Application of Airphoto Interpretation Techniques

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A soil classification system comprising seven units is described with respect to: physical characteristics of the soil, subsurface drainage conditions, frost susceptibility, settlement characteristics, relief, ease of excavation, and other significant characteristics. Reconnaissance engineering soil maps for an area of about 4,000 sq mi, and hundreds of miles of soil strip maps, have been prepared. Application of the procedure in soil and materials studies for a specific route study, and accuracy of the soil mapping, are described.

● THE Maine State Highway Commission in cooperation with the U.S. Bureau of Public Roads initiated a soils mapping program, employing airphoto interpretation techniques, in 1948. For the next six years a soils classification system based on geomorphological nomenclature was used for the preparation of engineering soils maps.

Because most of the engineers in the highway commission had little or no formal training in the earth sciences and were not familiar with the technical terminology designating various landforms, the soils maps were not fully appreciated and, as a result, were rarely used. To rectify the situation, it was obvious that a fresh approach was necessary to stimulate the engineer's interest in the utility of soils and terrain studies for various phases of highway engineering work. Also, it was necessary to demonstrate that airphoto interpretation techniques were ideally suited for the purpose of providing adequate terrain information rapidly and at a minimum of cost.

MAINE RECONNAISSANCE ENGINEERING SOILS CLASSIFICATION SYSTEM

In 1954, a soils classification system was developed to satisfy the following requirements:

1. The system should have an absolute minimum number of soils map units, yet provide adequate information required by engineers for planning and preliminary engineering phases of highway location work.
2. The system should employ non-technical terminology in describing the soils units which should be tailored for terrain and climatic conditions found in Maine.
3. The system should be adaptable to airphoto interpretation procedures and techniques to such a degree that adequate engineering soils maps could be produced with a minimum of costly and time-consuming field checking.

In the process of formulating a system to fulfill these objectives, it was recognized that in this climatic region the frost action phenomenon is of paramount interest to the highway engineer. Apart from complex local climatic factors, the amount of frost action, or the degree of frost susceptibility, is principally a function of soil texture and structure and the availability of ground moisture during the cold seasons of the year. Briefly, wet fine-grained mineral and organic soils are highly frost susceptible, whereas dry granular soils are not susceptible to detrimental frost action. Differential heaving due to frost action results in extensive damage to roadways and highway structures. During the spring break-up period the melting of segregated ice lenses formed in frost susceptible soils results in unstable subgrades and pavement deformations which comprise one of the major expenditures of the maintenance budget in Maine.

In addition to frost susceptibility, several other physical characteristics of the ground were taken into consideration. Settlement properties, subsurface drainage characteristics, relief and other natural influences which might affect, to one degree or another, an area as a highway construction site were evaluated and incorporated into the soils classification system.

Airphoto analysis of terrain conditions is based principally on the interpreter's ability to identify various geologic landforms and to translate the significance of these landforms into terms of the physical characteristics of the soil as described in the last few paragraphs. Although glacial history, mode of deposition, drainage patterns, peculiar relief forms, vegetation cover, land use and other features are of prime importance to the interpreter, the engineer is interested only in the soil per se and not its origin.

On the basis of these considerations, a classification system composed of seven basic soils units was developed. Each of the soils units is described with reference to the physical characteristics of the soil, subsurface drainage conditions, frost susceptibility, settlement characteristics, relief, ease of excavation and other significant characteristics where applicable.

Map Symbol	Soils Unit	Description
R	Rock	Bedrock within 5 ft of the surface, outcrops generally common. Type of rock and possible engineering problems at specific areas are described in text accompanying strip maps. Over-all drainage is generally good, except for local swampy pockets on flattened hilltops. Overburden is generally stony or bouldery till on upper slopes, and similar to that of adjacent soil units on lower slopes. Seepage and icing problems should be expected. Degree of frost susceptibility is dependent on character of overburden and local drainage conditions.
BG	Boulder granular	Very bouldery till and occasionally colluvial or alluvial deposits having a sandy or gravelly matrix. Boulders up to 5 ft in diameter are numerous. Volume of ledge-size boulders (in Maine, a 1-cu yd boulder is classed as ledge for excavation payment) is often 10 percent or more. Surficial and subsurface drainage is good. Slopes are usually smoother and less irregular than the rock type. Materials are slightly to moderately frost susceptible. Boulder granular areas are considered as good construction sites.
B	Bouldery clay	Bouldery till containing a matrix of silt or clay. Relief varies from rolling to practically flat. Permeability is very poor. Ledge-sized boulders occur infrequently in the densely packed fine-grained till. Excavation is often very difficult in well-drained sites. Frost susceptibility varies from moderate to very high. Local drainage ranges from poor to good. Adequate drainage must be provided to insure good road performance.
G	Granular	Well-drained sandy and/or gravelly materials not subject to detrimental frost action or only slightly frost susceptible. Included are such landforms as eskers, outwash, kames, dunes, deltas, terraces, beaches and flood plains. Coarse, clean granular materials suitable for base course construction are generally of glaciofluvial or alluvial origin. Granular soils of lacustrine and marine origin as well as wind-deposited soils are usually sandy and are suitable for fill materials. Well-drained granular areas are excellent construction sites.
F	Fines	Alluvial, lacustrine, marine or occasionally glacial and aeolian deposits composed principally of silt or clay. Surficial drainage is generally poor. Frost susceptibility varies from high to very high. In low-lying areas these soils are often soft and are subject to considerable settlement. This soil type should be avoided, especially in poorly drained sites.

Map Symbol	Soils Unit	Description
S	Swamp	Low-lying areas having the water table at or very near the surface throughout the year. Surficial organic layer is generally less than 3 ft thick. Small swamps are associated with ground moraines, valley plains, flat-topped bedrock hills, or any terrain type having local depressed areas containing a perched water table. Soils contained in small swamps of this type are similar to those found in the adjacent areas. Larger swamps are usually found in alluvial, lacustrine and tidal marsh areas where the soils are generally extremely soft, highly compressible silts and clays which are very frost susceptible. These areas are very poor construction sites and should be avoided where possible.
P	Peat	Boggy sites characterized by a high water table and a surficial layer of peat at least 3 ft thick, and often in excess of 10 ft. The thickness of peat is indicated at select sites on soil strip maps. Deepest peat deposits are primarily associated with filled-in lake beds, glacial kettles, back water swamps, old stream channels and other relatively deep depressional areas. Peat is highly compressible and frost susceptible. This soil type represents the worst type of construction site and should be avoided if at all possible.

In addition to the seven soils units described, water (W) is incorporated into the classification system. Natural and artificial ponds, beaver flowages, pulpwood water storage areas, lakes and other bodies of water generally over 2 ft deep are included in this category.

Reconnaissance engineering soils maps, covering an area of approximately 4,000 sq mi, about one-eighth of the total area of Maine, have been completed at this writing. These maps, having a scale of 2 in. = 1 mi, were prepared in blocks of about 100 sq mi (15-min USGS topographic quadrangles split into two sections, north and south halves). Maps of this type are used in the initial phases of planning. In addition, several hundred miles of soils strip studies along proposed construction projects have been made. The width of these strips varied from 0.5 to 5.0 mi depending principally on the distance between terminal points and the character of the terrain encountered. For more detailed strip studies, the classification system described previously was modified somewhat to provide additional information, especially in areas having organic and highly compressible mineral soils. Maps of this type were used in the preliminary engineering phase of highway construction.

APPLICATION

Three types of strip studies—soils, drainage and materials—made along the Augusta-Fairfield section of the Interstate Highway System, which was opened to traffic in November 1960, are described in the following paragraphs. Terrain information can be presented in a variety of formats, depending on the type of project and the preferences of the engineering personnel involved.

Detailed Engineering Soils Strip Map

One method of presenting soils information suitable for more advanced stages of highway engineering is to superimpose soils delineations on topographic maps of adequate scale and contour interval. Large-scale maps covering the tentative route of the Interstate Highway System north of Augusta were considered ideal for this type of format. Following are brief discussions on the use of the maps by highway engineers and an evaluation of mapping accuracy.

After the preliminary planning phase of the Augusta-Fairfield Interstate project was completed, large-scale aerial photographic coverage was obtained along the proposed route. This photography, taken at a scale of 1:5,400 with a 6-in. focal length precision camera, was flown in spring after the snow had melted and before leaves were developed on deciduous trees. Photography of this type is ideal for photogrammetric purposes and also for terrain photo analysis. Topographic maps at a scale of 1 in = 200 ft and a contour interval of 5 ft were made by a private photogrammetric concern for the entire length of the project.

A detailed airphoto analysis was made of a strip of photos centered on the preliminary line. Soils areas, based on the classification system previously described, were delineated on the photos. Because of the "hurry-up" nature of the project, no field checks were made. Time permitted only brief reconnaissance along the 20-mi long

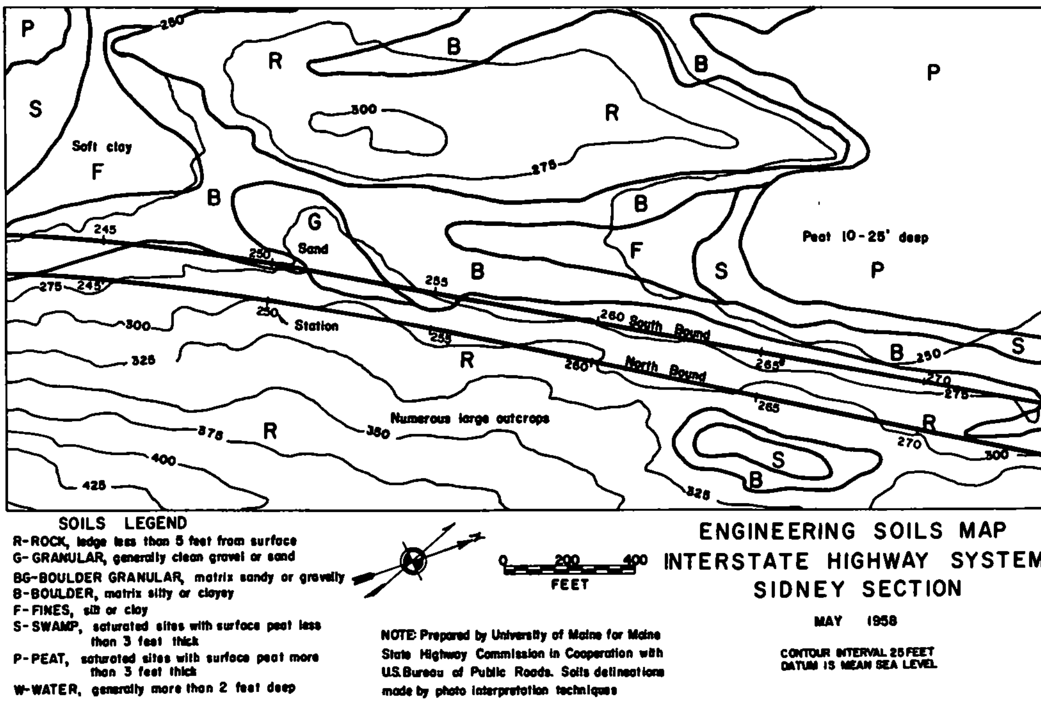

Figure 1. Engineering soils map units superimposed on a topographic base map. Original map was at a scale of 1 in. = 200 ft, with 5-ft contour interval.

study strip. In effect, the soils areas delineated were based only on airphoto interpretation. The soils areas were then transferred from the photos to the topographic maps described in the previous paragraph.

The location engineer then evaluated a number of median lines placed on the soils topo maps. Additional terrain information supplied by the airphoto interpreter included estimated thickness of peat, problem clay areas, potential seepage and icing slopes, extensive outcrop areas, location of granular deposits and other pertinent information which would, to one degree or another, contribute to the ultimate cost of the roadway.

After a more or less firm median line was selected the centerlines of the north and south lanes were plotted. Figure 1 shows the tentative road location on a soils-topo map about 10 mi north of Augusta. The map was modified slightly for reproduction purposes. Figure 2 is an uncontrolled mosaic of a strip of annotated photos centered on the area depicted in Figure 1, illustrating how two deep bogs were skirted in this particular area.

With plans and profiles in hand, field crews under the direction of the soils engineer conducted a detailed soils investigation along the north and south centerlines and offset locations where required. This information was used for design and cost estimate purposes.

For the purpose of evaluating the accuracy of the soils maps prepared by airphoto interpretation techniques, a portion of the 20-mi long study strip was selected for analysis. A total of 418 auger borings and soundings (for bedrock) were made along a 42,400-ft section of the Interstate. The locations of field checks were pinpointed on the soils map and actual field conditions were compared with the soils type indicated on the map. Table 1 gives the results of the evaluation.

Because of the relatively small number of field checks in the G, S and P soils areas encountered in this accuracy study it was not feasible to present a detailed statistical analysis of the data contained in Table 1. However, for a total of 418 field checks in all soil types, the mean error was 14.3 percent, and the range of error at 19.1 odds was 11 to 19 percent. In other words the engineering soils maps, based solely on airphoto interpretation with no field checks evaluated for this study, were accurate about 85 percent of the time.

It is emphasized at this point that the accuracy of a particular terrain analysis study is dependent not only on the competency and general background of the individual photo analyst, but also on such factors as the suitability of the aerial photography for interpretation purposes, complexity of the terrain and, especially in wilderness regions, the amount and type of forest cover.

Interpreters frequently use vegetation as soils indicators. In Maine, where the forests have been cut-over or burned-over a number of times during the past two centuries, the climax species composition of the forest has been so disturbed that the value of particular forest type as a soils indicator is limited. The significance of the present cover must be diagnosed in terms of general environment and probably botanical history of the area. Terrain blanketed with dense coniferous forests is very difficult to interpret because the surface of the ground is often completely obscured. In areas covered with mixedwood or hardwood forests it is possible to see the ground through the canopy on photos taken in spring or late fall when deciduous trees are barren of leaves. Consequently, the accuracy of the interpretation is considerably higher in these areas than in those having a dense softwood cover. From the point of view of vegetation cover

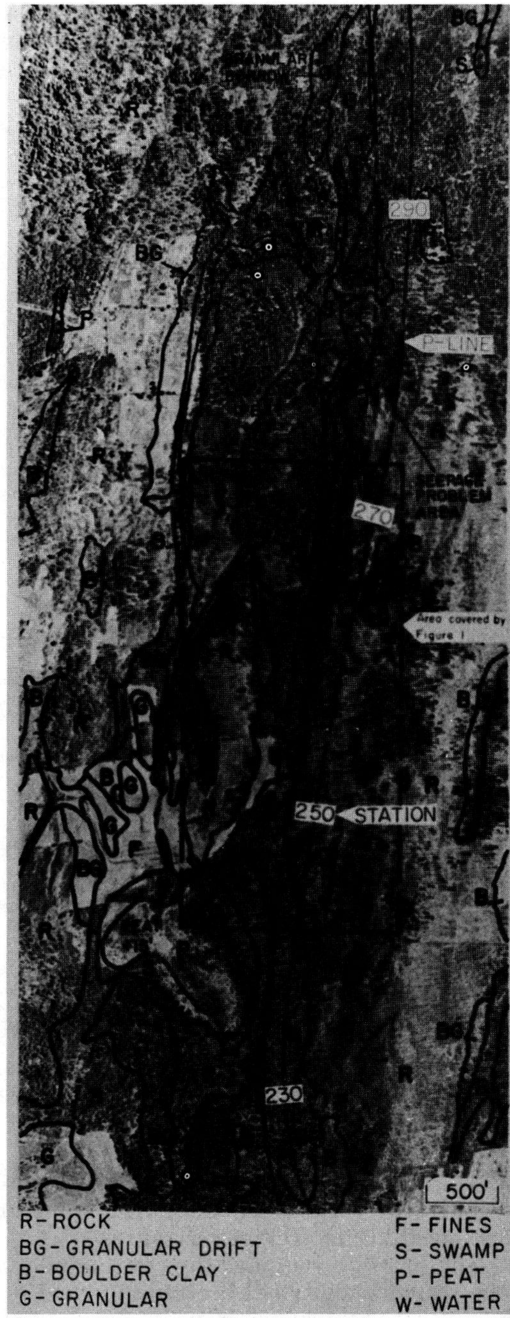

Figure 2. An uncontrolled mosaic strip showing soils delineations and annotations. Original photo scale—1 in. = 450 ft.

TABLE 1

COMPARISON OF SOIL UNITS AS MAPPED WITH ACTUAL FIELD CONDITIONS
(Map Classification by Photo Interpretation)

Soils Unit	R	BG	B	G	F	S	P
R	186	1	10	1	2	0	0
BG	5	46	0	2	4	0	0
B	2	1	48	5	19	0	0
G	0	0	0	4	4	0	0
F	0	0	2	1	63	0	0
S	0	0	0	0	0	11	1
P	0	0	0	0	0	0	0
Totals	193	48	60	13	92	11	1

Note: Underlined numbers indicate correct photo interpretation of soil unit designations confirmed by field checking; that is, in the B (boulder clay) column, out of a total of 60 field checks in areas classed as B on the soils map, 48 of the locations sampled were boulder clay, 10 areas were R (bedrock within 5 ft of the surface) and two areas were water-deposited silty soils.

only, regions containing some non-forested or partially forested areas are the least difficult to interpret. In coastal glaciated regions, such as Maine, the general geomorphological character of the landscape varies from very complex to relatively simple to evaluate by photo interpretation techniques.

As is suggested in the foregoing brief discussion of some of the factors which affect photo interpretation accuracy, it is evident that a considerable variation in accuracy should be expected. In any event, the quality of a soils study could be materially improved if the interpreter can make a brief reconnaissance of the study area, with photos in hand, before delineating the soil types on the photo. A review of previous soils studies made in the general area may provide useful data on soils conditions at specific points. Too often, however, information contained in published papers is too general to be of much value. In Maine the best source of reliable soils data which can be pinpointed is unpublished soil survey reports prepared by the soils laboratory of the state highway commission. After the office study is completed, a field check of questionable areas should be made and interpretation miscues can be readily rectified to improve the map accuracy. Obviously, the accuracy evaluation data contained in Table 1 are applicable only to the particular soils strip maps covering the study area discussed in this paper.

Drainage Study

A detailed photohydrological study was made of a portion of the Interstate Highway System described previously. Approximately 75 percent of the area was covered by hardwood and mixedwood forests. The aerial photography used for this study was taken in early spring before the deciduous leaves were developed, so it was possible to see most of the drainageways and ridge lines through the canopy. Photography taken in summer or late spring when foliage is fully developed is not satisfactory for drainage studies. The particular set of photography used for this survey was considered ideal, because the ground was saturated and every shallow depression was filled with water, making it relatively easy to trace small rills even in mixedwood forests which contained up to 50 percent softwood species. Figure 3 is an airphoto showing drainageways and ridge lines outlining watersheds in rolling terrain covered by several forest types.

Runoff information on 169 watersheds was gleaned from airphotos along a 15-mi section of the Interstate. The data on each watershed area were presented in the form as given in Table 2.

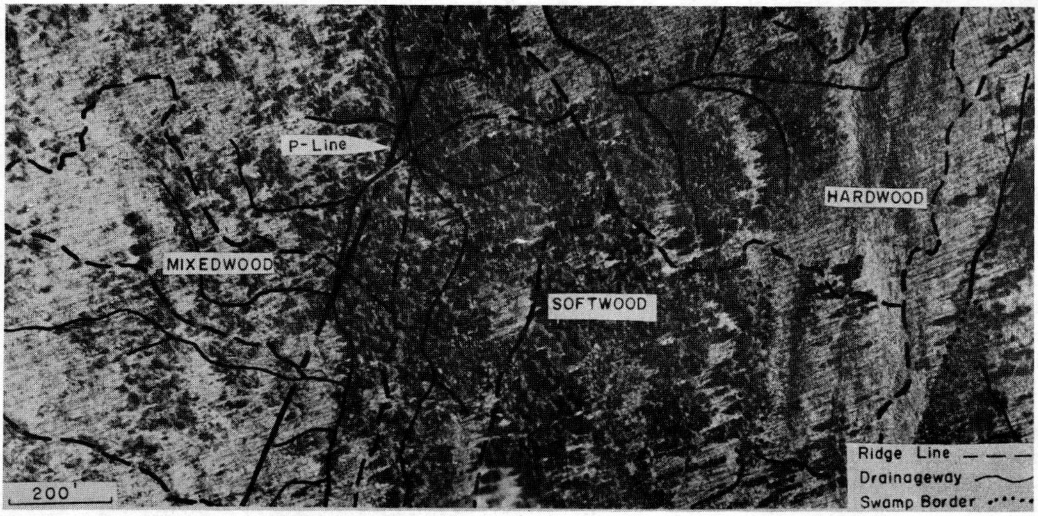

Figure 3. Drainageways and ridge lines visible beneath different forest types on an airphoto taken in early spring before foliage on deciduous trees was developed.

The information contained in this drainage report was used as design criteria for drainage structures in this section of the Interstate. Spot checks conducted by the design engineer and subsequent checks made during the construction stage revealed that the information extracted from the airphotos was substantially accurate with the exception of three watershed areas out of a total of 169. The three erroneous interpretations were misplaced ridge lines in heavily wooded softwood forests where it was not possible to see minor relief expressions through the dense canopy. All questionable interpretations should be field checked.

TABLE 2

RUNOFF INFORMATION OBTAINED BY PHOTO INTERPRETATION TECHNIQUES

No.	Station	Area (Acres)	Mean Slope (%)	Forest or Brush Cover (%)	Shape[a]	
54	799+20	52	6	95	800 x 3,200	A 12-acre storage area is located about 600 ft L℄ at Sta. 797. About 60 percent of the watershed contains some outcrops.
55	803+60	4	8	100	200 x 525	Can combine with Area No. 56.
56	805+00	27	3	80	600 x 1,900	See existing culvert 390 ft L℄ at Sta. 804+10. Northbound lane crosses a 20-ft wide swamp.

[a]General shape of watershed, width x length (in feet).

In more recent drainage studies, the column heading of "Forest or Brush Cover (%)", in Table 2, has been refined. Land use categories now used include (a) forested, (b) pastureland or hayland, and (c) cultivated land.

In Maine, engineers do not use soil type as design criteria in determining size of drainage structures. Peak runoff, principally in the form of melt water, occurs during the break-up period at which time the soil beneath the snow cover is frozen. This conditon effectively prevents percolation of melt water into the ground regardless of soil type.

In addition to the runoff factors given in Table 2, the rate of snow melting and, in effect, the ultimate runoff peak is also dependent on a number of complex environmental influences including air temperature variations, intensity and amount of spring rainfall, thickness and density of the snow cover, vegetation cover type, and slope gradient

Figure 4. A sample of an annotated airphoto furnished to field crews conducting materials investigations. Best access to suggested sampling points, distances, compass bearings and information useful for orientation purposes are noted on the photos. Crews are equipped with stereoscopes and scales for each set of photography.

and aspect. Considerable research is required to evaluate the relative contribution of these watershed influences to peak runoff volumes. As additional research data on runoff characteristics are incorporated in the design formula, information presented in the future drainage studies will be supplemented to meet the needs of the design engineer.

Materials Inventory

A photo analysis of potential granular deposits was made of a 6-mi wide band centered on the proposed Interstate location between Augusta and Fairfield. More than 100 granular deposits and about a dozen potential quarry sites delineated on the photos were sampled by field geologists and the materials were tested by the soils laboratory. Crews were furnished with annotated airphotos showing a variety of information designed to expedite the field investigation (Fig. 4).

A Materials Inventory Report, covering approximately 150 sq mi, contained the following information: (a) maps, at a scale of 2 in. = 1 mi, showing the location of each deposit (Fig. 5); (b) results of lab tests on rock samples; (c) tables containing detailed information on each deposit sampled; (d) grain-size distribution curves for each sample; and (e) large-scale sketch maps of deposits where detailed field investigations were made (Fig. 6).

Illustrated in Table 3 is the type of information and the method of presentation of

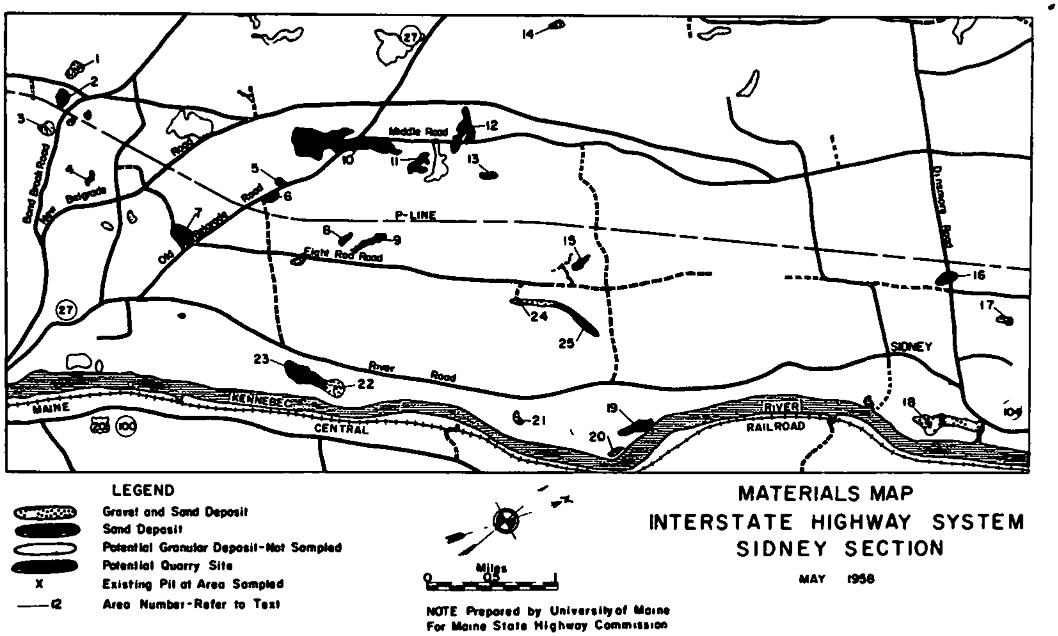

Figure 5. A portion of a granular deposit location map contained in a Materials Inventory Report. Original scale - 2 in. = 1 mile.

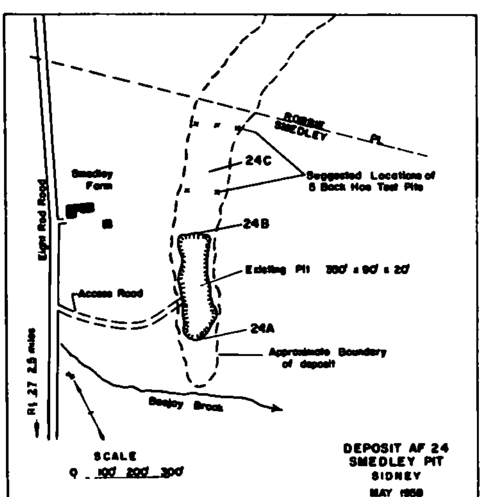

Figure 6. Sketch map of an individual deposit included in a Materials Inventory Report.

data on each of more than 100 deposits sampled.

In Maine, the free-haul distance is two miles. The maximum amount of admissible overhaul mileage is based on information contained in these reports and on the state construction engineer's evaluation of nearby deposits containing suitable quantities and qualities of materials for an individual project. Materials Inventory Reports were made available to bidders on construction projects located in this section of the Interstate covered by the study described in the previous paragraphs.

The Materials Inventory was also used for the selection of sources of maintenance and winter sand materials for this section of the Interstate.

CONCLUSION

The Maine Reconnaissance Engineering Soils Classification System described in this paper is accepted by Maine highway engineers and is readily adaptable to airphoto interpretation mapping techniques.

Reasonably accurate engineering soils maps suitable for planning purposes can be prepared directly from adequate airphotos with little or no field checking. Sufficient field checking is suggested, however, to improve map accuracy for use in the preliminary engineering phase. Soils maps are being used efficiently and effectively by Maine state highway location engineers both in the planning and preliminary phases of location studies.

For new location projects, Maine highway engineers are using, as the principal source of design criteria, drainage information obtained by airphoto terrain evaluation methods.

Materials inventory studies can be conducted most efficiently by employing an effective combination of airphoto analysis, field investigation and laboratory testing. Material sources near to construction projects can be used to minimize haul distances and to reduce construction costs.

TABLE 3

GRANULAR DEPOSIT EVALUATION SHEET[a]

Sample No.	Depth of Sample (ft)	Over-burden (ft)	Pit	Volume Estimate (cu yd)	Sieve Analysis % Passing 3 in.	1 in.	¾ in.	No. 100	No. 200	Passes MSHC Specs.	Remarks
24A1	3-6	3	Yes	38,000 (see remarks)	100	68	44	5.1	3.3	-	Owner. John Smedley, West Sidney Existing pit—350x90x20ft. Loc. A - East side of south face. Boulder clay floor. Can expand pit to south 125 ft. Volume estimate, 6,000 yards, gravel base, lower course. Loc. B - Center section of north face Boulder clay floor, water table at floor elevation. Loc. C - Hand dug pit located 200 ft NNE of Loc. B. Top strata similar to Samples 24B1 and B2. Materials at depth probably similar to 24B3 and B4. Volume estimate—extend existing pit 425 ft NNE to property line. Can remove top 10 ft separately for 12,000 yards of gravel borrow and lower 15 ft layer for 20,000 yards of gravel base, upper course. If entire 25 ft face is mixed, the material (Composite 24B1-B4) passes for gravel borrow See Sketch B-4 showing sampling locations and suggested locations of additional test pits, if desired
24A2	6-14	-	-	-	100	85	50	6.8	5 5	-	
24A3	14-19	-	-	-	92	70	38	5.0	2.8	-	
Composite (24A1, A2, A3)	-	-	-	-	97	77	45	5.9	4 2	Gravel base lower course	
24B1	1-7	1	Yes	-	100	100	98	12.6	9.1	-	
24B2	7-11	-	-	-	88	65	40	8.7	7 4	-	
24B3	11-19	-	-	-	100	66	48	4.9	4.0	-	
24B4	19-26	-	-	-	100	74	57	4.1	3.6	-	
Composite (24B1 and B2)	-	-	-	-	95	86	75	11 0	8 4	Gravel borrow	
Composite (24B3 and B4)	-	-	-	-	100	70	52	4 5	3.8	Gravel base upper course	
Composite (24B1, B2, B3, B4)	-	-	-	-	98	76	61	7 1	5.7	Gravel borrow	
24C1	2-5	2	No	-	100	100	92	10 8	8.0	-	
24C2	5-7+	-	-	-	95	61	44	8.0	6.8	-	

[a]Area No.—AF 24.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Raymond Woodman, Jr., Assistant Airphoto Interpreter, University of Maine, and various members of the Maine State Highway Commission, especially Robert Furber, Primary Division Location Engineer; Frederick Boyce, Jr., Soils Engineer; and Mrs. Arlene Waddell, Secretary. Airphotos in Figures 2, 3, and 4 are reproduced with the permission of the Maine State Highway Commission.