Comparison of General Routes by Terrain Appraisal Methods in New York State

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The appraisal of soil and geologic conditions of terrains by the engineering interpretation of airphotos and other methods of analysis has become a valuable procedure in ascertaining the optimum locations of proposed highways from the standpoint of subsurface conditions.

Frequently, it is important to compare the relative earthwork construction costs of two or more routes considered for any proposed highway. In this paper the method used by the New York State Department of Public Works to compare the probable relative earthwork costs of two general routes considered for a 90-mile section of a Federal Interstate Highway is demonstrated.

The soil and geologic conditions of the terrains traversed by the routes were first identified, delineated and classified. The actual earthwork costs of similar class highways constructed in the past on similar terrains were studied, and relative earthwork cost factors per mile were assigned to each class of terrain involved in the proposed routes. The probable total relative earthwork construction costs were then compared for the two general routes. These studies were utilized, along with other considerations, in selecting the most economical route for the proposed highway.

• NEW YORK State, except for that part of Cattaraugus County south of the big bend of the Allegany River, was entirely covered by continental glaciation. This occurrence of thousands of years ago left a legacy of assets and liabilities that greatly affect the problems and costs of highway construction. Fourteen physiographic provinces comprise the state. The terrain varies from the mountainous rocky Adirondack Province to the low Long Island section of the Atlantic Coastal Plain.

The subsurface conditions range from the bedrock of the mountains; the glacial tills of the rolling hills; the gravels of the outwash terraces, kame fields and eskers, to the deep, soft plastic silts and clays of the lacustrine plains and organic deposits of the swamps and marshes.

The climate ranges from the long cold winters of the northern Adirondacks, where deep frost penetration is common, to the relatively mild rainy winters of the Long Island area, and in summer from the hot humid lowlands to the relatively dry cool mountain and upland provinces.

Obviously, such extreme variations in the landscape and soils result in equally extreme variations in highway problems; and consequently, depending on the location of the project, considerable variations in highway costs as related to these factors.

The nature of the subsurface conditions involved in the construction of any highway has a considerable effect on the cost of the earthwork for that project. It is also recognized that the nature of the topography of the country traversed by a highway affects the total cost of the earthwork, because to a large extent it determines whether the cuts and fills are to be light or heavy to achieve the desired grade and alignment standards.

These topography-soil-earthwork relationships have long been recognized by the New York State Department of Public Works; consequently, the Bureau of Soil Mechanics of the Department has performed many engineering soil surveys, and the resulting reports and maps have been extensively utilized in major highway location work (*1*).

As part of those operations, the Bureau of Soil Mechanics prepared engineering soil maps for the design of approximately 400 mi of the New York State Thruway. During 1958, the Bureau prepared engineering soil and geology reports with maps for 105 mi of the Federal Interstate Program of the state. At present, such reports, including engineering soil and geology maps, engineering significance tables, and construction material resources reports, are prepared by the Bureau for proposed major highway routes on new locations.

In work of this nature, the word "terrain" is used to denote a relationship between general topography and subsurface conditions. "Terrain appraisal" is the evaluation of topography and subsurface conditions as related to design and construction problems and their effects on highway construction costs.

PURPOSE AND SCOPE

Because terrain conditions have a considerable effect on highway earthwork costs, it is reasonable to assume that if alternate routes for a proposed major highway are being considered, other factors being equal the route traversing the most favorable terrain will be the most economical to build.

Approximately one-third of the cost of a modern highway is spent on earthwork, and a vast percentage of the volume of material handled on any highway project consists of earthwork; therefore, its cost is an important factor in ascertaining the most economical route for a highway if alternate locations are presented.

The purpose of this paper is to present and demonstrate the terrain appraisal methods utilized by the Bureau of Soil Mechanics in ascertaining the relative earthwork costs of alternate routes for cost comparison purposes. To illustrate the methods used, a terrain evaluation and relative earthwork cost comparison for two general routes proposed for a 100-mi section of a Federal Interstate Highway in New York State is presented. For the purpose of simplicity of illustration of the technique, the evaluation of only two general widely separated alternate routes is included, although several more routes were studied for highway planning purposes. It is not the purpose of this paper to promote either route of the following study. The relative cost factors indicated were intended for terrain reconnaissance purposes only in the areas involved, and are not intended to be applied to the remainder of New York State.

THE PROBLEM

Early in 1958 the Bureau of Soil Mechanics was instructed to perform a terrain evaluation for two widely spaced alternate routes under consideration for the location of the portion of Interstate Route 502 between Glens Falls and Keeseville. This route, called the Northway, begins at Albany at an interchange with the New York State Thruway and terminates at the Canadian border north of Plattsburg.

Two general route locations were available for the section between Glens Falls and Keeseville, a distance of approximately 100 mi. It was desirable to ascertain the probable costs of these routes in order to select the more economical location from all standpoints. The function of the Bureau in this study was to evaluate the terrains traversed in relation to the probable relative earthwork costs of the two lines.

One line selected for study by the Bureau of Highway Planning ran north from Glens Falls, and throughout its length traversed the Adirondack Physiographic Province to Keeseville. This was the westerly line, called in the following the Adirondack route. The other alternate, and easterly line, designated as the Champlain route in the following, mainly traversed the Hudson-Champlain Low-

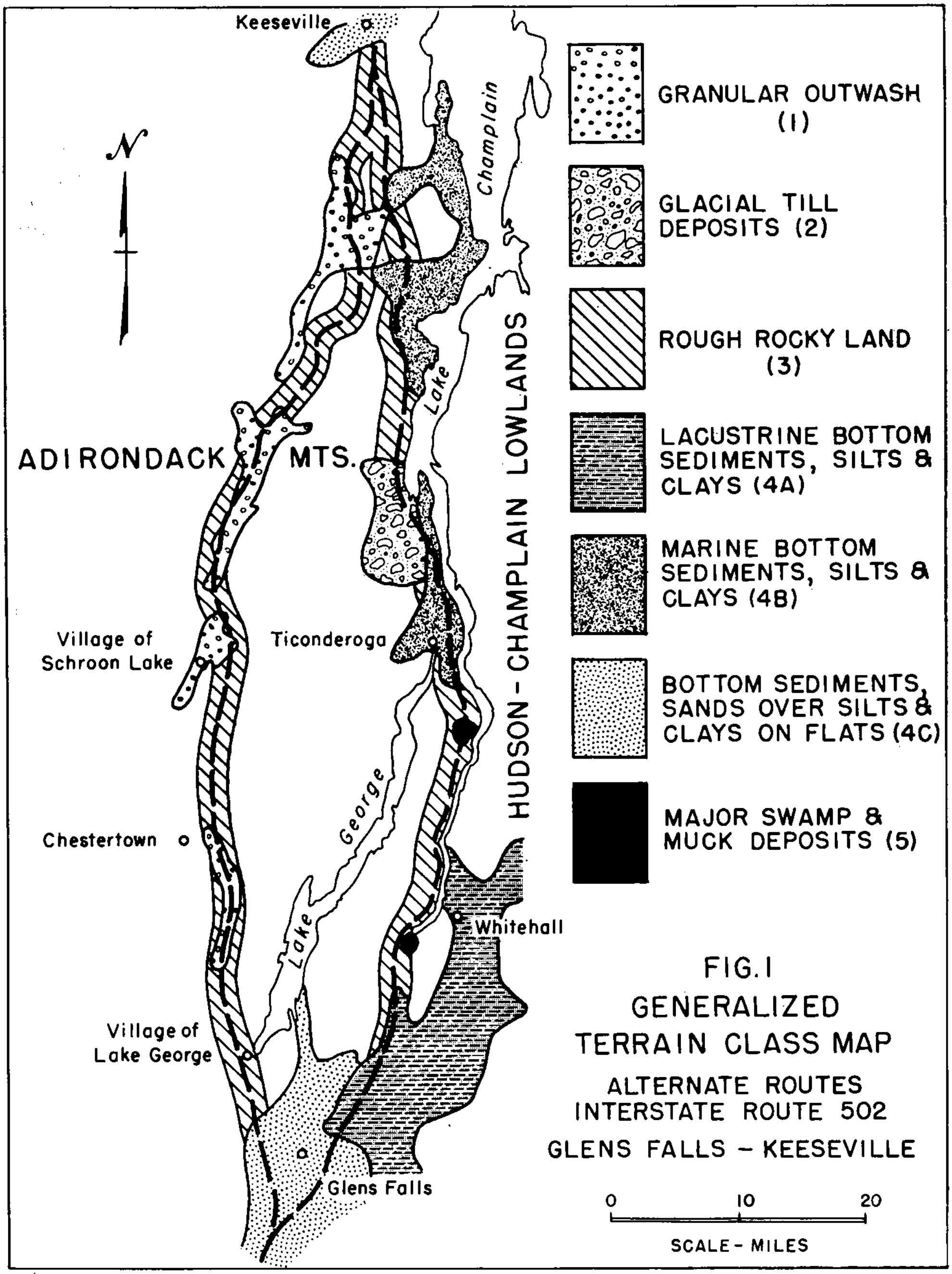
Keeseville
Champlain
Lake
ADIRONDACK MTS.
HUDSON - CHAMPLAIN LOWLANDS
Village of Schroon Lake
Ticonderoga
Lake George
Chestertown
Whitehall
Village of Lake George
Glens Falls
GRANULAR OUTWASH (1)
GLACIAL TILL DEPOSITS (2)
ROUGH ROCKY LAND (3)
LACUSTRINE BOTTOM SEDIMENTS, SILTS & CLAYS (4A)
MARINE BOTTOM SEDIMENTS, SILTS & CLAYS (4B)
BOTTOM SEDIMENTS, SANDS OVER SILTS & CLAYS ON FLATS (4C)
MAJOR SWAMP & MUCK DEPOSITS (5)
FIG. I
GENERALIZED TERRAIN CLASS MAP
ALTERNATE ROUTES INTERSTATE ROUTE 502
GLENS FALLS – KEESEVILLE
0 10 20
SCALE - MILES

Figure 1.

land Province, but in places traversed a very rugged part of the Adirondack Province. The locations of the two lines are shown in Figure 1. At first glance, it appeared that the practically "water level route" afforded by the Champlain route furnished the more desirable location for a major Interstate Highway.

PROCEDURE

The first phase of the study was a reconnaissance survey of the two routes to ascertain the types of terrain involved. During this survey the boundaries of the various types of terrain were drawn on USGS Quadrangle sheets. The various types of terrains were then grouped into five general classes, considered the optimum number for the conditions of the problem. The mileage of each line on each class was then scaled from the boundaries drawn on the USGS quads.

Terrain appraisal is actually a reconnaissance of conditions; its greatest value to the highway engineer and planner exists during the very preliminary stages of line studies for a major project. Terrain grouping should be limited, therefore, to the minimum number of classes necessary to present the over-all picture of the basic problems involved with each broad class of terrain.

The foregoing operations resulted in the generalized terrain class map (Fig. 1), which was based on the following sources of information:

1. Research of the existing scientific literature concerning the areas. This included a study of all available geologic, pedologic and land use reports and publications.
2. A review of the results of subsurface explorations and analyses performed in the past by the Bureau, in the vicinity of the two lines.
3. An analysis of the terrain patterns on airphotos of the areas.
4. A field inspection of the two lines, involving studies of the topography, rock and soil conditions, vegetation, uses of the land, and performance of existing highways in the areas. This inspection was performed by a team assigned to this project and composed of a soils engineer, an engineering geologist, and a soil scientist. It is the policy of the Bureau that terrain appraisal reports are never based solely on airphoto, 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.

TERRAIN GROUPING

The types of terrains involved in this problem were grouped into the following general classes and subclasses:

Class 1—Granular outwash deposits.
Class 2—Glacial till deposits.
Class 3—Rough rocky lands.
Class 4A—Lacustrine bottom sediments, silts, and clays.
Class 4B—Marine bottom sediments, silts, and clays.
Class 4C—Bottom sediments, sands over silts, and clays on flats.
Class 5—Major swamp and muck deposits.

Class 1—Granular Outwash Deposits

Description. These deposits were laid down by the melt waters of the glacier in the form of benches or terraces and other related landforms along the sides of the stream valleys. The materials contained in these formations consist mainly of water-sorted, stratified, relatively clean sands and gravels.

Engineering Significance. These deposits, because of the characteristics of the materials composing them, generally offer the most optimum highway construction and maintenance conditions in this section of the state. The sands and gravels composing the deposits possess excellent internal drainage characteristics and during construction provide suitable trafficability with a minimum of delays during long periods of wet weather. Because the landform for this type of deposit generally consists of flat-topped terraces, this terrain class usually offers excellent locations for highways, involving light bedrock-free earthwork and providing stable subgrades, embankment foundations and cut slopes. These deposits also generally furnish excellent sources of common borrow and granular materials for foundation courses, select subgrades, and structure backfill. Generally, if proper design and construction considerations prevail, for highways located on this class of terrain maintenance problems and costs due to foundation conditions are relatively low.

Class 2—Glacial Till Deposits

Description. This class of deposits consists of materials laid down by the ice of the glacier, with a minimum of particle size sorting by melt waters. The landform generally consists of gently rounded, rolling, undulating hilly topography. The soil materials composing this type of deposit generally consist of unstratified, unsorted heterogeneous mixtures of sand, silt, rock fragments, clay and boulders.

Engineering Significance. This class of terrain, because of the characteristics of the materials involved and the topography of the landforms common to this type of formation, offers highway construction and maintenance conditions only slightly lower in quality than those offered by Class 1. As a matter of fact, this class of terrain covers wide areas of New York State and a large percentage of the highway mileage traverses areas of this class. Therefore, the class can be considered the average criterion for road construction and maintenance considerations throughout the state. The materials composing these deposits possess fair to good internal drainage characteristics. The landforms and topography for this type of deposit usually require only medium, relatively ledge-rock-free earthwork volumes, although greater than Class 1, and furnish stable subgrades, excellent embankment foundations and stable cut slopes, with proper treatment. Materials excavated from cuts in these deposits form excellent embankments if suitable equipment and procedures are utilized. These deposits offer good to excellent sources of common borrow, but are not sources of granular materials. Large boulders may in some cases present a problem in the excavation and placement of the materials in these deposits.

Generally, if proper design and construction considerations prevail, the number of maintenance problems and the maintenance costs due to subsurface conditions vary from low to medium for highways located on this class of terrain. From a broad viewpoint, it can therefore be said that construction and maintenance costs for highways traversing this class of terrain vary from low to medium, being in general only slightly higher than those prevailing for roads located on Class 1 deposits.

Class 3—Rough Rocky Lands

Description. Areas included in this class consist predominately of steep, rough rocky hills, ridges and mountains composed of hard crystalline ledge rock of igneous or metamorphic origin. In some places the glacier has deposited a relatively thin mantle or veneer of very bouldery glacial till on the rock surface; in other areas, the rock is exposed in the form of outcrops, cliffs, and crags.

Engineering Significance. Due to the topography, highway construction in these areas will involve considerable volumes of ledge rock excavation and its attendant additional cost in comparison with earth excavation. Although the cost of excavating rock is generally greater than that for soil, the volume necessary to make a cut in rock is less than that in soil because steeper cut slopes are possible. These areas generally offer stable highway subgrades, excellent embankment and bridge foundations and, if proper design features based on geologic studies are included, stable cut slopes. Because of the cost of excavation, these areas do not offer economical sources of common borrow.

Generally speaking, areas of this terrain class require considerably higher construction expenditures, due to the rough topography and rock excavation, than do areas in Classes 1 and 2. However, the resulting highway, if properly designed and constructed, presents only low to medium maintenance expenditures and problems from the standpoint of subsurface conditions.

Class 4A—Lacustrine Bottom Sediments, Silts, and Clays

Description. Glacial melt waters transporting rock fragments and derived particles of widely varying sizes flowed into the large glacial lakes existing at that time. When the melt water streams entered the still waters of the lakes, the larger particles, such as sands and gravels, settled out immediately in the form of deltas near the shore, but the finer fractions, including those of colloidal size, settled slowly to the bottom of the lake, forming thick deposits of varved silts and clays. When the water level was lowered and the lake diminished or receded, large areas of these deposits were exposed and today form lake plains.

The materials contained in these deposits consist entirely of wet, soft, plastic, highly compressible silts and clays of low shear strength and poor internal drainage extending to considerable depths below the surface of the ground.

The characteristics of the materials comprising these deposits make them very undesirable from a highway engineering viewpoint; consequently, these soils present severe highway design, construction, and maintenance problems. The surface topography of these deposits consists of a flat plain exhibiting poor surface drainage characteristics, the pattern of which is severely limited to a relatively few widely-spaced gullies.

Engineering Significance. These deposits have shallow water tables. With the possible exception of a thin desiccated surface layer, they consist of a wet, soft, plastic "clay" having moisture contents considerably exceeding optimum. The moisture content can be reduced only by exposure in thin layers to warm sunny weather for long periods of time. Consequently, contractors often encounter considerable difficulty in excavating, transporting, placing and properly compacting these materials, which, of course, raises costs. It is quite possible that bid prices on projects involving large quantities of this material reflect this difficulty. Obviously, these deposits of "clays" in general do not offer sources of suitable borrow. Because the topography of Class 4A is flat, with poor surface and internal drainage characteristics, it is desirable to locate the grade line of highways constructed over Class 4A areas a minimum of 4 ft above the surface of the ground, not only to provide a stable subgrade, but also to facilitate base and pavement construction and snow control. Thus, considerable quantities of borrow are necessary to achieve this optimum grade line location. This borrow must usually be hauled relatively long distances, because the adjacent clay material of the plains is not generally suitable for such purposes, especially during prevailing periods of adverse weather.

The following general considerations apply to the design and construction of a highway traversing Class 4A terrain:

1. Because of the low shear strengths of the wet, soft plastic "clays," most fills exceeding approximately 20 ft in height require extensive stabilizing berms. This, of course, requires additional earthwork, greater widths of right-of-way, and longer culverts.
2. Because of the high compressibility of the "clays," all fills founded on these materials will undergo considerable long-term post-construction settlements, the magnitude of which is proportional to the height of the fill. Most bridge foundations require deep pile foundations extending to compact material.
3. All cuts into deposits of these materials require slopes of 1 on 3 or flatter to attain reasonable stability. The slopes of the deeper cuts (though deep cuts in these deposits should be avoided if at all possible) may require extensive benching and blanketing with gravel to attain stability of the entire slope and to prevent sloughing. This not only requires additional excavation and gravel quantities,

but also a considerable additional width of right-of-way.

4. Cuts deeper than 5 to 10 ft involve considerable difficulties in excavating, transporting, placing and compacting the wet "clay" materials. In the past, depending on the prevailing weather and other factors, it has frequently been found necessary to waste these materials.

Class 4B—Marine Bottom Sediments, Silts, and Clays

Description. The areas comprising marine bottom sediment deposits are topographically a plain, in many places severely dissected by gullies. The origin, degree of dissection and characteristics of the materials comprising the class 4B deposits are somewhat different from those of Class 4A.

Class 4A areas are topographically a slightly undulating, only slightly dissected, glacial lake plain formed by the deposition of mostly fine-grained sediments in a now extinct fresh water lake. The glacial lake sediments, except in the case of some sandy deltas, are mostly varved silts and clays, each varve representing a period of deposition.

The marine bottom sediments occupy a marine plain that had its origin, postglacially, when an enlargement of the Gulf of St. Lawrence covered much of the St. Lawrence and Champlain Lowland Provinces. This salt water embayment received fine-grained sediments carried by streams emptying into the gulf. The deposits are not usually varved but somewhat stratified; because of deposition in saline waters the materials have a flocculent structure. These "clays" have a high sensitivity. Natural shifting of large volumes of these deposits is known to have occurred (*7*). In some locations the deposition is against steeply sloping bedrock. Severe dissection of the marine plain has occurred, so that in places the erosion gullies are very deep and extend below the present elevation of Lake Champlain, which now occupies the gully bottoms as a series of embayments.

Engineering Significance. All that has been said of Class 4A terrain applies to Class 4B. Criteria 1 through 4, stated under Class 4A, also govern highway design and construction on Class 4B, and to an even more restrictive extent. In addition, 4B terrain presents even more serious problems because of the high clay content of the material, the extreme sensitivity of the soil structure, and the unavailability of good borrow within reasonable haul distances of these deposits.

With the possible exception of Class 5 terrain, Class 4B terrain generally presents the most severe combination of highway design, construction and maintenance problems in the general area of this study.

It is obvious from the foregoing that Class 4B terrain presents abnormal highway design and construction problems and difficulties that are relatively expensive to eliminate or minimize. Consequently, from both economic and practical viewpoints such terrain should be avoided for major highway routes, if possible.

Class 4C—Bottom Sediments, Sands over Silts, and Clays on Flats

Description. These deposits are essentially 4A materials covered with a surface layer of fine sand of variable thickness. Class 4C deposits generally have a shallow water table in the sand.

Engineering Significance. In general, the surface sand layer is beneficial because it affords better trafficability to construction equipment than does the exposed "clay" of Class 4A. Also, the sand offers adjacent sources of borrow for locating the grade line the optimum distance above the surface of the plain. Criteria 1 through 4, mentioned under Class 4A, may or may not govern design and construction on Class 4C terrain, depending on the thickness of the surface sand at each particular location.

Class 5—Major Swamp and Muck Deposits

Description. These deposits, the results of the accumulation of decomposed vegetation, are very soft, highly compressible peats, organic silts, and clays.

Engineering Significance. Generally these materials, because of their undesirable characteristics, are totally unsuitable for the support of a major highway. Depending on local factors, material characteristics, and depths, these deposits must either be excavated to firm material prior to construction of embankments and replaced with granular material, or special foundation treatment methods must be employed to displace the unsuitable material in order to result in a roadway of satisfactory stability. In either case, construction costs are considerable, because earthwork quantities are doubled; that is, payment must be made for the removal of the unsuitable material, and further payment must be made for its replacement with suitable material plus double payment for installation and removal of the necessary surcharges. Traversing major swamp and muck deposits with first-class highways is generally very expensive; therefore, these deposits should be avoided if economically feasible.

RELATIVE COSTS PER MILE

At this point of the study an over-all picture was available in the form of the terrain class map, the engineering significance data, and terrain-mileage distribution for both lines. Although the terrain class boundaries had been delineated and the engineering significance of each class in relation to construction problems recognized, the relative effect of each terrain on earthwork construction costs was still unknown.

Consequently, it was necessary to estimate the effect of terrain conditions on the earthwork costs of a highway located on each terrain class. The next step was to investigate the actual earthwork construction costs of existing highways constructed on similar terrains, to similar standards as the Interstate System, during a relatively short period of time such that the effect of changes in price indices was minimized. The recently completed 400-mi main line of the New York State Thruway furnished such a model for study, inasmuch as it was constructed in a relatively short period of time and traversed all classes of terrain involved in the study, with the exception of Class 4B.

Appropriate sections of the Thruway were selected and each section was assigned to the terrain class it traversed for the major portion of its length. The cost of the earthwork per mile was then computed for each section and assigned to the terrain class involved, then averaged for each terrain class. Inasmuch as terrain Class 1 furnished the optimum conditions of all the classes in the study, the cost of earthwork per mile on Class 1 terrain was established as a base, with a relative earthwork terrain factor of 1.0. By the ratio of earthwork cost per mile between Classes 1 and 2, an earthwork terrain factor of 1.7 resulted for Class 2 terrain. The earthwork on Class 2 terrain, therefore, will cost 1.7 times the cost of earthwork on Class 1 terrain.

To estimate the earthwork terrain factor for Class 4B terrain, consisting of marine bottom sediments, silts and clays, an average earthwork volume per mile was computed for the typical gully-dissected topography of Class 4B terrain, utilizing the general design Criteria 1, 2, 3 and 4 stated previously.

Two critical areas were found to exist on the Champlain route. At Fort Ticonderoga Station the lowlands are fully occupied by an existing state highway and railroad yards, confined by a cliff on the west and the lake on the east. It would be necessary to accommodate these features in the location of an Interstate Highway in this vicinity. Also, at South Bay of Lake Champlain the crossing would involve a deep swamp at the lake inlet surrounded by high walls of crystalline rocks. Both areas, therefore, were designated as Class 3X terrain—as requiring additional expenditures for earthwork, over and above Class 3, or rough rocky lands.

After the relative earthwork terrain factors were established for each terrain class, the mileage of each line on each class was multiplied by the factor for

TABLE 1

RELATIVE EARTHWORK TERRAIN COSTS

Terrain Class	Description	Earthwork Terrain Factor, F	Adirondack Route		Champlain Route	
			Mileage, M	$M \times F$	Mileage, M	$M \times F$
1	Granular outwash deposits	1.0	27.5	27.5	1.0	1.0
2	Glacial till deposits	1.7	8.1	13.8	Negl.	—
3	Rough rocky lands	4.3	45.4	195.2	24.7	106.2
3X	Class 3, restricted	6.7	Negl.	—	3.6	24.1
4A	Lacustrine bottom sediments	1.5	Negl.	—	36.8	55.2
4B	Marine bottom sediments	3.5	Negl.	—	16.1	56.4
4C	Bottom sediments, sands, clays	1.0	9.1	9.1	7.3	7.3
5	Major swamp and muck deposits	7.7	1.0	7.7	2.7	20.8
	Total		91.1	253.3	92.2	271.0

that class, and the results added to yield the relative earthwork terrain total for each of the lines. The results of this analysis are given in Table 1.

LAND VALUES AND LAND USE

Land use is directly related to terrain conditions. Land use is also a consideration in estimating land values for right-of-way acquisition purposes. In general, the Champlain route traverses for a considerable portion of its length lands that are relatively more adaptable and useful for agricultural purposes than are the sparsely settled areas traversed by the Adirondack route. This situation is not only the result of terrain conditions, but is also due to the influence of the more favorable climatic conditions along the shores of Lake Champlain.

For approximately 57.4 percent of its length, the Champlain route traverses Class 4A and 4B terrains, the only easily tillable soils in the general area. The remainder of the line traverses terrains that can generally be classed as non-agricultural soils.

In contrast, the Adirondack route traverses lands that are not agricultural. The line traverses a mountainous area, the soils of which are generally droughty, infertile and unproductive, supporting only forest growth.

Consequently, it can be estimated that approximately 52.9 mi, or 57.4 percent, of the Champlain route traverses lands that have a value per acre for agricultural purposes of from 10 to 20 times the value of the lands traversed by the Adirondack route. This consideration was not included in the cost analysis, but the aspects of agricultural land use, though intangible, may exert considerable influence in route selection.

RESULTS

Table 1 indicates that the relative earthwork terrain total for the Adirondack route is 253.3, and the total for the Champlain route is 271.0. Therefore, it is estimated that the cost of earthwork for a highway built to Interstate System standards along the Champlain route will be approximately 7 percent more than the cost of the earthwork for a similar highway constructed along the Adirondack route.

Although this difference in estimated earthwork costs may seem somewhat inconsequential at first glance, its significance becomes apparent when it is realized that a so-called "water level route" in a lowland physiographic province, which would seem to offer optimum location for a highway, actually would involve earthwork costs greater than those of a parallel line located in a mountainous upland physiographic province.

REMARKS

The team assigned to this study, composed of a soils engineer, an engineering geologist, and a soil scientist, required approximately three weeks to complete the work, including the preparation of the report. The relatively short time required to complete the work indicates the reconnaissance nature of this type of operation. The greatest value of terrain appraisal to highway engineering exists in the very preliminary phases of location studies, not only serving as a guide to economical location, but also indicating the nature and magnitude of the earthwork problems involved.

To obtain reasonably accurate, effective, and practical results from terrain appraisal operations, it is essential that the personnel assigned be thoroughly experienced in the area and in actual highway design and construction problems of the terrains involved. Without this, it is quite possible that the results of such operations may be meaningless or misleading to location and planning engineers.

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