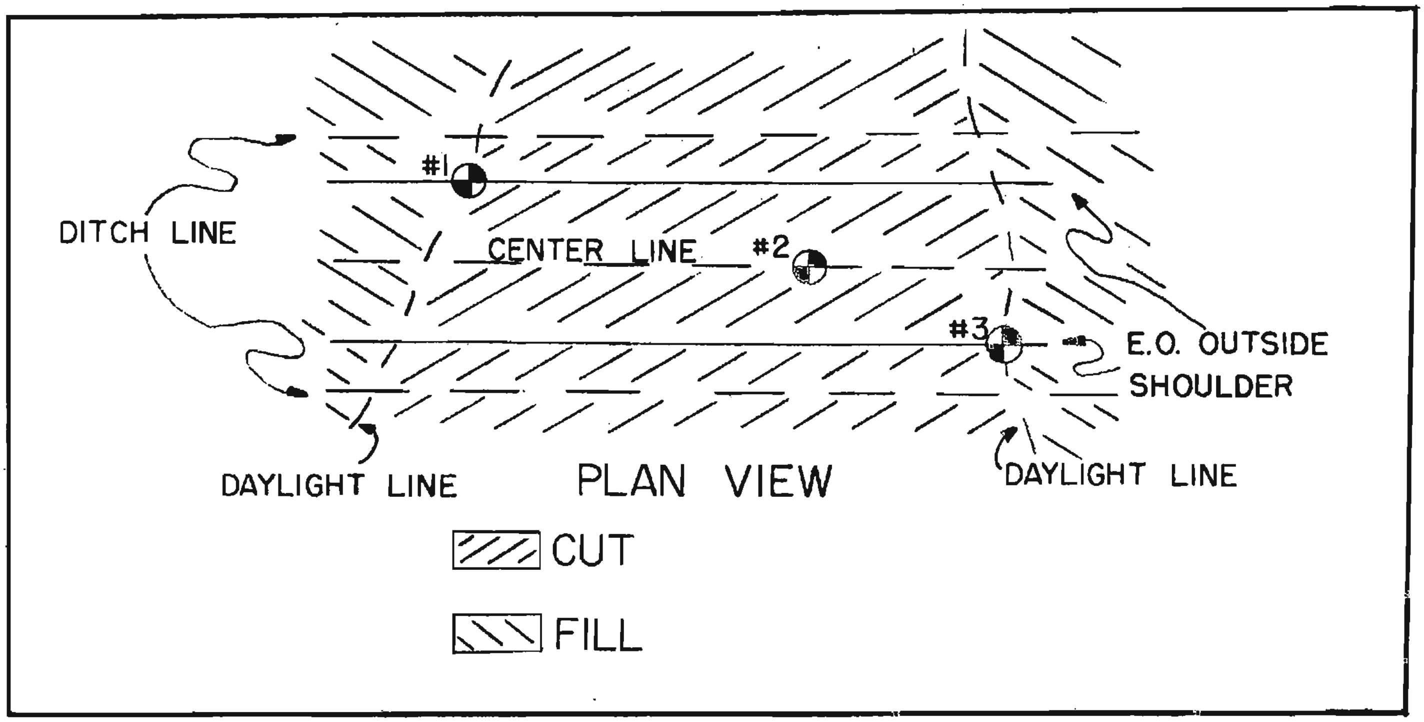

FIGURE 1. Recommended location of test holes in cut section.

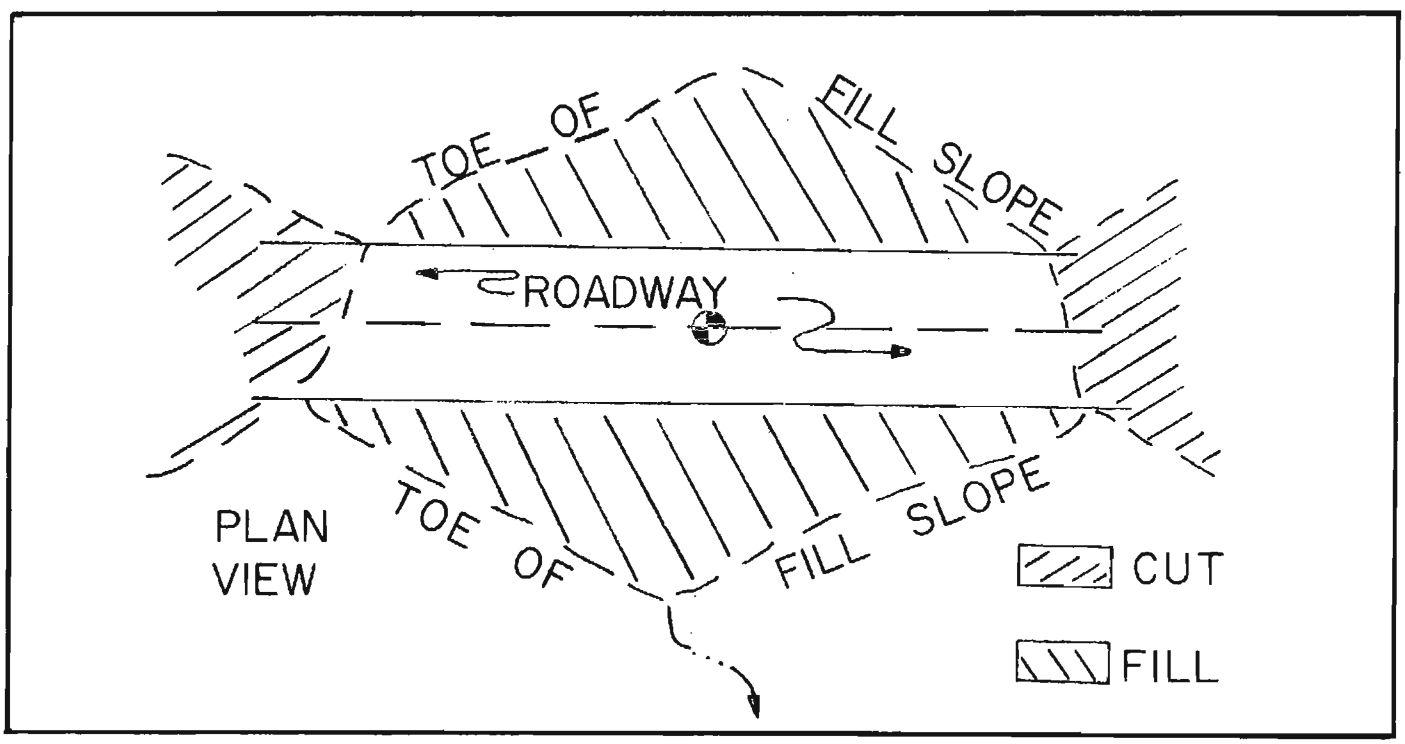

FIGURE 2. Recommended location of test holes in fill section.

2.4 Test Hole Depths and Sampling Recommendations

Test holes shall extend at least 3 feet below finished grade. If that depth is greater than the depth capability of the equipment available to the Districts, the Denver Engineering Geology Unit will be requested to provide drilling services. Such services would be performed under supervision of District personnel, assisted by Central Laboratory geologists if desired.

If topsoil is going to be required on the project, the lateral extent and depth of material which could be utilized for topsoil should be noted on the DOH Form 107.

A sample should be taken for each soil encountered except for the material which might be used as topsoil. If the same soil is found in more than one hole, it may be similarized to a soil already sampled. However, care should be exercised in similarizing soils, and additional samples taken where doubt exists. Similarization will be limited to one mile.

Test holes should be numbered consecutively from hole #1, preferably beginning at the smaller station. Each soil layer encountered in the test hole shall be identified by the hole number followed by letter A, B, C, etc. In hole #1, the first layer would be 1-A, the second 1-B, etc. Each layer shall be sampled in bulk or similarized. A bulk sample should be composed of at least one full sack, and should weigh at least 40 lbs.

For proposed cut sections the depths of test holes and sampling requirements should be as shown in Figure 3. As at test hole location 2, Figure 3, soil and/or rock layers A, B, C, and D should be separately sampled or similarized.

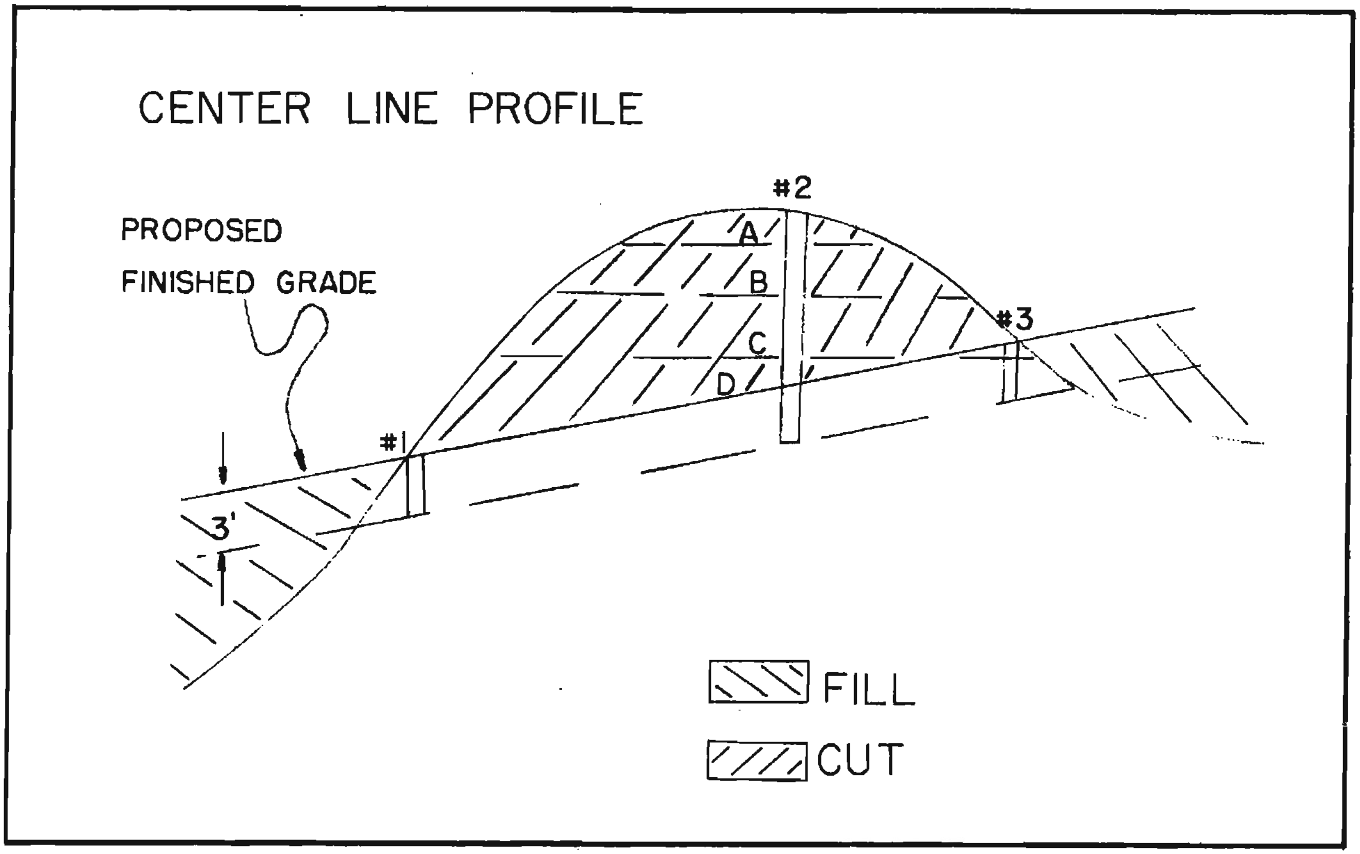

FIGURE 3 - Recommended depth of test holes in cut sections

For embankments whose proposed maximum height is more than 20 feet, the depths of test holes and the sampling recommendations should be as shown in Figure 4. Unless the bedrock or firm base as diagrammed in Figure 4 is too hard for the drilling method being employed, all test holes such as location 1, Figure 4, should penetrate at least 5 feet into the hard substratum. Where the depth from existing ground to the top of the substratum is more than 20 feet, such as at major river crossings, this recommendation can be waived. However, in such cases the desirability of drilling to hard bedrock should be considered in at least one test hole. Test borings for major structures as logged by the Denver Engineering Geology Unit will be suitable for this purpose if available.

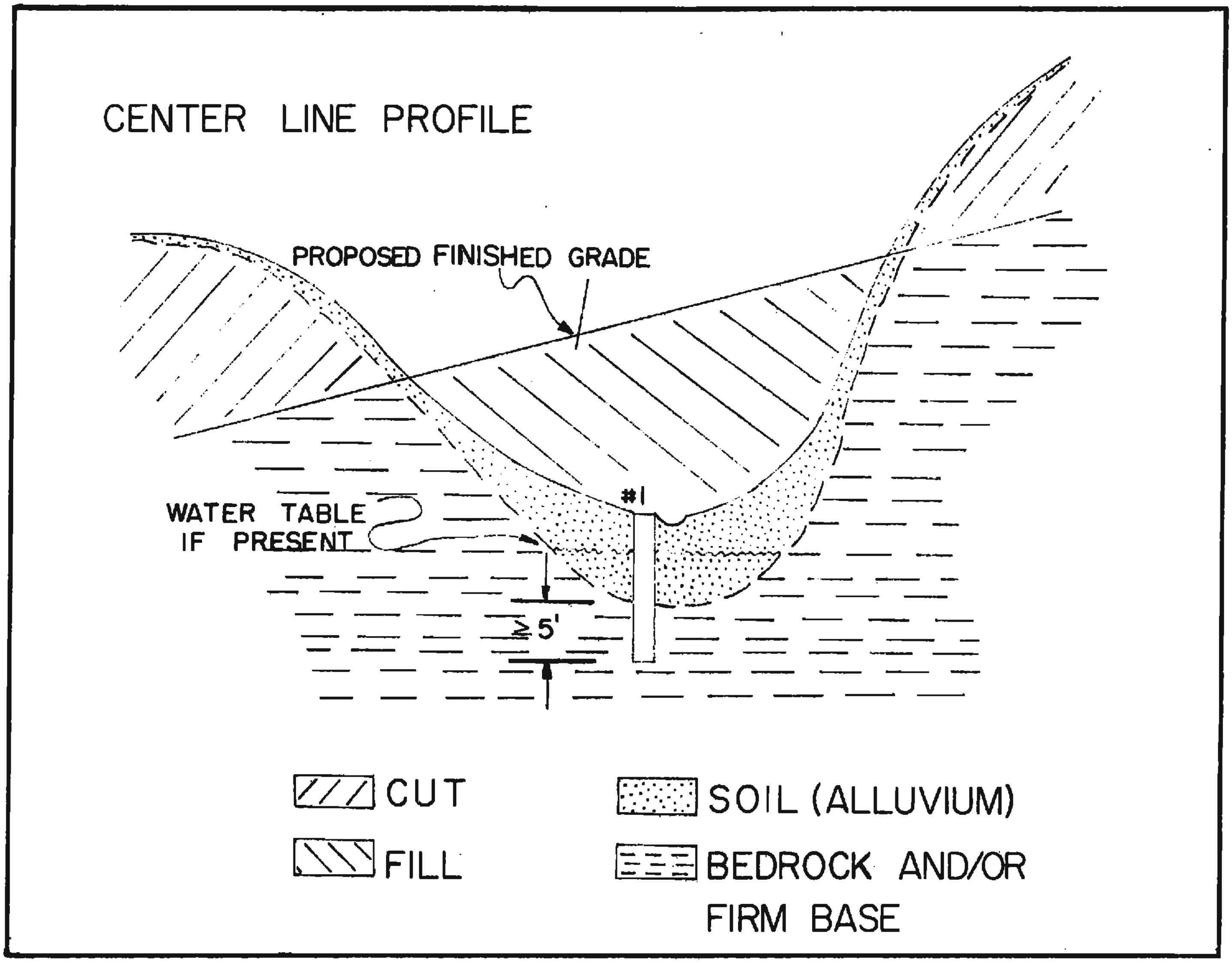

FIGURE 4 - Recommended depths of test holes in fill sections

Where alluvial soils as shown in Figure 4 are composed of soft, compressible, fine-grained materials, it may be advisable to request a foundation investigation by the Denver Engineering Geology Unit.

For at-grade sections all test holes shall extend at least 3 feet below existing ground. All soils shall be sampled in bulk or similarized.

2.5 Hydrological Conditions

The distribution and mode of occurrence of surface and subsurface water should be noted and included as part of all reports.

Where free water is encountered in any test hole the water level is to be checked and noted on the DOH Form 107-1, together with the date and hour of the observation. In cases where a high water table is suspected, it is recommended that the test hole be drilled or dug at least to the elevation of the water table and preferably a few feet below. Where possible the hole is to be left open for a period of at least 24 hours and the water level, date, and hour recorded.

The location of all springs should be determined both horizontally and vertically with respect to center line and grade line. The location of lakes, ponds, swampy areas, and reservoirs should be noted. Notes should especially be taken if the water is expected to influence the stability of pavements, cut slopes, or embankments.

The normal annual precipitation at the project site should be determined from the most recent isohyetal map.

2.6 Condition of Existing Pavements

The condition of existing concrete or asphalt pavements should be taken into account for stabilization and may be noted on a station to station basis on the DOH Form 107. This information is used for assignment of strength coefficients. Type and thickness of existing pavement and type of stabilization previously used should also be reported.

2.7 Adjacent Terrain Data

This information is used primarily by staff hydrologists in determining rainfall runoff factors in the design of drainage structures. Rather than noting conditions on a station to station basis, a general statement relative to the project as a whole should be made. If there are distinct breaks over the length of the project, each type of terrain should be noted. Such designations as rolling grassland, steep timbered slopes, paved commercial, etc......are appropriate.

2.8 Regional Factor

The regional factor is a number which is used to adjust flexible pavement design to include effects of climatic and other environmental conditions listed below. These conditions should be determined during the preliminary soil survey and entered on the DOH Form 107. The following is reprinted from Section 603.3B of the CDH Design Manual for guidance in evaluating conditions:

"The regional factor is determined by assigning values to the following categories. The summation of these assigned values will be the regional factor to be used for the project. Normally this factor will be supplied by the District personnel who are most familiar with local conditions."

Annual Precipitation	Reg. Factor	Elevation	Reg. Factor	Local Drainage	Reg. Factor
Over 24"	1.5	Over 9500	1.5	Very Poor	2.0
18" to 24"	1.0	8500 to 9500	1.0	Poor	1.0
14" to 17"	0.5	6500 to 8500	0.5	Fair	0.5
Less than 14"	0.25	Less than 6500	0.25	Good	0.25

Other conditions that may influence the choice of regional factors are:

(1) Elevation of grade line, especially in swampy areas where the roadbed soils may be saturated for long time periods.

(2) Number of freezing and thawing cycles during the winter and early spring.

(3) Steep grades on sections carrying a large volume of heavy truck traffic. (Slow moving vehicles cause greater damage than fast moving vehicles).

(4) Areas of concentrated turning and stopping movements, such as bus stops, etc.

Adjustments in the factor for these conditions can only be made on the basis of judgment.

Theoretically, conditions would require the use of different factors for various portions of a project; however, the design will normally be based on the highest regional factor that prevails for a substantial portion of the project. In extreme cases, two or more regional factors may be used.

2.9 Excavation Characteristics

During the investigation, notes should be kept concerning the estimated excavation characteristics of all soil or rock materials encountered. Materials should be classified as (1) common excavation, (2) ripping required, or (3) preblasting required. This information can be used in the preparation of the Preliminary Job Memo (DOH Form 785).

If oversize material is encountered during the investigation, it should be noted on the DOH Form 107-1. (See DOH Memo 325, APPENDIX E.)

For large jobs where it is important to define these factors more precisely, it may be requested that the Denver Engineering Geology Unit perform seismic rippability determinations.

2.10 Embankment Foundations

The construction of highways over weak, compressible soil presents some of the more difficult problems in soil mechanics. If embankments are constructed over foundation soils having insufficient strength to support the added load, shear failure or slipouts may occur, or the underlying soft material may displace by outward plastic flow. If the foundation soil is highly compressible, excessive settlement of the embankment may occur, resulting in damage or destruction of the pavement, damage to structures, or hazards to traffic due to distortion of the profile and cross section of the roadbed. Such settlement may occur even if the strength of the foundation is high enough to preclude shear failure.

For the above reasons, it is recommended that District personnel request that a foundation investigation be performed by the Engineering Geology Unit of the Central Laboratory where embankments more than 20 feet in height will be constructed on soft foundation soils.

2.11 Swelling Soils

Swelling soils are common in Colorado and are frequently encountered during highway construction. To minimize damage to roadways from swelling action, it is necessary that these soils be recognized when encountered in the field and that the boundaries of the soils along the project be determined during the preliminary soil survey.

Approximate locations of the worst areas of swelling soils throughout the state are shown in Figure 5. A detailed map showing boundaries of swelling soil areas classified by amount of swell potential has been published by the Colorado Land Use Commission and has been distributed to the Districts. This map should be consulted prior to commencing any soils survey, whether reconnaissance or preliminary.

It is sometimes difficult to identify swelling soils visually, but the following criteria are often helpful:

1. When dry, natural surface exposures of swelling soils usually exhibit an irregular or pebbly texture resembling popcorn.

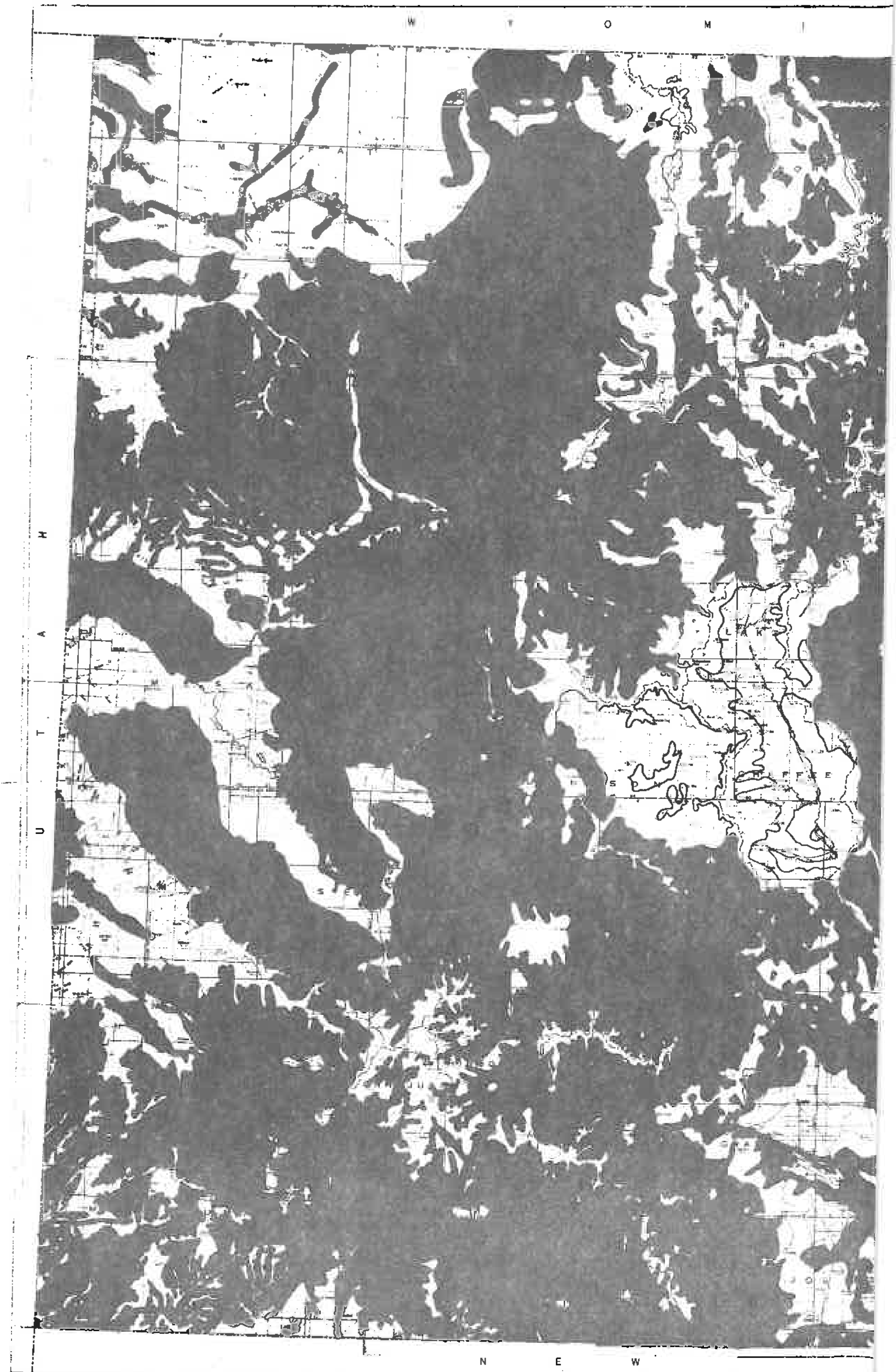

FIGURE 5. Ge
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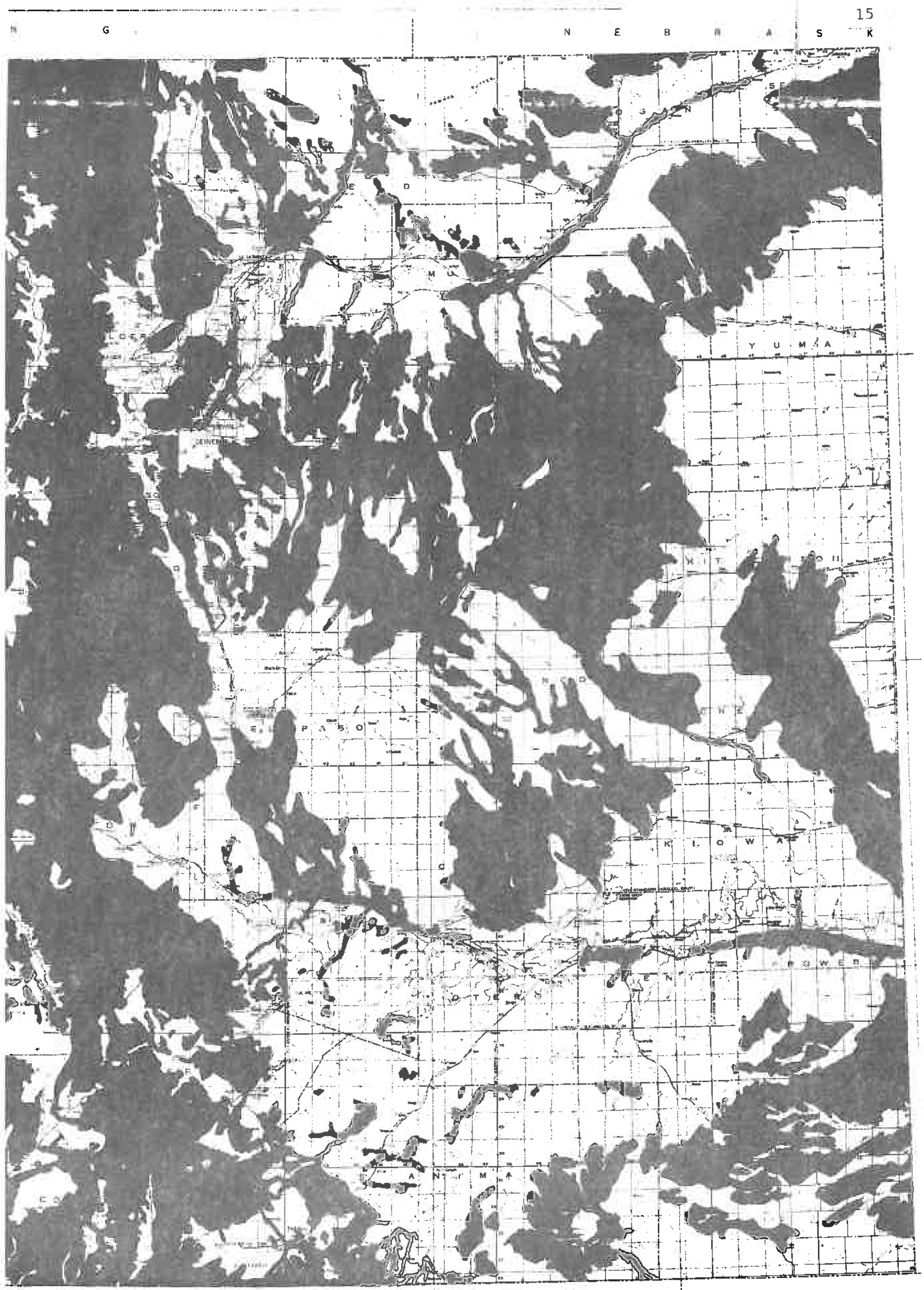

eral location of Colorado
ls having swell potential

2. All swelling soils are plastic and most are highly so. The presence of plasticity can be determined in the field by moistening a sample and attempting to roll a thread in the palm of the hand.

3. A common clay causing swell in soils is bentonite, which usually occurs in shales, either as fine particles invisible to the naked eye or as thin, light colored bands which contrast with the darker color of the shale and are oriented parallel to the bedding. The bands range in color from light tan to light greenish gray and may range in thickness from a fraction of an inch to as much as two or three inches. Pieces of this material will adhere to the tongue, and will break down in a matter of minutes if dropped into water.

If any of these characteristics are noted during the soil survey, particularly in those areas indicated on the map, or if the possibility of swell is suspected for any other reason, notation to this effect should be made on the DOH Form 107.

Even though a soil contains expansive clays, it may not swell if the in-place moisture is high enough. It is therefore important to know the actual moisture content of the soil in order to assess the possibility of problems due to swell. For this reason, if swelling soils are identified or suspected during the soil survey, moisture samples should be taken at or slightly below the elevation of the proposed grade line in those areas where the soils are present.

Additional information concerning swelling soils is contained in DOH Memo 323, attached as APPENDIX F and Chapter 200 of the Materials Manual.

2.12 Culvert Corrosion

Soil or water may contain certain substances in high enough concentration to cause decomposition of concrete or corrosion of galvanized pipe. The best evidence of this is a past history of corrosion in that location. If there is no history, as in a new location, or if the amount or degree of corrosive action is questioned, a soil and/or water sample must be submitted for chemical analysis. It is important that the soil survey as documented on DOH Form 107 make positive or negative reference to corrosive conditions and include all the evidence needed to support any decision on the existing Corrosive Resistant Level.

Reference is made to APPENDIX G, Determination of Need for Culvert Protection, for more detailed procedural guidelines.

DOH Form No. 37
(10-06)41
June 1974

DIVISION OF HIGHWAYS, STATE OF COLORADO
STAFF MATERIALS DIVISION
4340 E. Louisiana Ave., Denver, Colorado 80222

TO: ALL DISTRICT MATERIALS ENGINEERS Date: AUGUST 27, 1974

FROM: B. A. BRAKEY

SUBJECT: REVISION OF DOH FORM NO. 107

Attached is a set of the revised DOH Form No. 107, Field Report of Soil Survey, and a copy of DOH Form No. 107-1, Soil Survey - Preliminary. These forms have been revised in order to fit the new Soil Survey Procedural Manual to be published in the near future. All obsolete DOH Forms No. 107 and DOH Forms No. 41 should be destroyed. The revised Form 107 shall be used as the first sheet on each Soil Survey. Full distribution, as indicated on the form, will be made at the time samples are transmitted to the Laboratory. The report number from the Form 107 shall be placed on all of the Form No. 107-1 sheets included in the Soil Survey. The Form 107-1 may be used in place of the field notebook. However, it must be neat and legible when transmitted to the Laboratory with the samples.

The District office may elect to type the information from the field notebook or original Form 107-1 on to another Form 107-1. The original legible copy of the Form 107-1 will be sent to the Laboratory with the Laboratory copy of the Form 107. A copy of Form 107-1 may be made for District Materials files. No other distribution of the partially completed Form 107-1 is necessary.

When samples have been processed in the Laboratory, the Form 107-1 will be completed. Distribution of photo copies will be made as indicated on Form No. 107.

An example of Form 107-1 as submitted by the field and as completed by the Laboratory is attached. Also attached is a completed Form 107 as submitted by the field. Copies of these examples and this letter should be made available to all District personnel involved in taking soil surveys.

Under separate cover we are sending you a supply of these forms which will be stocked in the Central Laboratory. When re-ordering please contact W. R. Brown in the Documentation Section.

B. A. Brakey

B. A. Brakey
Staff Materials Engineer

BAB:eh

Attch.: 3

cc: Egger
Gilmore
Gray

DIVISION OF HIGHWAYS
STATE OF COLORADO
DOH Form No. 107
Revised: June 1974

FIELD REPORT OF SOIL SURVEY

REPORT 143 DISTRICT 2

PROJECT NO. F 0050-1(12)

LOCATION Carlton - Granada

DATE March 1, 1974

White Copy: Staff Design
Pink Copy: Materials Division
Blue Copy: District Office
Green Copy: District Materials Engineer
Canary Copy: Resident Engineer

HWY. SYS.	SURF. TYPE	FUNCTION	PART.
11	30	3020	P

Begin Station 189+00 End Station 569+00 Length 5.3 Mi.

Equations (Stations) 212+00 Bk. = 212+10 Ah.

Structures (Stations) 240+00, E-12-B, Plum Creek; 312+00, E-17A, Wolf Creek; 640+00, E-18-F, Dry Wash.

Type of Construction New alignment Compaction: T 99 ☒ T 180 ☐

No. of Test Holes 25 No. of Samples 17 Proposed Pavement Type: Flexible ☒ Rigid ☐

Adjacent Terrain Data Rolling hills

18k EDLA 100 Serviceability Index 2.5

Regional Factor:

Precipitation	13"	0.25
Elevation	5500	0.25
Drainage	Fair	0.50
Other (Heavy truck traffic)		1.00
Total		2.00

Type of drilling equipment used Williams Drill

Resident Engineer John Smith

Perform Tests for Swelling Soil. Yes ☒ No ☐

Are old uncoated culverts corroding? Yes ☒ No ☐
If yes, or area does not contain uncoated pipe, either descriptive documentation, samples or both are required per "Soil Survey Procedural Manual."

Record number and type of samples submitted for corrosion analysis. If submitted on separate DOH Form 157, give report No.

2	Water
3	Soil
2	Water (157 #C2883)

COMMENTS

Swampy area between 345+50 - 348+25
Existing landslide in hillside at 350+00, 30' Lt.
Centerline located adjacent to pond between 410+25 - 414+00
All excavation will be common except rock outcrop between 470+20 - 472+50 which will require blasting.
Large boulders (2- 3 ft. in diameter) embedded in ground between 501+00 and 514+00.

Sampled By R. Brown, W. Allen, J. Jones

Title P.E.T. E.T., Drill Oper.

Signed By H. R. White, Dist. Mat'ls. Engr.

Return Address Pueblo H.R.White

DOH Form No. 107-1 6/74

SOIL SURVEY

PRELIMINARY

STAFF DESIGN DIVISION
STAFF MATERIALS DIVISION
DISTRICT OFFICE — AS REQUIRED

107 Report No. 143
Project No. F 0050-1(12)

STATION AND LOG	TEST NO.	DESCRIPTION	MAX. SIZE	PERCENT PASSING 3"	1"	3/4"	3/8"	#4	#10	#40	#200	LIQUID LIMIT	PLASTIC INDEX	CLASSIFICATION AND GROUP INDEX	MOISTURE %	"R" VALUE
190+00, 25' Rt. 0.0'-4.3'	1A	Silt, sandy, tan, loose, dry														
4.3'-6.0'	1B	Clay, brown, soft, moist														
6.0'-8.7'	1C	Sand, fine, brown, medium dense, wet														
Top hole elev. 4260.5		Test 1A represents Sta. 189+00 to 195+00														
		Water table 3:00 PM 2/21/74 - 5.8 ft., 4:00 PM 2/22/74 - 4.9 ft.														
197+50 c.l. 0.0'-6.0'	2A	Silt, sandy, tan, dry		Similar to test 1A												
6.0'-7.5'	2B	Sand, silty, brown, moist														
7.5'-9.0'	2C	Clay, light brown, firm, moist				Similar to test 1B										
Top hole elev. 4275.2		Represents Sta. 195+00 to 203+00														
206+00, 15' Lt. 0.0'-4.3'	3A	Clay, silty, brown, stiff dry, contains cobbles & roots				Similar to test 1B										
4.3'-5.7'	3B	Silt, sandy, brown, moist		Similar to test 2B												
5.7'-8.5'	3C	Sand, silty, tan, dense moist, contains a few cobbles				Similar to test 1C										
Top hole elev. 4283.4		Represents Sta. 203+00 to 210+00.														

EXAMPLE
AS SUBMITTED BY
FIELD FORCES

NOTE: WHEN SCREEN INFORMATION FOR TEST IS LEFT BLANK BY FIELD, THIS INDICATES SAMPLE SELECTED AND SUBMITTED.
ELEVATION OF TOP OF TEST HOLE REQUIRED ON PROJECTS CONTAINING GRADE AND ALIGNMENT CHANGES OR WHERE TEST HOLES ARE NOT ON ROADWAY.

DOH Form No. 107-1 6/74

SOIL SURVEY

PRELIMINARY

STAFF DESIGN DIVISION
STAFF MATERIALS DIVISION
DISTRICT OFFICE — AS REQUIRED

107 Report No. 143
Project No. F 0050-1(12)

STATION AND LOG	TEST NO.	DESCRIPTION	MAX. SIZE	PERCENT PASSING 3"	1"	3/4"	3/8"	#4	#10	#40	#200	LIQUID LIMIT	PLASTIC INDEX	CLASSIFICATION AND GROUP INDEX	MOISTURE %	"R" VALUE
190+00, 25' Rt. 0.0'-4.3'	1A	Silt, sandy, tan, loose, dry						100	98	94	70	25	8	A-4(3)		45
4.3'-6.0'	1B	Clay, brown, soft, moist							100	92	85	37	17	A-7-6(18)		12
6.0'-8.7'	1C	Sand, fine, brown, medium dense, wet	(As run)	 100	 98	100 95	92 87	81 77	52 49	18 17	11 10	NV	NP	A-1-a(0)		83
Top hole elev. 4260.5		Test 1A represents Sta. 189+00 to 195+00														
		Water table 3:00 PM 2/21/74 - 5.8 ft., 4:00 PM 2/22/74 - 4.9 ft.														
197+50 c.l. 0.0'-6.0'	2A	Silt, sandy, tan, dry		Similar to test 1A										A-4(3)		45
6.0'-7.5'	2B	Sand, silty, brown, moist				100	97	93	86	75	31	30	6	A-2-4(0)		73
7.5'-9.0'	2C	Clay, light brown, firm, moist				Similar to test 1B								A-7-6(18)		12
Top hole elev. 4275.2		Represents Sta. 195+00 to 203+00														
206+00, 15' Lt. 0.0'-4.3'	3A	Clay, silty, brown, stiff dry, contains cobbles & roots				Similar to test 1B								A-7-6(18)		12
4.3'-5.7'	3B	Silt, sandy, brown, moist		Similar to test 2B										A-2-4(0)		73
5.7'-8.5'	3C	Sand, silty, tan, dense moist, contains a few cobbles				Similar to test 1C								A-1-a(0)		83
Top hole elev. 4283.4		Represents Sta. 203+00 to 210+00.														

EXAMPLE
AS COMPLETED BY
LABORATORY

NOTE: WHEN SCREEN INFORMATION FOR TEST IS LEFT BLANK BY FIELD, THIS INDICATES SAMPLE SELECTED AND SUBMITTED.
ELEVATION OF TOP OF TEST HOLE REQUIRED ON PROJECTS CONTAINING GRADE AND ALIGNMENT CHANGES OR WHERE TEST HOLES ARE NOT ON ROADWAY.

APPENDIX B

SOIL IDENTIFICATION AND DESCRIPTION

1. Soil (definition) - for engineering purposes soil is defined as any naturally occurring unconsolidated material composed of mineral grains with gases or liquids occupying the intergranular spaces.

2. Soil identification - a complete soil identification for engineering purposes includes (a) a description of grain size, (b) color, (c) consistency, (d) moisture content, and (e) other descriptive factors, preferably in that order.

   a. Grain size distribution - The soil should be primarily identified by the dominant grain size fraction present. The sub-dominant grain size fractions present may be noted as modifiers of the dominant grain size. Example: Sand, silty; gravel, sandy.

   b. Color - Without the use of a standard color chart, soil color can not be precisely determined due primarily to different lighting under different weather conditions. Moreover, the same soil sample will shade differently with varying moisture content. Accordingly field notes as to color should be broad and general unless the soils exhibit some unique color shade such as a distinct red or green.

   c. Consistency - Consistency of a soil can be defined as that soil's resistance to penetration. It is related to the soil's density, degree of cementation, and moisture content. The strength and consolidation characteristics of all soils are strongly and directly related to consistency. If extremely soft clayey soils or loose sands and gravels are encountered in test holes, notation to this effect should be included in field logs.

APPENDIX B (cont.)

d. Moisture content - For engineering purposes the field moisture content, especially in fine-grained soils, is very important. The moisture has a very strong influence on such engineering properties as compaction, shear strength, slope stability, and consolidation under embankment loads. It is recommended that the field moisture content of all soils encountered, whether sampled or not, be estimated and noted on the DOH Form 107 as follows:

(1) Cohesive Soils

a. Dry - loose or crumbly, cannot be formed into a pellet.

b. Moist - can be formed into a pellet.

c. Wet - exudes free moisture when squeezed.

(2) Granular Soils - The above tests cannot always be successfully applied to granular materials since these soils often will not form into pellets. In such cases, the moisture content must be visually estimated, using the terms "dry", "moist", or "wet."

e. Other descriptive factors - Soils often possess other characteristics not described by the above four factors which may influence the engineering behavior of the material and should be reported. These include but are not limited to the following:

(1) Unusual structure - "Honeycomb" texture or interbedded thin layers of alternating fine and coarse material may indicate low strength.

(2) Presence of roots or decayed organic material at depth in a test hole - May indicate a buried soil horizon. These usually have low strength.

(3) Presence of unusual minerals - Whitish streaks or crack-fillings of caliche indicate the presence of sulfate minerals which may be detrimental to concrete or metal structures. Streaks, coatings, or crack-fillings of reddish-brown or yellowish-brown iron minerals indicate that ground water has been present in the past and may therefore return.

(4) Presence of man-made material, such as broken glass, cinders, concrete and metal fragments, etc - Indicates that the soil is actually fill. While constructed fills such as highway embankments usually have adequate strength, other types of fills, particularly old dumps, may be very weak and may grow weaker with time if they contain large amounts of degradable or compressible material (tin cans, paper, plastic, etc).

(5) Oversize material - If materials such as gravel, cobbles, or boulders are present but in relatively small amounts, they may be mentioned separately.

The following examples illustrate the use of the above system of description:

Clay, sandy, brown, soft, wet

Silt, sandy, light tan, firm, moist. Contains streaks of caliche and occasional 1' - 2' boulders.

APPENDIX C

ROCK IDENTIFICATION AND DESCRIPTION

1. Rock (definition) - for engineering purposes rock is defined as a naturally-occurring mineralogical aggregate which in an intact, unfractured sample will yield a laboratory unconfined compressive strength greater than or equal to 200 psi.

2. Rock Description - a complete rock description for engineering purposes includes (a) classification, (b) color, (c) hardness and degree of cementation, (d) a description of the partings in the rock, and (e) moisture content.

    a. Classification - reference is made to the Rock Classification Table, APPENDIX E. This is a relatively simple but practical system which can be used by the field man, whether geologist, engineer, or technician.

    b. Color - as for soils (APPENDIX B)

    c. Hardness and degree of cementation:

        (1) soft - can be scratched with fingernail

        (2) moderately hard - can be scratched easily with a knife but cannot be scratched with fingernail

        (3) hard - difficult to scratch with knife

        (4) very hard - cannot be scratched with knife

    d. Partings - including fractures, faults, and joints

        (1) intact - no partings

        (2) widely fractured - partings more than 10 feet apart

        (3) closely fractured - partings less than 10 feet apart but more than 6 inches apart

        (4) brecciated - partings less than 6 inches apart

e. Moisture content - Moisture content in rock cannot be determined by simple tests such as those used for soil (APPENDIX B, par. 2d), but should be estimated visually. As with soils, the terms dry, moist, and wet are adequate for field description.

APPENDIX D

ROCK CLASSIFICATION

SEDIMENTARY ROCKS	* coarse grained	conglomerate	dominant grain size is boulders or gravel
		sandstone	dominant grain size is sand
	** fine grained	shale	thin-bedded - dominant grain size is clay and silt
		limestone	usually light-colored, composed of calcite and/or dolomite (will usually effervesce with dilute HCI)
IGNEOUS AND METAMORPHIC ROCKS	* coarse grained	gneiss	composed of alternating bands of different colored minerals
		schist	major component is mica - layered structure
		marble	coarse-grained limestone
		granite	granular, ranging in color from light to medium gray to salmon pink
		diorite	contains approximately equal proportions of dark and light colored minerals
		gabbro	granular dark gray to black
	** fine grained	rhyolite	nearly white to light gray
		quartzite	composed entirely of quartz
		andesite	medium gray
		basalt	dark gray to black (sometimes porous or "vesicular")

** fine-grained - individual crystals or fragments which compose the rock can not be seen with the unaided eye.

* coarse-grained - individual crystals or fragments which compose the rock can be seen with the unaided eye.

APPENDIX E

DOH MEMO #325
May 24, 1972

CONSTRUCTION
(Embankments)

DIVISION OF HIGHWAYS, STATE OF COLORADO
4201 East Arkansas Avenue
DENVER, COLORADO 80222

TO DISTRICT ENGINEERS:

It is often necessary to construct shallow embankments from cuts or borrow pits that contain boulders too large to be buried in the fills. The disposal of such boulders is a problem on each job where this condition occurs and the problem is usually resolved by handling this matter on a force account basis. The FHWA has frowned on this practice and in some instances has disallowed Federal participation in the cost of disposal.

In the future please study the fill heights on all projects with all other preliminary investigations and the class of material expected to be encountered in the excavation or borrow pits. If the condition referred to is anticipated please advise the Staff Design Division so that a special provision for disposal of large oversize boulders can be provided in the specification.

DOH Memo #325, dated May 27, 1964, is hereby cancelled.

L. C. BOWER
CHIEF ENGINEER

LCB: ALP:pt

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APPENDIX F

DOH Memo #323
1/5/66

(CONSTRUCTION)
Swelling Soils

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
4201 East Arkansas Avenue
Denver, Colorado 80222

TO STAFF DIVISION ENGINEERS AND DISTRICT ENGINEERS:

For a number of years the Department has been studying the problem of swelling soils. To date we do not have the complete answer to this problem. However, sufficient research work has been performed that we feel the following method of control of swelling soils should be used by the Department until more information is available.

Pavement distortion from swell has been found only on expansive soils and was most prevalent on soils of the A-6 and A-7 groups and on borderline soils between the A-4 and the A-6 and A-7 groups. Also, certain A-2-6 and A-2-7 soils which are borderline with the A-6 and A-7 groups have produced some swell.

Critical problems in the past have occurred primarily in cut areas where moisture-density treatment has been to comparatively shallow depths (one foot or less).

The following tables are intended as a guide to determine the depth of treatment in cuts for the soil types described above.

SUGGESTED TREATMENT BELOW NORMAL SUBGRADE ELEVATION
FOR PROJECTS ON INTERSTATE AND PRIMARY SYSTEM

Plasticity Index	Depth of Treatment
10 - 20	2 feet
20 - 30	3 feet
30 - 40	4 feet
40 - 50	5 feet
over 50	6 feet

SUGGESTED TREATMENT BELOW NORMAL SUBGRADE ELEVATION
FOR PROJECTS ON SECONDARY AND STATE SYSTEM

Plasticity Index	Depth of Treatment
10 - 30	2 feet
30 - 50	3 feet
over 50	4 feet

APPENDIX F (cont.)

DOH Memo #323
1/5/66

-2-

Treatment shall consist of removing the material throughout the cut to the required depth. Swelling soils removed can be used elsewhere on the project because they will have been broken up and soil particles will have been disoriented. We have not experienced problems in embankments constructed of swelling soils. Backfill materials may be obtained from any other cut or source developed on the project and may be of the same soil classification as materials removed. Also, if it proves to be economically sound, the materials removed may be hauled back in and used as backfill. All backfill materials are to be compacted in accordance with plans and specifications. It is of primary importance that any swelling soils used either in embankments or as backfill be thoroughly broken up with sheepsfoot rollers or other suitable equipment which will assure complete disorientation of soil particles.

Agreement on actual depth to be treated should be reached between the Design Engineer, Materials Engineer and District Engineer prior to completion of the plans of each project involving swelling soils.

L. C. Bower

L. C. BOWER
Deputy Chief Engineer

TCR:ntw

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APPENDIX G

DETERMINATION OF NEED FOR CULVERT PROTECTION

Field Observations and Sampling

1. The best time to observe, sample, or report conditions indicating the need for corrosion protection of culverts is on the preliminary soil survey (DOH Form 107). However, completed soil surveys should be reviewed where it seems necessary. If additional samples are required, submit on a DOH Form 157.

2. Past performance of culvert material is the best source of information. The local Maintenance Foreman can provide a history of culvert performance in the area. Observation of culverts on recent projects in adjacent areas of similar soil conditions will also provide useful information. Uncoated galvanized pipe that shows no corrosion after at least two years of service does not require soil or water sampling. However, a coated pipe that shows no corrosion may be in an environment that would not attack a less expensive pipe. Samples of both the soil in contact with the pipe and the water going through it would provide this information.

3. The chart in Section 624 of the CDH Standard Specifications shows six Corrosion Resistance levels, which are described below. Actually there are two more. The first is where there is no corrosive situation, and this may be thought of as CR 0. Here any pipe in Item 617 may be used, unless some other reason for selecting a specific type of pipe exists.

   The other condition is the possibility of abrasion. This situation is rare enough and varied enough to be considered individually. It might be well to consult with the Hydraulics Unit for special design recommendations.

   The six Corrosive Resistant Levels may be described briefly as follows:

   CR 1 Mildly corrosive substances in both soil and water.

   CR 2 Mildly corrosive substances in the water that will flow through the culvert, but little in the soil in which the culvert will be located.

   Example: In some mining areas.

   CR 3 Mildly corrosive substances in the soil in which the culvert will be located, but the water to flow through the culvert is noncorrosive.

   Example: In average Pierre or Mancos Shale.

   CR 4 Moderately corrosive conditions

   Example: Where type II cement should be used.

APPENDIX G (cont.)

CR 5 Heavily corrosive conditions.

Example: Areas of known high corrosion, such as Fruita or Rocky Ford.

CR 6 Strongly acid or alkaline conditions.

Example: Areas of severe mining conditions.

Remember that:

a) Conditions can change:

1. Agriculture now uses more and different fertilizers that can leach corrosive salts into the drainage runoff.

2. Encroachment by mining activities or industrial development can change the corrosion environment.

b) The condition of the interior of a culvert tells only half the story. Most corrosive substances are in the soil in contact with the pipe; therefore, to truly appraise the amount of corrosion attack, it is necessary to expose and examine some of the exterior of existing pipe. When the backfill material is granular, an impervious type of soil is often used near the pipe ends. The exposure should include the contact surface for both types of soil. The presence of extensive rust spots, approaching 50% of the pipe's surface would indicate a serious condition. A soil sample should be taken near the corrosion to determine if it is due to a high or low pH, or to some corrosive salts. The extent and location of the corrosion whould be noted on the DOH Form 107.

c) Additional signs to look for:

1. Crystals, encrustations and alkali deposits in the stream bed near the water line, are signs of a possibly corrosive water. Stains on the rocks are usually associated with minerals, therefore a tailing dump or mine drainage should be looked for upstream. If found, it should be noted on the DOH Form 107.

   Water that seeps out of the ground or from some layer in an embankment will probably have variations in the amount of dissolved salts from season to season, depending on the volume of water moving through the soil and the amount and availability of soluble mineral matter. It may be necessary to sample such water in spring, summer, and fall to be sure.

2. Alkali deposits on the soil, soils from Mancos and Pierre Shales, and fine silty soils should be suspected.

3. The Central Laboratory recommends that all suspected soils and water be sampled. The accompanying DOH Form 107 or 157 should mention the conditions that prompted the sampling, and the exact location in reference to the proposed or existing culvert.

APPENDIX G (cont.)

Soil and water samples will be run in the Laboratory to determine pH, hardness, alkali content, etc. Recommendations from the Laboratory concerning required protective action may be based on evaluation of one or several of these test results and their interactions. Unusual stains, encrustations of salt or alkali, even unpleasant odors, should be mentioned on the DOH Form 107 or 157, as these are indicative of conditions which may cause culvert corrosion. The possible existence of an abrasive condition should also be noted. A serious problem should be discussed with the Hydraulics Unit for possible solution.

A water sample should be at least a pint in volume and be in a clean, uncontaminated container. The soil sample should weigh at least a pound and be sent in a plastic bag or metal can with a tight lid.

On the basis of field observations and laboratory tests (where deemed necessary) the District shall recommend to the Staff Design Engineer the types of culvert to be used and their location.

<u>Tests Performed in Chemical Analysis of Soil and Water and Some of Their Significance</u>

1. Physical and visual examination of samples often give clues to significant characteristics, i.e. the odor of H_2S or SO_3 may indicate either mill tailings or sewage effluent. So will green water or black streaks in soil or clay, marsh or swampy areas.

2. pH. This test is made to determine the acidity of a soil or water. A pH of 7 is indicative of neutral conditions. Values less than 7.0 are "acid" and those greater are defined as "alkaline," i.e. pH less than 4.5 can cause significant deterioration to concrete pipe. Aluminum pipe is susceptable to damage when the pH falls below 5 or goes above 9. pH values greater then 7 are often indicative of presence of sulfates, hydroxides, or carbonates which may contribute to deterioration of pipe.

3. Alkali or sulfate content. The term "alkali," is a bit of a misnomer as it is generally applied to all white deposits on or in a soil. For our purpose of evaluation it refers to "water-soluble" sulfates. Generally "alkali" concentration in soil greater than 0.1% (or 150 ppm for water) requires some special protection to reduce corrosion. Conditions of "alkali" content in excess of 0.2% for soil, (and 2000 ppm for water), receive recommendations for maximum protection.

4. Presence of chloride and other "anions" in water are also significant as they directly attack unprotected culvert materials under appropriate conditions.

5. Other tests may be run. The significance of these or any of the above tests can vary with different conditions, and are not intended as absolute guides.