photographic processing is likely to remain of great importance for surveys in developing countries.

Despite the high quality of Landsat photographic images, Landsat data can only be fully used when images are generated from the digital data held on computer tapes. The resolution of these images is limited to the 80-m pixel size of the scanner, but they convey a large amount of spectral (color) information about the terrain. Developments are taking place in interactive viewing systems away from the concept of large, sophisticated machines toward smaller, simpler systems, which often consist of assemblies of standard components linked to a microcomputer that can perform functions similar to those of a large machine but concede some limitations of speed and flexibility.

With greater international interest being shown in the development of Third World countries, the role of remote sensing to highway engineering, as with all natural resource studies of terrain, will increase in importance. Refinements in sensing systems will enhance our ability to detect subtle changes in terrain conditions, and improvements in data handling will permit more sensitive interpretations to be made.

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REFERENCES

1. I.D. Hill, ed. Land Resources of Central Nigeria. Land Resources Development Centre, Tolworth, Land Resources Study 29, 7 Volumes, 1978-1981.
2. R.G. Robbins, ed. Lands of the Ramu-Madang Area, Papua New Guinea. Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia, Land Res. Series 37, 1976.
3. R. Webster and P.H.T. Beckett. Terrain Classification and Evaluation Using Air Photography: A Review of Recent Work at Oxford. Photogrammetria, Vol. 26, 1970, pp. 51-75.
4. M.W. Witczak. Relationships Between Physiographic Units and Highway Design Factors. NCHRP, Rept. 132, 1972.
5. D.R. Lueder. Aerial Photographic Interpretation. McGraw-Hill, New York, 1959.
6. M.J. Dumbleton and G. West. Air Photography Interpretation for Road Engineers in Britain. Road Research Laboratory, Ministry of Transport, Crowthorne, Berkshire, England, RRL Rept. LR 369, 1970.
7. W. Heath. Inexpensive Aerial Photography for Highway Engineering and Traffic Studies. Transport and Road Research Laboratory, Department of the Environment and Department of Transport, Crowthorne, Berkshire, England, TRRL Rept. SR 632, 1980.

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Terrain Analysis for Transportation Systems in British Columbia

TERJE VOLD

A terrain classification system was developed in British Columbia and accepted nationally in Canada. The mapping system emphasizes features that can be interpreted from aerial photographs and readily verified by field checking. Genetic materials classified according to their mode of deposition form the substance of the terrain map unit. The material's texture, surface expression, and the presence of any geologic processes of modification are additional components of the system. This system also provides the framework for much of the soil mapping in the province, since soils have inherited many properties from these parent materials. A manual on terrain interpretations for roads and linear developments that involve shallow excavations has been prepared. The manual is designed for planners and indicates how terrain information may be used to assess capability for these transportation-related uses. Physical land constraints and natural hazards that affect transportation systems are explained. Interpretive maps that show the distribution of natural hazards and physical land constraints for development can be prepared from base terrain and soil maps. These maps can be of use to planners in assessing alternative transportation corridors and in anticipating potential trouble spots before construction has commenced.

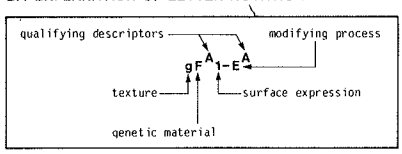
Terrain analysis refers to the inventory and assessment of the physical conditions of land. This is a general term that includes both geological and pedological (soil) evaluations. There are three distinct, although somewhat interrelated, groups of scientists who study the physical nature of land: geologists, soil scientists (pedologists), and soil engineers (geotechnical engineers). Each of these professions focus their work on a slightly different aspect of the earth's surface.

A terrain classification system was developed in British Columbia (1) in 1976 and accepted nationally in Canada in 1978 by soil surveyors (2); it is also widely used by most consultants in British Columbia (3). The system encourages a common approach to terrain inventory and provides standard nomenclature that has improved communications between earth scientists (4). This system also provides the framework for much of the soil mapping in the province and elsewhere in Canada, since soils have inherited many properties from their parent materials.

The terrain classification system was developed for reconnaissance mapping surveys (scales of 1:50 000 to 1:100 000) by government (5,6) but has also been applied for detailed surveys (scales of 1:20 000) by consultants (3). The system emphasizes features that can be interpreted from aerial photographs and readily verified by field checking, thereby enabling coverage of approximately 2590 km^2/mapper/year at a scale of 1:50 000. Genetic materials classified according to their mode of deposition form the basis of the terrain map unit.

Figure 1. Terrain map symbols.

B.1 EXPLANATION OF LETTER NOTATION



B.2 GENETIC MATERIALS

LETTER SYMBOL	NAME (PROCESS STATUS[1])
A	anthropogenic (A)
C	colluvial (A)
E	eolian (A)
F	fluvial (I)
F^G	fluvioglacial (I)
I	ice (A)
L	lacustrine (I)
L^G	glaciolacustrine (I)
M	morainal (I)
O	organic
O^B	organic (bog) (A)
O^F	organic (fen) (A)
O^S	organic (swamp) (A)
R	bedrock (I)
U	undifferentiated (I)

B.3 TEXTURE

LETTER SYMBOL	NAME
b	bouldery
g	gravelly
s	sandy
ɨ	silty
c	clayey
d	diamicton
r	rubbly
a	blocky

B.4 SURFACE EXPRESSION

LETTER SYMBOL	NAME
a	apron
b	blanket
f	fan
h	hummocky
l	level
m	rolling
r	ridged
s	steep
t	terraced
u	undulating

B.5 MODIFYING PROCESSES

LETTER SYMBOL	NAME (PROCESS STATUS[1])
A	avalanched (A)
C	cryoturbated (A)
D	deflated (A)
E	channelled (I)
E^G	channelled by glacial meltwater(I)
F	failing (A)
G	frost shattered (A)
H	kettled (I)
K	karst (A)
N	nivated (A)
P	piping (A)
S	soliflucted (A)

B.6 QUALIFYING DESCRIPTORS

LETTER SYMBOL	NAME
G	glacial
B,F,S	bog, fen, swamp
A, I	active, inactive (process status descriptors)

B.7 COMPOSITE UNITS

	.	the components on either side of this symbol are approximately equal.
	/	the component in front of the symbol is more extensive than the one that follows.
	//	the component in front of the symbol is considerably more extensive than the one that follows.
e.g.	Mb//R	Mb is considerably more extensive than R.
	Mb//R.Cv	Mb is considerably more extensive than R; R and Cv are of roughly equal extent.
	Mb/R//Cv	R is less extensive than Mb; Cv is considerably less than R.

B.8 ON-SITE SYMBOLS

drumlin, drumlinoid ridge
escarpment
cirque
kettle

[1] See Qualifying Descriptors for definition of Process Status.

Figure 2. Terrain map.

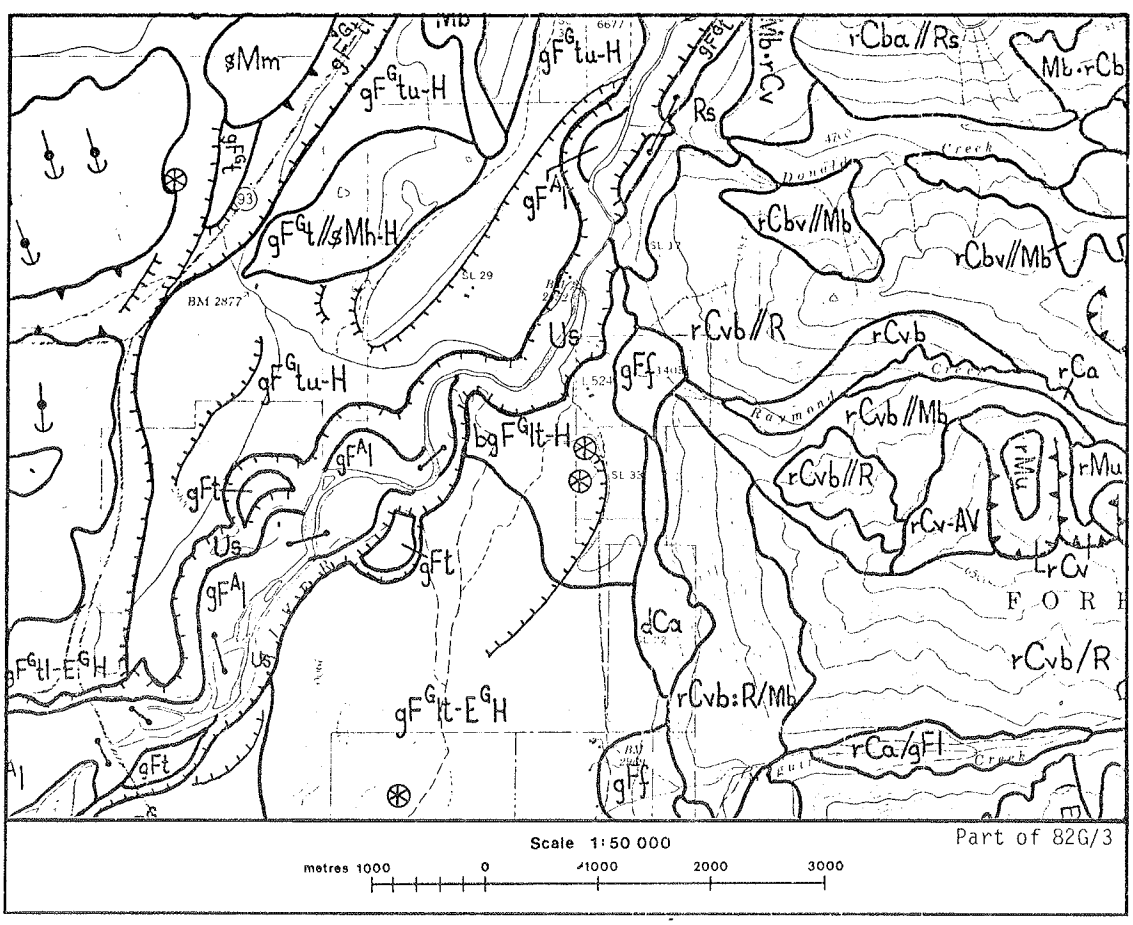


Table 1. Physical requirements and limitations that determine ease of excavation.

Optimal Conditions	Potentially Troublesome Conditions
Depth to water table and impervious layer more than 3 m	Imperfect to very poorly drained soils; water table or impervious layer within 3 m of surface
Bedrock more than 3 m below the ground surface	Bedrock within 3 m of the surface
Slopes less than 10 percent	Depending on the size of excavation, slopes in excess of 20-25 percent; undulating topography; depressional areas
Cohesive or cemented materials that have good sidewall stability; moderately coarse to fine-grained sands with a binding matrix	Plastic silts and clays (CH, MH[a]); gravels (GW, GP), and coarse sand (SW, SP) with no cohesive binder; organic sediments (OL, OH, Pt); highly indurated materials (e.g., basal till or cemented gravels); large proportion of boulders or a few very large boulders
No restrictive conditions within 3 m of surface	Bedrock, water table, or impervious horizon within 3 m of surface; a confined aquifer below an impermeable surface material Permafrost; periglacial processes

[a]CH, MH, and other alphanumeric symbols represent unified soil groups.

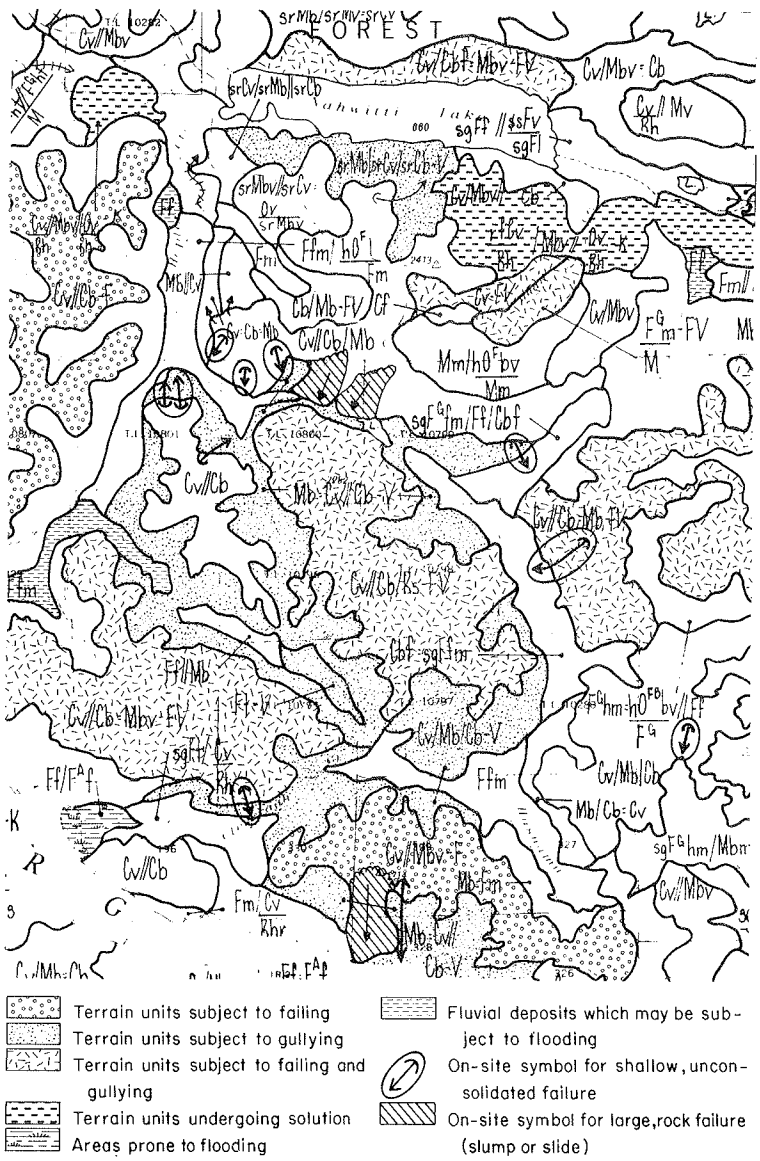
The material's texture, surface expression, and the processes of modification are additional components of the system (see Figure 1). A portion of a terrain map is shown in Figure 2 (6).

The symbols on a terrain map are descriptive, and they are located so that a lower-case textural symbol comes first, followed by an upper-case symbol that denotes material type. Common genetic materials in glaciated environments include moraine, colluvium, fluvial, lacustrine, and organic deposits. Following the material symbol is a lower-case symbol that denotes its surface expression; for example, whether the terrain is fan-shaped, hummocky, level, ridged, steep, or terraced. Blanket is an expression used for deposits thicker than 1 m, and veneer is used for those less than 1 m when materials conform to the topography of the underlying deposit (e.g., bedrock).

Any modifying processes that are affecting a terrain unit are represented by an upper-case symbol that follows a dash. For example, areas that are subject to snow avalanching, failing (landslides), frost churning, channeling, and gullying are shown.

Terrain and related soil inventory data at a reconnaissance scale of 1:50 000 exist for most of

Figure 3. Geological hazards map.



British Columbia. New transportation systems are being planned for remote areas; for example, an infrastructure of new highways, railways, and town sites is being examined by government in order to support the development of coal-bearing regions of the province (7).

In order to bridge the gap between the inventory terrain and soil maps and their utility for transportation planning, a manual on terrain interpretations for roads, sources of sand and gravel, linear developments that involve shallow excavations, and related concerns has been developed (8). The manual is designed to indicate to planners how terrain information may be used to assess capability for these transportation-related uses.

Natural hazards and physical land constraints that affect transportation systems are explained in the manual. At a reconnaissance scale, hazards such as flooding, snow avalanching, and the presence of active failures can be derived from the terrain maps.

Physical characteristics that commonly affect the ease and cost of land development include characteristics and behavior of surficial materials, hydrologic conditions, stratigraphic conditions, topography, and bedrock conditions. The manual indicates which terrain conditions are optimal and potentially troublesome for development. As an example, Table 1 (8) summarizes physical requirements and limitations that determine ease of excavation.

Interviews with land use planners and engineers in British Columbia were recently conducted to determine their preferences in interpreting engineering uses of soil and related terrain information (9). Land use planners generally want terrain scientists to provide interpretive ratings based on physical constraints to development. Engineers, on the other hand, were most interested in the base maps and data alone and many would not use the interpretations. The interviews indicated that planners and engineers are two distinct users of terrain information.

Planners do not generally have expertise in earth sciences and thus want terrain scientists to summarize their knowledge about particular terrain or soil units by indicating the degree of constraints to use in terms like slight, moderate, or severe. Most engineers felt that interpretations would be misconstrued as recommendations and incorrectly used for making on-site decisions and thus should not be provided. A few engineers perceived the use of interpretations for small-scale planning purposes, which could alert the designer to future site problems or direct engineers to areas that require more detailed investigation.

Interpretive maps that show natural hazards [see Figure 3 (5)] and physical land constraints for development can be derived from terrain and soil maps (10). These maps are useful to planners in assessing alternative transportation corridors, in determining general benefit/cost ratios of particular route locations, and in anticipating potential trouble spots before construction has commenced. Terrain or soil maps, of course, are available for those engineers who do not need interpretive maps.

REFERENCES

1. Terrain Classification System. E.L.U.C. Secretariat, British Columbia Ministry of Environment, Victoria, British Columbia, Canada, 1976, 54 pp.
2. The Canadian System of Soil Classification. Canada Soil Survey Committee, Agriculture Canada, Ottawa, Ontario, Canada, Pub. 1646, 1979, 164 pp.
3. H.W. Nasmith and R.F. Gerath. Geotechnical Air Photo Interpretation: Application of the E.L.U.C. Terrain Classification System to Engineering Projects. British Columbia Professional Engineer, Aug. 1979.
4. M. Walmsley, G. Utzig, T. Vold, D. Moon, and J. van Barneveld, eds. Describing Ecosystems in the Field. British Columbia Ministries of Environment and Forests, Victoria, British Columbia, Canada, RAB Tech. Paper 2, 1980, 224 pp.
5. D.E. Howes. Terrain Inventory and Geological Hazards: Northern Vancouver Island. British Columbia Ministry of Environment, Victoria, British Columbia, Canada, APD Bull. 5, 1981, 105 pp.
6. J. Ryder. Biophysical Resources of the East Kootenay Area: Terrain. British Columbia Ministry of Environment, Victoria, British Columbia, Canada, APD Bull. 7, 1981, 152 pp.
7. Northeast Coal Study--Preliminary Environmental Report, 1977-1978. Environment and Land Use Subcommittee on Northeast Coal Development, British Columbia Ministry of Environment, Victoria, British Columbia, Canada, 1978, 173 pp.
8. D. Maynard. Terrain Capability for Residential Settlements: Summary Report. British Columbia Ministry of Environment, Victoria, British Columbia, Canada, 1979, 61 pp.
9. T. Vold, P. Daykin, and D. Moon. Comparison of Two Alternative Methods for Interpreting Engineering Uses of Soils. Paper presented to Expert Committee on Soil Survey, Ottawa, Ontario, Canada, March 2-6, 1980.
10. T. Vold. Resource Folio for Bullmoose Creek (Map Sheet 93P/3). British Columbia Ministry of Environment, Victoria, British Columbia, Canada, 1978, 20 pp.

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