Terrain Reconnaissance and Mapping Methods in New York State

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This paper describes the methods used by the Bureau of Soil Mechanics of the New York State Department of Public Works for the reconnaissance of terrain conditions; how the information obtained is presented to engineers concerned with the location, design and construction of highways in New York State; and how the information is used by those engineers.

● WITH few exceptions, all engineering works are founded on soil or bedrock. The exceptions are floating structures and structures founded on the polar ice. Even aircraft are supported on soil or rock during a major portion of their life. Sufficient knowledge of the foundation conditions is essential to the economic location, design and construction of all engineering works. Obviously, an adequate knowledge of such conditions is essential to the proper location, economical construction and satisfactory performance of any highway. Highways differ from most other engineering works in that they have considerable linear extent, and consequently may, particularly in glaciated areas, involve a large variety of subsurface conditions.

The Bureau of Soil Mechanics of the New York State Department of Public Works has been performing terrain reconnaissance and mapping operations for public works projects from the time of its formation in 1945. During 1959, the Bureau produced such reports with maps, covering 530 square miles, for 106 route miles of projects and for an entire county. During the design of the New York State Thruway, the Bureau prepared maps covering approximately 400 route miles for that project.

The purpose of this paper is to describe the technique used for terrain reconnaissance, to illustrate the method used to present the resulting data and to describe how the information is used in the location and design of highway projects. A portion of the map and report prepared for a section of the Route 17 Expressway, from the Broome County Line to the Village of Owego, in southwestern New York State, is used for illustration and demonstration purposes.

DEFINITION

Terrain reconnaissance is the operation of reviewing available information from various sources and reconnoitering the landscape, to view it with regard to its suitability for engineering purposes, describing the extent and characteristics of the areas encountered, and making an engineering interpretation of the findings.

PURPOSE OF TERRAIN RECONNAISSANCE

Too often, in highway engineering work, there exists a wide gap between the planning and location considerations and the design and construction considerations. Although highways are usually planned and located with due regard for the topography, the relationship between subsurface conditions and topography is often ignored. This often results in uneconomical location, expensive and difficult construction, poor performance and high maintenance costs.

It should be realized that approximately one-third of the cost of the average modern highway is spent on earthwork, and that a very large percentage of the volume of materials handled during construction consists of earth materials. The characteristics of the earth materials handled and the characteristics of the earth materials comprising the foundation of the highway have a major influence on the cost and performance of the highway.

Proper use of a thorough terrain reconnaissance, mapping and appraisal program in the very early stages of any proposed highway project, particularly on new location, will invariably result in suitable location, reasonable costs and satisfactory performance of the completed highway. It must be emphasized that the greatest value of terrain reconnaissance and appraisal operations to the highway designer exists during the early preliminary planning stages of design for a major project, for it is during these stages that adjustments in line and grade can most easily be made to adapt the route to the actual terrain conditions.

Terrain reconnaissance and appraisal operations are performed by the New York State Department of Public Works for at least six main purposes:

1. To serve as a basis for the appraisal of terrain conditions by correlating the characteristics of the various soil areas with the past construction experiences and performances of existing highways on similar areas.
2. To indicate to the highway planning and location engineers the relative merits and potential design and construction problems for the mapped areas of different terrain conditions along the general route, so that, if feasible, the optimum areas be occupied and the adverse areas avoided.
3. To serve as a guide in establishing the optimum grade line relative to topography and subsurface conditions.
4. If the adverse areas cannot be readily avoided, to serve as a guide for subsurface investigation and analysis programs, resulting in cost estimates, and indicating the relative costs of traversing the adverse areas or avoiding them.
5. To serve as a general guide for the efficient planning of the necessary subsurface exploration, testing and analysis program for the line finally selected. This reduces the surveys in the "good" areas to an efficient minimum, and permits effective concentrations in the problem areas.
6. To indicate the general earthwork construction material situation, and to indicate the probable locations of borrow and granular materials so that those areas may be explored and sampled for specification and cost estimate purposes. The results of these investigations are reported to the designer in the form of a "Material Resources Report" for the project. In this respect, every effort is made to adjust the specifications and design so that, if possible, readily available local materials are economically used.

PROCEDURE

Sources of Information

Terrain reconnaissance and appraisal surveys are based on the following sources of information:

1. Research of the available scientific literature concerning the area. This includes reports and publications on geology,. physiography, pedology and land use.

The soil survey reports, particularly the more recent ones, prepared by the U.S. Department of Agriculture are excellent sources of information. Where air photos are used for base maps for the agricultural soil maps, the accuracy of the boundaries is usually satisfactory. Much information pertinent to engineering can be gleaned from such soil maps and reports, even though they are prepared primarily for agricultural purposes. The pedological series boundaries and characteristics can usually be readily translated into areas of different geologic origins and, consequently, different soil characteristics. This is particularly true of glaciated areas, such as New York State, where the soils are relatively young and hence the glacial geology of the soil material is a major influence in soil formation.

Land-use information is sometimes available and is used in the economic evaluation of the various soil areas.

2. An analysis of terrain patterns on air photos of the area. Air photos are an excellent tool for terrain reconnaissance purposes and are particularly valuable for the interpretation of physiography and land use. The scale and quality of the prints and the time of year of flight are extremely important to the proper use of air photos for such purposes. The Bureau never relies entirely on air photos for terrain reconnaissance purposes, but recognizes air photos as one of the valuable tools available. Their use must be properly correlated with other sources of information if accurate results are to be obtained.

3. A field inspection of the areas, including studies of the topography, rock and soil conditions, vegetation and performance of existing highways and other engineering works. This information is correlated with a review of the results of subsurface explorations and analyses performed, in the past, by the Bureau on similar terrain in the general area, and with a review of past construction and maintenance experiences with existing highways in the general area under similar terrain conditions. Terrain patterns are repetitious, and engineering experiences can be anticipated for one pattern area by correlation with past experiences with similar pattern areas elsewhere. It must be emphasized that it is the policy of the Bureau that terrain reconnaissance reports are never based solely on air photo, map and other office paper studies, but that the terrain must actually be occupied and inspected in order that all aspects and factors be properly evaluated.

Area Grouping

After all available field and office information, gathered for any terrain reconnaissance survey, is correlated and compiled and the areas of various soil and rock conditions delineated, the areas are grouped into units, each unit possessing significantly different engineering characteristics.

The selection of mapping units is of the utmost importance in any terrain mapping program. The units in use by the Bureau of Soil Mechanics have been developed on the basis of five criteria:

1. The units must be recognizable by terrain reconnaissance procedures.
2. There must be significant differences in engineering considerations between each of the units.
3. The same general characteristics and engineering considerations should apply wherever the unit is encountered.
4. The number of units should be limited to the minimum that is practical and necessary to adequately define the variation in conditions and engineering considerations.
5. The units must be based on actual conditions and not on factors assumed for convenience.

These criteria are very important in glaciated areas where significant variations in terrain conditions are usually numerous along any line and, consequently, engineering design must sometimes be based on average conditions, and sometimes on limiting conditions rather than adjusted locally for each soil variation.

The Bureau uses a method of grouping based on the geologic origin of each deposit as identified by landform and characteristics of the materials contained in the deposit. The groups are depositional units, each unit having a different name. The depositional unit grouping method is not an arbitrary classification, but is based on field investigations and experiences throughout New York State over a period of approximately 15 years. Each depositional unit is an individual entity possessing surface and subsurface conditions that will significantly affect some important aspects of highway design and construction quite differently than any other unit.

At present, the Bureau uses a total of 20 general depositional units, as follows:

1. Thick till
2. Thin till
3. Variable till
4. Bedrock
5. Outwash deposits
6. Kame field deposits
7. Lacustrine bottom sediments
8. Delta deposits
9. Beach and bar deposits
10. Recent alluvial deposits

11. Esker deposits
12. Old alluvial deposits
13. Organic deposits
14. Alluvial fan deposits
15. Man-made fills
16. Windblown sands
17. Marine bottom sediments
18. Coastal plain sediments
19. Tidal marsh deposits
20. Undifferentiated urban areas

It is recognized that other units exist; however, these units have been sufficient for the Bureau's terrain reconnaissance purposes to date.

In addition, significant variations in bedrock conditions may exist. Where these variations will affect design and construction, a bedrock map will be prepared. For the purposes of clarity, the terrain and bedrock are mapped separately. Bedrocks having similar engineering characteristics are grouped together as in soil-terrain mapping.

Some rock conditions which may affect highway design decisions are:

Rock Structure and Rock Composition.—These may influence excavation methods and costs, rock cut slope design and the suitability for processing into granular materials if natural deposits of such materials are unavailable.

Thickness of Soil Overburden and Elevation of Buried Rock.—These conditions influence the selection of a grade line and the availability of the soil overburden for earth borrow.

Generally, only a portion of the foregoing 20 units will be involved in any single project. Figure 1 shows a portion of the strip map prepared for Route 17 Expressway, Broome County Line to Owego, Tioga County, New York.

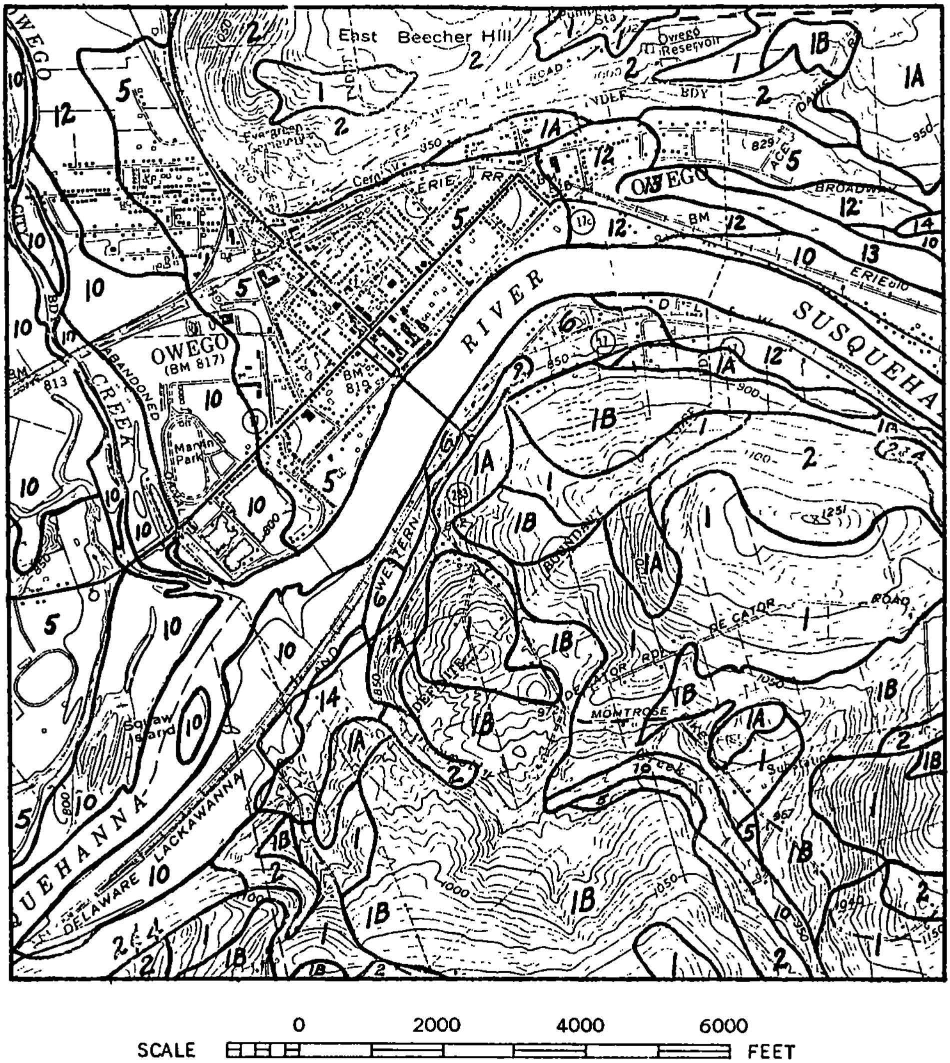
Description of Depositional Units

Throughout the state, there can be a considerable variation in the characteristics of certain of the depositional units. For example, the matrices of the thick tills range from non-plastic, predominately granular materials in certain general areas of the state to plastic silts and clays in other general areas. The natural densities of the tills range from loose to compact, and the origin of the parent materials ranges from hard crystalline rock to soft shales. Variations on a statewide basis occur in other depositional units as well.

Consequently, it is necessary to adequately describe the local characteristics of each depositonal unit involved in any particular report. If the general depositional units are separable into units having significantly different characteristics, the units are subdivided and each subdivision is described.

To illustrate this point, the description of the thick till units of the aforementioned Route 17 Expressway report is as follows (note that on Figure 1 the subdivisions of the thick till deposits are delineated):

Map Symbol	Depositional Unit	Unit Description
1	Thick till—compact	Mostly sloping upland areas of very compact, unstratified long-graded ice-laid mixtures of all soil fractions, ranging from silt and clay to boulders with silt being the dominant material. This till is derived from weak sandstones and brittle shales. These deposits have a drainage retarding hardpan layer in the B-horizon of the soil solum. Below this horizon is the C-horizon of parent soil-forming material which, in its upper weathered portion, is less compact than the same material at lower depths. The till deposits occupy valley sides and drainage is mostly run-off. In the lower portions of the valley sides, the



SOIL KEY

1	- THICK TILL (COMPACT)	5	- OUTWASH DEPOSITS
1A	- THICK TILL (LOOSE)	6	- KAME DEPOSITS
1B	- THICK TILL (POORLY DRAINED)	10	- RECENT ALLUVIAL DEPOSITS
2	- THIN TILL	12	- OLD ALLUVIAL DEPOSITS
2&4	- THIN TILL (WITH SOME OUTCROPS OF BEDROCK)	13	- MUCK DEPOSITS
		14	- ALLUVIAL FAN OUTWASH DEPOSITS

Figure 1. Portion of engineering soil map for Route 17 Expressway, Broome Co. line to Owego, Tioga County, N.Y.

Map Symbol	Depositional Unit	Unit Description
		accumulation of run-off is considerable because these areas not only receive rainfall, but must accommodate the run-off from higher areas. Compact till soils

Map Symbol	Depositional Unit	Unit Description
		have good surface drainage and with depth they are generally at low moisture contents because they are so compact. The depth to bedrock in till deposits is variable, but the thickness generally decreases as the degree of slope increases near the upper valley slopes. Local deposits of poorly sorted material and some silt pockets can be expected.
1A	Thick till—loose	These areas are mostly sloping upland areas of relatively loose, mostly unstratified, generally long-graded, ice-laid mixtures comprised of dominantly silty material with considerable rounded stones, but in a few places, including large flaggy rock fragments. In these deposits, some local sorting has occurred, and so silt pockets and pockets of granular material will be found. These deposits usually occupy some of the upper slopes of the valley sides. They receive run-off and run-in from areas above. In general the 1A till deposits have no hardpan layer such as is found in Type 1 deposits, and so run-in is not seriously restricted. Drainage is both by run-in and run-off. Deep cuts may intercept the water table. The depth to bedrock is variable. It generally decreases toward the valley walls.
1B	Thick till—poorly drained	These areas are ice-laid material similar to Type 1 soils. However, in 1B areas drainage is restricted either by a practically impermeable layer near the soil surface or in other places by topographic position. At the surface these materials have an organic layer. In most instances the organic material is mixed with some inorganic soil. The natural vegetation may include cat-tails and sedges. It should be noted that in general even the poorly drained deposits in tills become less wet with depth.

Engineering Significance Tables

The information compiled from the previously described terrain reconnaissance and appraisal operations must be so organized and presented that it will be readily available to the highway planning, location, and design engineers, with a minimum amount of time-consuming reading and interpretation. The number of mapping units is kept as small as is practical and necessary to present and explain the significant differences in characteristics. The influence of each depositional unit on the various aspects of highway location, design and construction and the engineering considerations involved with each depositional unit are indicated on an "Engineering Significance Table." Table 1 gives the "Engineering Significance Table" for the Route 17 project.

TABLE 1

GENERAL ENGINEERING SIGNIFICANCE, SOILS, ROUTE 17 EXPRESSWAY, BROOME COUNTY LINE TO OWEGO

Map Symbol	Depositional Unit	Design Considerations: Embankment Foundation	Cut Slope Treatment	Rock in Deep Cuts	Rock in Shallow Cuts	Optimum Grade Line	Construction Considerations: Compaction	Condition of Subgrade in Cuts	Source of Materials: Common Borrow	Select Borrow	Select Subgrade	Foundation Course
1	Thick till, compact	Good	Standard	Possibly	No	Anywhere	Normal as required	Possibility of silt lenses[1]	Yes	No	No	No
1A	Thick till, loose	Good	Standard[3]	Possibly	No	Anywhere	Normal as required	Possibility of silt lenses[1]	Yes	No	No	No
1B	Thick till, poorly drained	Good	Standard[3]	Possibly	No	Anywhere	Normal as required	Possibility of silt lenses[1]	Yes	No	No	No
2	Thin till	Good	Probably a composite-soil over rock[4]	Yes	Yes	High[5]	Normal as required	Rock in bottom of cuts[6, 7, 8]	No[9]	No	No	No
2 and 4	Thin till and rock outcrops	Good	In places a composite-soil over rock	Yes	Yes	High[5]	Normal as required	Rock in some cuts[6, 8]	No[9]	Possibly[25, 10]	No	No
5	Outwash deposits	Good	Standard[3]	Possibly	No	Anywhere[11]	Normal as required[12]	Variable, possibility of silt strata[13]	Yes	Yes[14]	Yes[14]	Yes[14]
6	Kame deposits	Good	Standard[15, 3]	Possibly	No	Anywhere	Normal as required	Variable, possibility of silt strata[13]	Yes	Yes[14]	Yes[14]	Yes[14]
10	Recent alluvial deposits	Variable[16, 17]	Avoid cuts[17]	-	-	High[18]	Variable, may be wet[19]	Avoid cuts	Variable[14]	Variable[14]	Possibly[14]	Possibly[14]
12	Old alluvial deposits	Variable depending on underlying material[16]	Variable[15, 20, 19, 3]	Possibly	No	Anywhere[21]	Normal as required[12]	Variable, possibility of silt strata[13, 22, 19]	Yes[15]	Probably[14]	Possibly[14]	Possibly[14]
13	Muck deposits	Very poor[23, 24]	Avoid cuts	-	-	High[18]	Unsuitable material[23]	Very poor, unsuitable[23]	No	No	No	No
14	Alluvial fan deposits	Variable	Avoid cuts[19]	-	-	-[19]	Variable, may be wet		Yes	Possibly[14]	Possibly[14]	No

Note The information shown is considered general and preliminary only and is based on the following work by the Bureau of Soil Mechanics, N Y S , D P W (a) A review of existing literature on the subject project, including an engineering interpretation of the pedologic and geologic maps of the area (b) A limited field surface reconnaissance survey of the area (c) A soils engineering interpretation of aerial photos of the route (d) A correlation of past engineering and construction experiences in this area

[1]Remove and replace silt lenses to sufficient depth to obtain uniformity and trafficability [2]Slope blanket should be provided, to be used A O B E , for correcting slope instability due to adverse water conditions [3]Skim cuts and fills should be avoided, where possible [4]High rock slopes may require special treatment, including variable slopes and benches as recommended by Bureau of Soil Mechanics [5]In areas of flat topography, grade line should be high to avoid rock excavation in ditches [6]See Standard Sections use optional deep ditches in rock or blasted rock trench where adverse seepage conditions exist [7]Where rock excavation is used for embankments, account for swell factor of broken rock in estimate [8]Proper benching and transition treatments are extremely important to assure uniform subgrade support [9]Generally uneconomical, low yield per acre. [10]If 2EC of broken rock is to be placed on soft material, provide granular foundation blanket to prevent rock from penetrating soft material [11]Except as modified by character of underlying material if intercepted by grade line or by the elevation of the water table [12]These materials generally require addition of water during construction season [13]Susceptible to frost heaves in cuts, due to possibility of adverse drainage conditions and non-uniform subgrade To reduce possibility, care should be taken to provide adequate drainage and uniform subgrade Each cut a separate problem in this respect [14]The suitability of each deposit must be individually determined [15]If predominately sandy, may present severe problems in fill slope, cut slope, and shoulder edge erosion, necessitating positive methods of run-off disposal, and slope treatment [16]Possible settlement and stability problems in fills of moderate height and over [17]This material becomes wetter with depth and even cuts of moderate depth usually involve the handling of material that considerably exceeds the optimum moisture content Depending upon prevailing weather, this may require the wasting of the wet material for practical reasons For quantity estimate purposes, all cuts in this material should be thoroughly explored and natural and optimum moisture contents profiled, hence, cuts are not recommended [18]A high grade line is necessary to avoid possible inundation of road during flood or high water periods [19]These deposits may have a high water table and may contain a wide range of good and poor materials, and excavation may involve the handling and disposal of fine grained, saturated, flowing, unstable materials, presenting problems in poor subgrade, slope stability and compaction Each deposit a separate problem, depending upon adequate subsurface explorations [20]These slopes frequently present problems in seepage and subsequent erosion and sloughing Therefore, special treatment may be necessary to achieve a stable slope [21]Deep cuts may encounter the water table [22]Frequently requires installation of layer of suitable granular material under foundation course to obtain trafficability during construction [23]Organic deposits should be considered unsuitable for highway foundation purposes, such material should, therefore, be removed, wasted, and replaced with suitable granular material [24]Consider wasting these materials or using to flatten slopes beyond normal 1 on 2 side slopes of embankments [25]Feasibility of crushing and processing only sound acceptable rock from cuts should be investigated

Use of Reports

Each terrain reconnaissance report always includes three basic features: an engineering soil map, a complete description of each depositional unit involved, and the general engineering significance of each depositional unit in tabular form. The reports may contain other information of importance to the particular project involved. Frequently, the over-all conditions of a project are summarized in the form of a synopsis. A concise summary is frequently of value in briefly describing the important general terrain considerations for the project.

Copies of the reports are furnished to all departmental units involved, including the appropriate district engineer and his district soils engineer. The reports are then used for the purposes described in the foregoing "Purpose of Terrain Reconnaissance." The reports are particularly useful in "line" conferences held to select or review the preliminary line and profile for projects on new location. These conferences are attended by representatives of all departmental units concerned, including the Bureau of Soil Mechanics.

During these conferences, significant terrain conditions are emphasized and discussed. This is the time when the possibility of adverse foundation conditions must be emphasized. Unless terrain reconnaissance reports reach the engineers responsible for the location, design and soils investigations in the very early stages of any project, the effort expended in the preparation of such reports may be largely wasted. Provided such reports are available in the early stages of the project, terrain reconnaissance reports can be effectively used for any project, large or small.

Practically all engineering data have their limitations, depending on their nature. Terrain reconnaissance reports are no exception. Terrain reconnaissance is an extremely useful tool, provided it is properly used by experienced engineers who recognize both its advantages and limitations. It must be emphasized that these reports are never intended to supplant subsurface investigations that should be an important part of any engineering program. Such reports serve as guides, indicating both desirable locations and potentially troublesome areas. Adequate subsurface exploration, testing and analysis programs can then be properly concentrated on the troublesome areas occupied by the line, and the most suitable areas covered by a minimum program sufficient to indicate the actual conditions. This method, therefore, furnishes an efficient, effective, economical and time-saving procedure for line location and subsurface investigation programming. It is certainly far more efficient and economical, at least in New York, than progressing subsurface explorations arbitrarily at certain predetermined distances along a line to locate the line and ascertain the foundation conditions.

To achieve reasonably accurate, effective and practical results from terrain reconnaissance operations, it is essential that the personnel assigned be thoroughly experienced in the area and with the actual highway design and construction problems of the depositional units involved. Unless this condition prevails, it is quite possible that the results of terrain reconnaissance operations will be meaningless or misleading to the planning and location engineers.

BIBLIOGRAPHY

1. American Society of Photogrammetry, "Manual of Photographic Interpretation." Washington, D.C. (1960).
2. Bennett, E.F., and McAlpin, G.W., "An Engineering Grouping of New York State Soils." HRB Bull. 13, pp. 55-65 (1948).
3. Cline, M.G., "Basic Principles of Soil Classification." Soil Science, 67:2, 81-92 (Feb. 1949).
4. Hofmann, W. P., and Fleckenstein, J.B., "Comparison of General Routes by Terrain Appraisal Methods in New York State." HRB Proc., 39:640-649 (1960).
5. Moon, J.W., Ligon, W.S., and Henderson, J.R., "Soil Classification and Soil Maps—Original Field Surveys." Soil Science, 67:2, 169-175 (Feb. 1949).
6. Soil Survey Staff, "Soil Survey Manual." U.S. Dept. of Agriculture, Handbook No. 18 (1951).
7. Stockstad, O. and Humbert, P.R., "Interpretive Soil Classification—Engineering Properties." Soil Science, 67:2, 159-162 (Feb. 1949).