CHAPTER SEVEN
SUMMARY OF CONSTRAINT EVALUATIONS

Eleven of the thirteen properties discussed in Chapter 6 are summarized in Table 2 where the range assigned to each of the four constraint classes is indicated for each property. Soil chemistry and climatic influences do not have definitive limits and so are not included. The table provides a quick reference to the constraints for effluent absorption imposed by soil properties.

7.1 EVALUATING SOIL CONSTRAINTS

To evaluate the constraints for effluent absorption caused by individual soil properties, determine under which constraint class in Table 2 the value or class of the property occurs. For example, a percolation rate of 10 min/2.54 cm falls in the 2.5-15 min/2.54 cm range and therefore is a slight constraint. Similarily, a 25% slope is in the 15-30% range, and is therefore a severe constraint and an S5 stoniness class is a very severe constraint.

In evaluating constraints for effluent absorption of the soil as a whole, it is first necessary to determine the constraint classes for all of the soil properties indicated in Table 2. The soil can then be evaluated as having all of the moderate, severe and very severe constraints indicated by this property evaluation. For example, a soil inspection may indicate the following information: percolation rate of 8 min/2.54 cm, 20% slope, depth to bedrock of 200 cm, no restrictive layers, no groundwater within 200 cm, no flooding, rapidly drained, 65% coarse fragments, stoniness class 3, sandy loam texture, and subangular blocky structure. Individual evaluation of these properties indicates slight constraints due to percolation rate, depth to bedrock, depth to restrictive layers, depth to groundwater, flooding, texture, and structure; moderate constraints due to drainage and stoniness; and severe constraints because of topography and coarse fragment content. This soil is therefore

Table 2. Soil Constraints for Subsurface Septic Tank Effluent Absorption

CONSTRAINT	CONSTRAINT CLASS [1]			
Soil or Site Property[2]	Slight (1)	Moderate (2)	Severe (3)	Very Severe (4)
Percolation Test Rate (Permeability) (B)	2.5 - 15 min/ 2.54 cm	15-30 min/2.54 cm or 1.0 - 2.5 min/ 2.54 cm	30-60 min/ 2.54 cm or <1.0 min/2.54 cm	>60 min/ 2.54 cm
Topography (T)	0-9% slopes	10-15% slopes	15-30% slopes	>30% slopes
Depth to Bedrock (R)	>200 cm	120-200 cm	60-120 cm	<60 cm
Depth to Other Restrictive Layers (D)	>200 cm	120-200 cm	60-120 cm	<60 cm
Depth to Groundwater (X)	>200 cm	120-200 cm	60-120 cm	<60 cm
Flooding (I)	none	rare (<1 in 200 year interval)	occasional (between 1 in 20 and 1 in 200 year interval)	frequent (>1 in 20 year interval)
Soil Drainage (W)	well	moderately well, rapid	imperfect	poor, very poor
Coarse Fragment Content (G)	0-20%	20-50%	>50%	-
Stoniness Class (P)	S0-S2 (0-3% stones)	S3 (3-15% stones)	S4 (15-50% stones)	S5 (>50% stones)
Soil Texture[3] (S)	sandy loam, loam, silt loam	silt, sandy clay loam, silty clay loam, clay loam, loamy sand	silty clay, clay, sandy clay, heavy clay	-
Soil Structure[3] (C)	granular, subangular blocky	blocky, columnar, platy, prismatic	massive, single grained	-
Soil Chemistry	See discussion on pages 37 to 39.			
Climatic Influences	See discussion on pages 39 to 40.			

1. See pages 12 to 14 for definitions of constraint classes. Abbreviations for constraint classes are given in brackets.

2. See Chapter 6 for complete discussion of the effects on use of each factor and rationale behind the ratings. Abbreviations for properties are given in brackets.

3. Criteria not completely definitive. See also discussion on pages 34 to 37.

evaluated as having severe constraints due to topography and coarse fragment content and moderate constraints due to drainage and stoniness. The appropriate sections of Chapter 6 could be referred to for discussions of the implications of these moderate and severe constraints.

The basic procedure is the same whether using site-specific information (as in the above example) or using information from soil and terrain maps and reports. It is important to note, however, that the precision and reliability of constraint evaluations change as the level of detail and the reliability of the basic information changes. Evaluations based on site-specific information are the most reliable because each property is accurately determined and evaluated. Evaluations based on map and report information may not be precise because ranges in some properties may correspond to more than one constraint class. For example, the slope may vary between 10 and 30% in a map polygon and this range corresponds to both moderate and severe constraints. Also, soil and/or terrain descriptions may not always adequately define all of the properties which are of interest and they must then be inferred or omitted from the evaluations. Shortcommings such as these do not negate the value of making constraint evaluations based on maps and reports; they simply substantiate the need for final on-site investigation after the preliminary evaluations based on map and report information are made.

It should be noted that these constraint evaluations only indicate the nature and severity of problems related to septic tank effluent absorption that are associated with each soil. Value judgements as to the relative suitability of one soil versus another are left to the user, taking into account the implications of each constraining property (Chapter 6) and knowledge of local conditions. Methods of evaluating soil suitabilities are discussed further in Chapter 8.

7.2 PRESENTATION OF CONSTRAINT RATINGS

When several soils are being evaluated, the results are usually presented in either tabular or map form. Both formats have been used in British

Columbia. The nature of the study usually determines which approach is most suitable.

7.2.1 Tabular Presentation

Soil constraint evaluations are commonly presented in tabular form, particularly in general purpose studies where constraints or limitations for a number of different land uses are considered. Tables are easier to include in reports and are less time consuming to prepare than maps. Therefore, it is common to have one map showing the areal extent of soil map units and a series of tables, one for each type of interpretation (e.g. soil constraints for effluent absorption fields), showing the constraints of the soils in those map units. This approach, illustrated in Figure 3 and Tables 3 and 4, is particularly suited to presenting the results of evaluations which are based on existing maps since no additional map preparation is required.

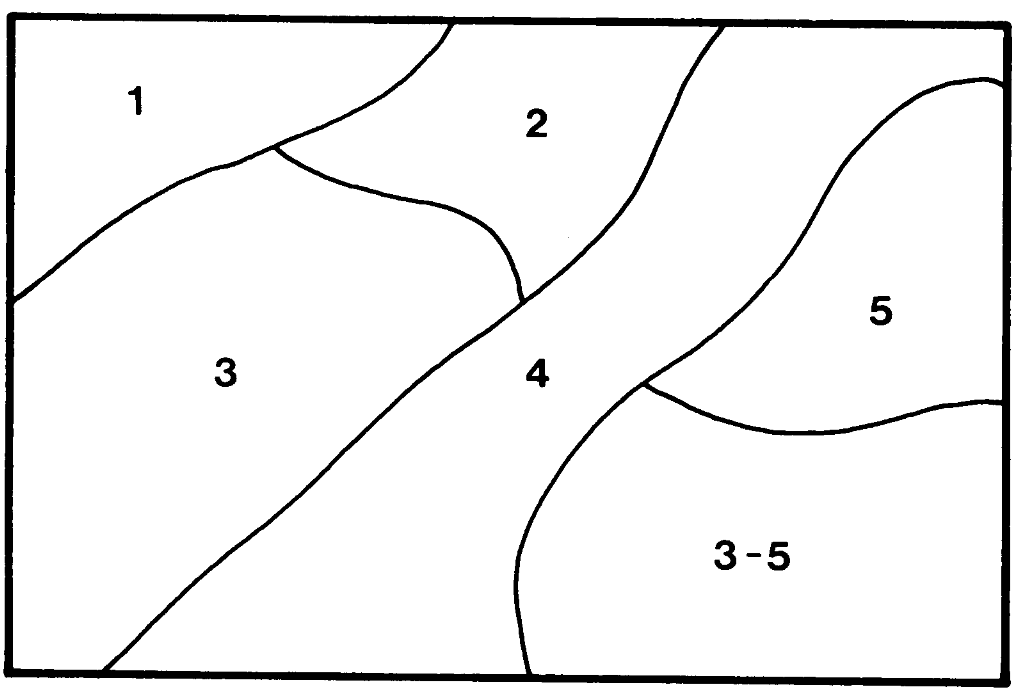

Figure 3. Example of soil map.

Table 3. Relevant Properties of Soils Shown on Map in Figure 3

SOIL PROPERTIES											
Map Symbol	Percolation Rate (min/2.54 cm)	Topography (Slope)	Depth to Bedrock (cm)	Depth to Restrictive Layers (cm)	Depth to Groundwater (cm)	Flooding Frequency (Years)	Soil Drainage	Coarse Fragment Content	Stoniness Class	Soil Texture	Soil Structure
1	10	40%	50	not present	not present	no flooding	well	75%	S2	sandy loam	subangular blocky
2	5	12%	150	not present	> 200	no flooding	well	40%	S2	loam	subangular blocky
3	25	5%	> 200	not present	> 200	no flooding	well	10%	S1	silt loam	subangular blocky
4	10	5%	> 200	not present	> 200	no flooding	well	5%	S1	loam	subangular blocky
5	15	2%	> 200	not present	75	10	imperfect	5%	S0	silt loam	subangular blocky

Table 4. Example of Constraint Ratings in Tabular Form

Soil	Constraint Class and Properties	Symbols
1	very severe - topography - depth to bedrock severe - coarse fragment content	4TR 3G
2	moderate - topography - depth to bedrock - coarse fragment content	2TRG
3	moderate - permeability	2B
4	slight	1
5	very severe - flooding severe - depth to water table - drainage	4I 3XW

Each of the soils (numbered 1 to 5) shown in Figure 3 is described in terms of its relevant soil characteristics in Table 3. The results of the constraint evaluations based on these properties are indicated in Table 4. It is preferable to show all of the constraining properties (other than slight constraints) because the implications of the constraints are cumulative. Properties not indicated can then be assumed to be slight constraints. Constraints may be written out in full or abbreviated as indicated. Symbols for each constraint class and constraining property are given in Table 2.

It should be noted that one map polygon on the example map is designated as 3-5. This indicates that this polygon contains both soil 3 and soil 5. Accordingly, portions of the area have constraints corresponding to soil 3 and the remainder has constraints corresponding to soil 5. Complexes such as this are common on some soil and terrain maps due to scale limitations (the individual soils occupy such small discrete areas or are so intermixed that they cannot be shown separately on the map). More detailed mapping or on-site investigations are needed to determine more precisely the areal extent of the constraints in this map polygon.

7.2.2 Presentation on Maps

Map presentations of constraint evaluations often are easier to use than tabular formats because the constraints are indicated directly in the map polygons. There is then no need to cross-reference between tables and a map. This approach is preferred when interpretations are only being made for one or a few uses so that the resulting number of maps is manageable. An example of a map presentation of constraint evaluations is given in Figure 4. The map polygons and ratings correspond to those of Figure 3 and Table 4, but the ratings are now shown directly in the polygons. <u>For simplicity of presentation, only the constraint class of the most severely constraining property(s) is usually shown and the number of constraining properties</u>

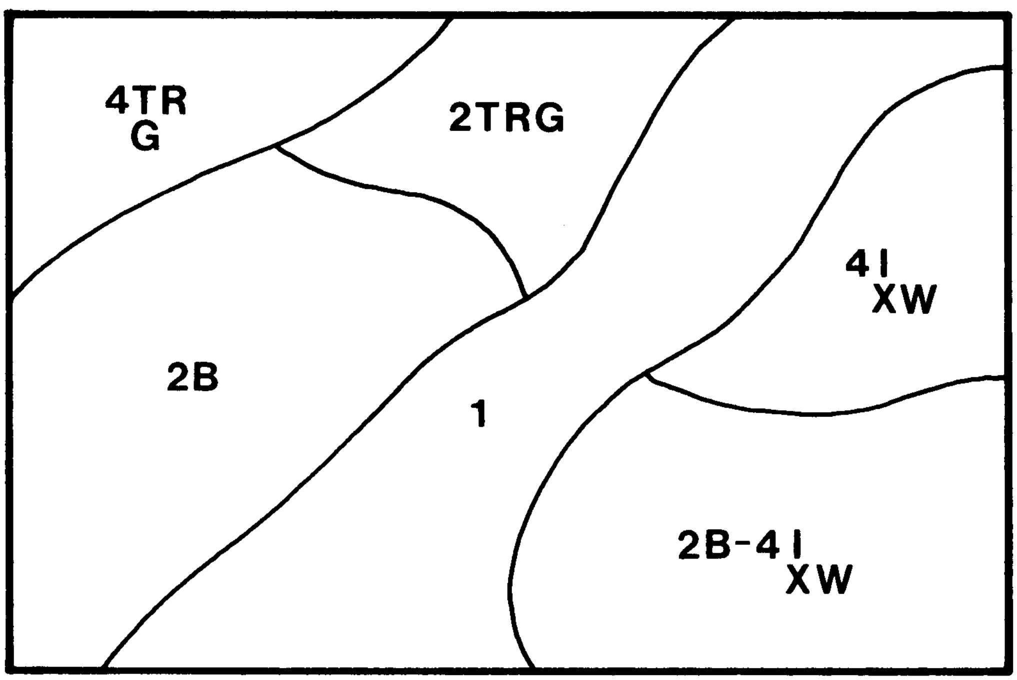

Figure 4. Example of constraint map.

indicated for each constraint class symbol is limited to a maximum of three. Constraints at a less severely constraining level may be shown if three constraints are not already indicated. Such a lesser constraint(s) is shown on a lower line. Thus for Soil 1, the severe constraint due to coarse fragment content is indicated on the lower line. Similarly for Soil 5, severe constraints due to depth to water table and drainage are indicated along with the very severe constraint due to flooding. The map polygon containing the complex of two soils contains a two component symbol indicating the presence of two soils with differing constraints. A decile on the line above the constraining property symbols may be used to indicate proportions of each of the soils.

CHAPTER EIGHT
SOIL SUITABILITY

The publication to this point has discussed and shown methods of presenting constraint ratings for individual soil properties that affect successful effluent absorption. These ratings indicate the nature and severity of problems related to effluent absorption which are associated with soil properties, but do not make direct judgements as to the overall suitability of one soil in relation to another. It is often necessary to make such judgements, however, especially when allocating areas to different uses such as in the planning process.

8.1 SUITABILITY BASED ON THE MOST CONSTRAINING PROPERTIES

The simplest rating of soil suitability is on the basis of the most severely constraining soil properties. A soil with all properties at the slightly constraining level has good suitability, a soil with one or more moderately constraining properties and the remainder slightly constraining has medium suitability, a soil with one or more severely constraining properties has poor suitability and a soil with one or more very severely constraining properties has very poor suitability. Constraining properties still should be indicated for the suitability rating so that comparisons can be made among soils in the same suitability class (e.g. comparing a soil with medium suitability due to moderately constraining topography with a soil having medium suitability due to both moderately constraining drainage and flood hazard). This approach differs very little from simply presenting constraint ratings as described in Chapter 7 and has been widely used in the past by Surveys and Resource Mapping Branch personnel and others. Presentation formats are similar to those described in Sections 7.2.1 and 7.2.2.

8.2 SUITABILITY BASED ON NUMERICALLY WEIGHTED CONSTRAINTS

It is readily apparent that the most suitable soils are those in which all of the soil properties fall into the ranges corresponding to slight constraints. It is also apparent that the more properties a soil has that fall under moderate, severe or very severe constraints, the less suitable that soil is for effluent absorption. Accordingly, a second method of rating soil suitability assigns a numerical value to each constraint class. Each soil property receives the value of the constraint class that it falls under and the numerical values are then totaled for each soil. For example, numerical values of 0, 1, 2 and 4 can be assigned to slight, moderate, severe and very severe constraint classes, respectively. Using this approach, the five soils used as examples in Tables 3 and 4 have scores of 11, 3, 1, 0 and 8, respectively. These scores can be directly used to the rank soils as to their relative suitability, or the range of scores can be arbitrarily divided into three, four, five or as many suitability groups as desirable.

The numerical values of 0, 1, 2 and 4 are suggestions only and can be modified to suit the needs of any particular study. The values suggested imply that two moderately constraining properties are equal to one severely constraining property and that two severely constraining properties are equal to one very severely constraining property. These numbers also imply that a constraint value for one soil property is equivalent to a similar constraint value for another soil property.

8.3 SOIL SUITABILITY BASED ON UNEQUAL NUMERICALLY WEIGHED CONSTRAINTS

A variation of the above approach is to assign different numerical values to different properties within the same constraint class. This allows greater flexibility for taking into account local objectives, conditions and costs. For example, constraints due to depth to groundwater could receive different numerical ratings depending upon whether the area is served by community water systems or whether wells are used. Similarly, constraints due to high percolation rates (low permeability) could receive different numerical ratings depending upon whether lots can be made large enough to accommodate alternate absorption fields or whether prohibitive land costs result in minimal lot sizes. Assigning varying numerical values to constraints requires knowledge of local objectives and conditions. It is therefore impractical to suggest such values on a province-wide basis. The soil potential system which has been introduced in the United States is similar to this variable weighting approach and is being applied on a county by county basis (Guthrie and Latshaw, 1980). Presentation of results can be in tabular or map form similar to the formats discussed in Sections 7.2.1 and 7.2.2 above.

8.4 OTHER SUITABILITY EVALUATIONS

Several other soil suitability evaluation and/or presentation approaches can also be used, particularly if visual impact in presentation is desired. The first approach is to overlay single factor (constraint) transparencies with shades of gray corresponding to degrees of constraint imposed by that factor. The darkest map areas in composite then represent land areas with poorest suitability. Another similar approach is using varying densities of cross-hatching or other screening. Coloured maps with green, yellow and red for good, medium and poor suitabilities can also be useful for presentation.

The objectives of the study will determine whether it is sufficient to simply indicate the nature and severity of individual soil property constraints or whether it is necessary to determine suitabilities as described previously. Constraint evaluations are probably most useful when examining problems in specific areas while suitability ratings are perhaps more useful when determining relative suitability over large areas.

CHAPTER NINE
FURTHER WORK AND RESEARCH REQUIRED

This manual briefly presents the principles of soil behavior in relation to sub-surface septic tank effluent disposal and applies them to specific soil properties so that soils can be evaluated with regard to their constraints for conventional septic tank effluent disposal systems. No research was conducted as background to the preparation of this manual and many of the references cited do not present specific research results to substantiate their interpretations. The class limits as presented are therefore somewhat arbitrary and can perhaps be further refined if more studies of absorption field performance under various soil conditions are conducted.

This manual is primarily concerned with soil constraints for conventional absorption field systems. Much of British Columbia has soils with severe and very severe constraints for conventional systems because of a variety of factors. There is, however, increasing pressure for new housing development on these lands and a need to develop alternate systems to satisfactorily overcome these constraints (other than relying on costly sewer systems). Development of satisfactory alternate systems to overcome specific constraints can help to alleviate the wastewater disposal problems on lands that are currently poorly suited for septic tank effluent disposal.

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APPENDIX A
SOIL PERVIOUSNESS CLASSES
(from Walmsley *et al.*, 1980)

Soil perviousness classes refer to the potential of a soil to transmit water internally, and are inferred from soil characteristics such as structure, texture, porosity, cracks, organic matter content, and shrink-swell properties. They are closely related to measures of permeability, percolation rate, and infiltration rate, but these are reserved for actual measurements using standard techniques. Perviousness applies to the whole soil profile. Because of this, the perviousness class is determined by the least permeable layer in the soil "control section" (Canada Soil Survey Committee, 1978, p. 22). It is important to distinguish between soil drainage and perviousness. For example, a rapidly pervious soils could be receiving excessive seepage and thus be poorly drained.

a. Rapidly pervious - the capacity to transmit water vertically is so great that the soil will remain wet for no more than a few hours after thorough wetting. The horizons and soils have large and continuous or connecting pores and cracks that do not close with wetting.

b. Moderately pervious - the capacity to transmit water vertically is great enough that the soil will remain saturated for no more than a few days after thorough saturation. Most moderately pervious soils hold relatively large amounts of water against the force of gravity, and are considered good, physically, for rooting and supplying water to plants. Soil horizons may be granular, blocky, weakly platy or massive (but porous) if continuous conducting pores or cracks are present which do not close with wetting.

c. Slowly pervious - the potential to transmit water vertically is so slow that the horizon or the soil will remain saturated for a period of a week or more after thorough wetting. The soil may be massive, blocky or platy, but connecting pores that conduct water when the soil is wet are few, and cracks or spaces among peds that may be present when the soil is dry, close with wetting. Even in positions accessible to plant roots, roots are usually few or absent. When present, roots are localized along cracks.

APPENDIX B

STANDARD PERCOLATION TEST

(from Government of British Columbia, 1975)

(i) Percolation test holes shall be made at points and elevations selected as typical in the area of the proposed absorption field.

(ii) One of these test holes shall be dug at each end of the area of the absorption field. Further holes may be required, depending upon the nature of the soil, the results of the first tests and the size of the proposed absorption field.

(iii) Test holes shall be 25 cm (12 in)square and excavated to the proposed depth of the absorption field.

(iv) To make the percolation test more accurate, any smeared soil should be removed from the walls of the test holes.

(v) If the soil contains considerable amounts of silt and/or clay, the test holes must be presoaked before proceeding with the test. Presoaking is accomplished by keeping the hole filled with water for four hours or more. Proceed with the test immediately after presoaking.

(vi) To undertake the test, fill the test hole with water. When the water level is 12.5 cm (5 in) or less from the bottom of the hole, refill the hole to the top. No recording of time need be done for these two fillings.

(vii) When the water level, after the second filling (step vi) is 12.5 cm (5 in) or less from the bottom of the hole, add enough water to bring the depth of water to 15 cm (6 in) or more.

(viii) Observe the water level until it drops to the 15 cm (6 in) depth. At precisely 15 cm (6 in), commence timing. When the water level reaches the 12.5 cm (5 in) depth, stop timing. Record the time in minutes.

(ix) Repeat procedures (vii) and (viii) until the last two rates of fall do not vary more than 2 min/2.54 cm (2 min/in).

(x) Record and report all rates of fall in minutes per 2.54 cm (min per in).

(xi) Determine the percolation rate for the proposed sewage disposal system by averaging the slowest rate determined for each of the test holes.

(xii) Backfill the holes with the excavated soil and flag their locations.

APPENDIX C
RESTRICTIVE SOIL LAYERS

1. CEMENTED HORIZONS (from USDA, 1975 and CSSC, 1978)

Cementation of soil material refers to a brittle hard consistence caused by some cementing substance other than clay minerals, such as calcium carbonate, silica, or oxides or salts of iron and aluminum. Typically the cementation is altered little if any by moistening; the hardness and brittleness persist in the wet condition. Semi reversible cements, which generally resist moistening but soften under prolonged wetting, occur in some soils and give rise to soil layers having a cementation that is pronounced when dry but very weak when wet. Some layers cemented with calcium carbonate soften somewhat with wetting. Unless stated to the contrary, descriptions of cementation imply that the condition is altered little if any by wetting. If the cementation is greatly altered by moistening, it should be so stated. Cementation may be either continuous or discontinuous within a given horizon.

1. Weakly cemented: Cemented mass is brittle and hard but can be broken in the hands.

2. Strongly cemented: Cemented mass is brittle and harder than can be broken in the hand but is easily broken with a hammer.

3. Indurated: Very strongly cemented; brittle, does not soften under prolonged wetting, and is so extremely hard that for breakage a sharp blow with hammer is required; hammer generally rings as a result of the blow.

a. Duric horizon - a stongly cemented horizon that does not satisfy the criteria of a podzolic B horizon. Usually it has an abrupt upper boundary to an overlying podzolic B or to a Bm horizon and a diffuse lower boundary more than 0.5 m below. Cementation is usually strongest near the upper boundary, which occurs commonly at a depth of 40-80 cm from the mineral surface. The color of the duric horizon usually differs little from that of the moderately coarse textured to coarse textured parent material, and the structure is usually massive or very coarse platy. Air-dry clods of duric horizons do not slake when immersed in water, and moist clods at least 3 cm thick usually cannot be broken in the hands.

b. Ortstein horizon - a strongly cemented Bh, Bhf, or Bf horizon at least 3 cm thick that occurs in more than one-third of the exposed face of the pedon. Ortstein horizons are generally reddish brown to very dark reddish brown.

c. Placic horizon - a thin layer (commonly 5 mm or less thick) or a series of thin layers that are irregular or involuted, hard, impervious, often vitreous, and dark reddish brown to black. Placic horizons may be cemented by Fe, Al-organic complexes (Bhfc or Bfc), hydrated Fe oxides (Bgfc), or a mixture of Fe and Mn oxides.

d. Carbonate cementation - meets the definition of strongly cemented. The cemented layer is whitish in color and strongly effervesces when dilute HCl is added.

2. ACCUMULATION HORIZON (Bt)

A Bt horizon is one in which silicate clay has accumulated by illuviation. The most obvious field clues for recognition are a finer texture (see Appendix F) then the overlying or underlying horizons and the presence of coatings of clay on the surfaces of pores, peds or individual grains. These coatings are usually brown in color and when they are present in quantities sufficient to restrict permeability, they are usually visible to the naked eye.

3. SLOWLY PERMEABLE PARENT MATERIALS (from E.L.U.C., 1976)

a. Morainal - The material transported beneath, beside, on, within and in front of a glacier; deposited directly from the glacier and not modified by any intermediate agent.

The deposits generally consist of well-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, often in a matrix of sand, silt and clay. Non-compacted, coarse-textured, morainal deposits are an exception to the generally slow permeability.

b. Marine - Sediments that have settled from suspension in salt or brackish water bodies or that have accumulated at their margins through shoreline processes such as wave action and longshore drift.

The sediments consist of unconsolidated deposits of clay, silt, sand or gravel, well to moderately well-sorted, well-stratified to moderately-stratified, and in some places containing shells. Well-sorted and stratified gravelly marine deposits are an exception to the generally slow permeability.

c. Lacustrine - Sediments that have settled from suspension in bodies of standing fresh water or that have accumulated at their margins through wave action.

Lacustrine sediments commonly consist of stratified fine sand, silt and clay. Lacustrine deposits that contain only fine sand and silt may be moderately permeable.

APPENDIX D

FLOOD HAZARD CHARACTERISTICS

(Modified from Miles and Harding, 1980)

FLOOD HAZARD	LITTER COVER	OVERBANK DEPOSITS ETC.	FLUVIALLY TRANSPORTED DEBRIS	VEGETATION	TERRAIN HEIGHT	TERRAIN UNIT	ESTIMATED FLOOD FREQUENCY	SOIL CLASSIFI-CATION*
FREQUENT	No litter to a thin layer of non-decomposed material.	Presence of recent silt or sand deposits. Occasional scour holes.	Fluvially deposited logs and organic debris on channel banks. Occasionally debris in lower branches of trees.	None; or species typical of primary colonization; or species typical of wetlands.	Low lying areas.	Active Flood-plains, or fans, includes active channels side channels, drainage channels and areas of marsh or swamp.	1-3 year return interval.	Orthic and Cumulic Regosols.
OCCASIONAL	Thin litter cover present ranging from recent to partly or completely decomposed material.	Silt and/or fine sand deposits interbedded with organic litter.	Fluvially deposited logs and organic debris may be present on the ground and in the lower branches of trees.	Mature trees. Possibly containing some species typical of primary colonization.	Areas of moderate elevation.	Area of valley flat disected by back, side and drainage channels.	Less than 50 year return interval.	Cumulic Regosols.
RARE	Thick litter cover, lower layer completely decomposed.	No evidence of "recent" overbank deposits.	Not present.	Mature trees.	Areas of higher elevation.	Areas of low terraces, fluvial fans, or colluvial deposits.	In the range of 50 to greater than 200 year return interval.	Cumulic Regosols; Brunisols.
NO HAZARD	Thick litter cover, lower layer completely decomposed. Soil profile development.	No evidence of "recent" overbank deposits.	Not present.	Mature trees.	Areas of higher elevation.	Areas of higher teraces, fluvial fans, colluvial deposits, etc. Usually adjacent to the valley walls.	This unit is unlikely to be flooded under the present hydrologic logic conditions.	Usually not Regosolic; will depend on area surveyed.

*for fluvial materials

APPENDIX E
SOIL DRAINAGE CLASSES
(from Walmsley *et al.*, 1980)

The soil drainage classes are defined in terms of (i) actual moisture content in excess of field moisture capacity, and (ii) the extent of the period during which such excess water is present in the plant-root zone. It is recognized that permeability, level of groundwater, and seepage are factors affecting moisture status. However, because these are not easily observed or measured in the field, they cannot be used generally as criteria for drainage classes.

It is further recognized that soil profile morphology, for example mottling, normally, but not always, reflects soil drainage. Although soil morphology may be a valuable field indication of drainage class, it should not be the overriding criterion. For example, a soil may exhibit the morphology of a poorly drained soil, but recent changes (either natural or artificial) may result in the soil being imperfectly drained. Some soils that are considered to be well drained are mottled during the early spring, but lack mottling throughout most of the growing season. Other well drained soils are permanently mottled because of the nature and the distribution of minerals within them. Therefore, soil drainage classes cannot be based solely on the presence or absence of mottling. Topographic position and vegetation, as well as other soil characteristics, are useful field criteria for assessing soil drainage classes.

The recommended definitions of the soil drainage classes are underlined. As a guide, additional comments under each class indicate some of the pertinent soil morphological features that are commonly, but not necessarily found.

a. Rapidly drained - The soil moisture content seldom exceeds field capacity in any horizon except immediately after water additions. Soils are free from any evidence of gleying or mottling throughout the profile. Rapidly drained soils often occur on steep slopes.

b. Well drained - The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year. Soils are usually free from mottling in the upper 1 m, but may be mottled below this depth.

c. Moderately well drained - The soil moisture in excess of field capacity remains for a small but significant period of the year. Soils are often faintly mottled in the lower B and C horizons or below a depth of 0.7 m. The Ae horizon, if present, may be faintly mottled in fine textured soils and in medium textured soils that have a slowly permeable layer below the A and B horizons. In grassland soils the B and C horizons may be only faintly mottled and the A horizon may be relatively thick and dark.

d. Imperfectly drained - The soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year. Soils are often distinctly mottled in the B and C horizons; the Ae horizon, if present, may be mottled. The matrix generally has a lower chroma than in the well drained soil on similar parent material. Soils are generally "gleyed" subgroups of mineral soil orders.

e. Poorly drained - The soil moisture in excess of field capacity remains in all horizons for a large part of the year. The soils are usually strongly gleyed. Except in high chroma parent materials, the B, if present, and upper C horizons usually have matrix chromas of 3 or less, prominent mottling may occur throughout. Soils are generally in the Gleysol or Organic orders.

f. Very poorly drained - Free water remains at or within 30 cm of the surface most of the year. The soils are usually strongly gleyed. Subsurface horizons usually are of low chroma and yellowish to bluish hues. Mottling may be present within 30 cm or at depth in the profile. Soils are generally in the Gleysol or Organic orders; mineral soils are ususally a peaty phase.

APPENDIX F
SOIL TEXTURE
(from Walmsley *et al*., 1980)

Textural classes are defined in terms of the size distribution of primary mineral particles (2 mm dia. or less) as estimated by sieve and sedimentaton analysis, or field estimation. The basic textural classes are indicated in Figure 5, in terms of percent clay (finer than 0.002 mm), silt (0.002 to 0.05 mm), and sand (0.05 - 2.0 mm), with the code symbols indicated in the textural triangle.

If necessary, the lab can be requested to further separate any of the sand, silt, or clay sizes to further refine the soil texture classes as follows (or in some other way):

Name of Separate	Diameter (mm)	Symbol
Very coarse sand	2.0-1.0	vcs
Coarse sand	1.0-0.5	cs
Medium sand	0.5-0.25	ms
Fine sand	0.25-0.10	fs
Very fine sand	0.10-0.05	vfs
Silt	0.05-0.002	si
Clay	<0.002	c
Fine clay	<0.0002	fc

Please note: for silt, the soil notation is "si", while the terrain notation is "s̸".

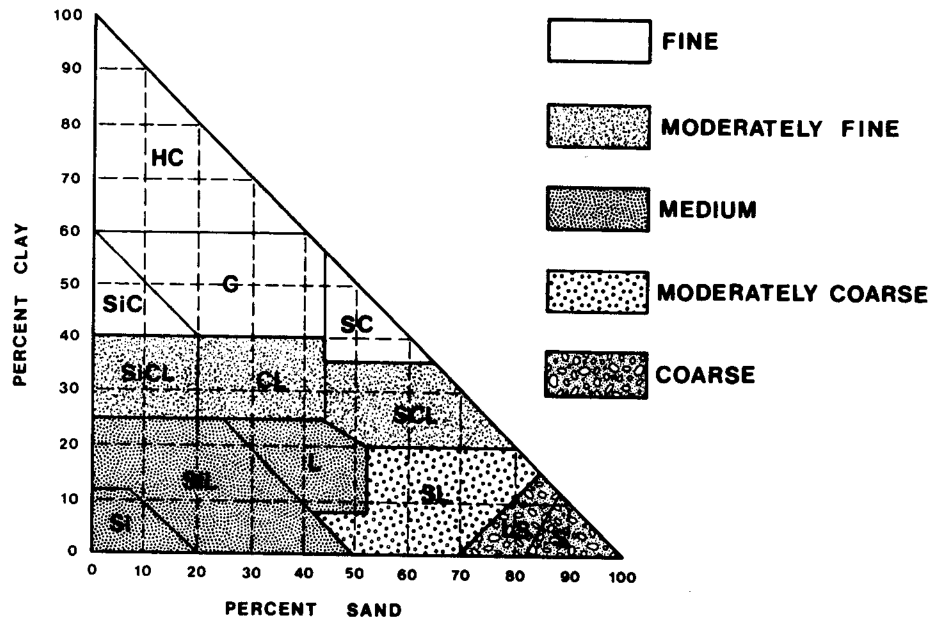

Figure 5. Soil textural triangle.

Soil Texture Classes:

Sands - 85% or more sand; the percentage of silt, plus 1.5 times the percentage of clay, does not exceed 15.

Coarse sand - 25% or more very coarse and coarse sand, and less than 50% any other one grade of sand.

Medium sand - 25% or more very coarse, coarse, and medium sand, and less than 50% fine or very fine sand.

Fine sand - 50% or more fine sand, or less than 25% very coarse, coarse and medium sand and less than 50% very fine sand.

Very fine sand - 50% or more very fine sand.

Loamy Sand - upper limit of sand is 85-90%, and the percentage of silt plus 1.5 times the percentage of clay is not less than 15; lower limit of sand is 70-85%, and the percentage of silt plus twice the percentage of clay does not exceed 30.

Sandy Loam - contains either 20% clay or less, with the percentage of silt plus twice the percentage of clay exceeding 30, and 52% or more sand, or less than 7% clay, less than 50% silt, and 43-52% sand.

Loam - contains 7-27% clay, 28-50% silt, and less than 52% sand.

Silt Loam - Contains 50% or more silt and 12-27% clay, or 50-80% silt and less than 12% clay.

Silt - contains 80% or more silt and less than 12% clay.

Sandy Clay Loam - contains 20-35% clay, less than 28% silt, and 45% or more sand.

Clay Loam - contains 27-40% clay and 20-45% sand.

Silty Clay Loam - contains 27-40% clay and less than 20% sand.

Sandy Clay - contains 35% or more clay and 45% or more sand.

Silty Clay - contains 40% or more clay and 40% or more silt.

Clay - contains 40% or more clay, less than 45% sand, and less than 40% silt.

Heavy Clay - contains more than 60% clay.

APPENDIX G
COMPARISON OF SOIL (USDA), UNIFIED & AASHO TEXTURES
(from USDA, 1971)

USDA Texture Class and Symbol	Unified Symbol	AASHO Symbol	Soil Properties Related to Classifications
Clay; silty clay "c"; "sic"	CH MH CL	A-7 A-7 A-7	High shrink-swell clays. Mica, iron oxide, kaolinitic clays. Low LL. Generally <45 pct clay.
Silty clay loam "sicl"	CL ML-CL CH MH	A-7 A-7 A-7 A-7	Low LL. Plastic. (A-6 if clay <30 pct). Low LL. Mod. plastic. (A-6 if clay <30 pct). High LL. High shrink-swell clays. High LL. Mica, iron oxide, kaolinitic.
Clay loam "cl"	CL ML-CL CH MH	A-6 or A-7 A-6 A-7 A-7	Low LL. Plastic. Low LL. Moderately plastic. High LL. High shrink-swell clays. High LL. Mica, iron oxide, kaolinitic.
Loam "l"	ML-CL CL ML	A-4 A-6 A-4	Moderately plastic (A-6 if clay >21 pct.) Plastic (A-4 if clay <22 pct). Low plasticity (A-7 if clay >21 pct).
Silt loam "sil"	ML-CL ML CL	A-4 A-4 A-6	Moderately plastic (A-6 if clay >21 pct). Low plasticity (A-7 if clay >21 pct). Plastic.
Silt - "si"	ML	A-4	Low plasticity.
Sandy clay "sc"	CL SC	A-7 A-7	Fines >50 pct. Fines 50 pct or less.
Sandy clay loam "scl"	SC SC CL	A-6 A-2-6 A-6	Plastic. Fines 36-50 pct. Plastic. Fines 35 pct or less. Plastic. Fines >50 pct.
Sandy loam "sl"	SM SC SM-SC	A-2-4 or A-4 A-2-4 A-2-4	Low plasticity. Plastic. Moderately plastic.
Fine sandy loam "fsl"	SM ML ML-CL SM-SC	A-4 A-4 A-4 A-4	Nonplastic. Fines 50 pct or less. Nonplastic. Fines >50 pct. Moderately plastic. Fines >50 pct. Moderately plastic. Fines 50 pct or less.
Very fine sandy loam "vfsl"	ML-CL ML	A-4 A-4	Moderately plastic. Low plasticity.
Loamy sands "ls"; "lfs" "lvfs"	SM SM-SC SM ML	A-2-4 A-2-4 A-4 A-4	Nonplastic. Fines 35 pct or less. Moderately plastic. Fines 35 pct or less. Low plasticity. Fines >35 pct. Little or no plasticity.
Sand; fine sand "s"; "fs"	SP-SM SM SP	A-3 A-2-4 A-3	Fines approx. 5-10 pct. Fines approx. >10 pct. Fines <5 pct.
Very fine sand "vfs"	SM ML	A-4 A-4	Low plasticity. Little or no plasticity.

USDA Texture Class and Symbol	Unified Symbol	AASHO Symbol	Soil Properties Related to Classifications
Coarse sand	SP; GW	A-1	Fines >5 pct.
"cs"	SP-SM	A-1	Fines 5-12 pct.
	SM	A-1	Fines 13-25 pct.
	SM	A-2-4	Fines >25 pct.
Gravel, "G"	GP;GW	A-1	Fines <5 pct.
50 pct passes No.200	GM or GC	A-1	Fines 5-25 pct.
50 pct of coarse	GM or GC	A-2	Fines 26-35 pct.
passes No. 4 sieve	GM	A-4	Fines >35 pct.
	GC	A-6	Fines >35 pct.

APPENDIX H

TEXTURE OF SURFICAL MATERIALS

(Modified from Wentworth Scale, E. L. U. C. Secretariat, 1976)

Texture

Texture refers to the size, roundness and sorting of particles in clastic sediments, and the proportional fibre content of organic sediments.

Symbol	Name	Size (mm)	Other Characteristics	
Clastic	Sediments			
b	bouldery	>256	rounded & subrounded particles	includes a minor amount of finer interstitial material and sand matrix
k	cobbly	64-256	rounded & subrounded particles	
p	pebbly	2-64	rounded & subrounded particles	
g	gravelly		a mixture of pebbles, cobbles and possibly boulders in a sand matrix	
s	sandy	0.625-2		
ś	silty	.004-.0625		
c	clayey	<.004		
f	fines		a mixture of clay, silt and possibly fine sand	
r	rubbly	2-256	angular and subangular particles	includes a minor amount of finer interstitial material
a	blocky	>256	large angular and subangular particles, commonly ranging up to 2 m diameter, with rubble and finer interstitial material	
Organic	Sediments			
e	fibric	--	the least decomposed of all organic materials: there is a large amount of well-preserved fibre that is readily identifiable as to botanical origin.	
m	mesic	--	organic material in an intermediate stage of decomposition: an intermediate amount of fibre is present that can be identified as to botanical origin.	
h	humic	--	highly decomposed organic material: there is a small amount of fibre present that can be identified as to botanical origin.	

Explanatory Notes

1. The absence of a textural term from a unit symbol indicates that texture of the material was not observed in the field and cannot be reliably interpreted from air photos or from a knowledge of the bedrock geology.
2. Where two textural terms are used together, they are written in order to increasing importance. e.g. śs is silty sand, sg is sandy gravel.

APPENDIX I
FIELD DETERMINATION OF TEXTURE (HAND-TEXTURING)
(from Walmsley et al., 1980)

The determination of soil texture "by feel" requires a great deal of practice and comparison with standards having known particle size distributions. It depends on the ability to feel sand grains at one extreme of particle size and plasticity and stickiness of clays at the other. Ability to feel sand grains is a uniform criterion in all soils, but different clay minerals may feel differently. Consequently, standards of "feel" established in one region may not apply in others where clay types are different. Montmorillonite clays are much more plastic and sticky than illite clays. Oxide clays are much less plastic and sticky than others. In volcanic tropical areas (e.g. Hawaii), soils containing 90% clay "feel" like silty clay loams (27 to 40% clay) of British Columbia. Other variables affecting the feel of a given texture class are particle size differences (coarse versus fine clay, for example), the dominant exchangeable cation, and organic matter content. Criteria for British Columbia soils in general were used in the following key.

Frequently clay particles are grouped into small hard aggregates that give a feel of sand when dry. The soil must be moistened and rubbed vigorously between the fingers to release all of the primary particles.

For determination of texture by feel, the soil should be moist but not saturated (at moisture levels slightly above field capacity). Proper moisture content is the most difficult factor to judge. Generally coherent soil should be as wet as necessary to permit it to be rolled between the palms of the hands and pressed into a "ribbon" between thumb and forefinger leaving moisture on the skin when handled, but without sticking to the fingers. As the soil is handled, it loses moisture and becomes less and less pliable. One should start at the maximum moisture the soil will hold without sticking to the fingers and note the change as it dries.

Surveyors must remember that horizons of the same soil textural class, but varying in particle size distribution, may have a different feel (and different physical properties).

Key to General Texture Groups

A Rub the moist soil between thumb and forefinger. If you can feel individual sand grains distinctly as a major part of the mass, proceed to A1. If not proceed to B.

A1 Press the dry soil hard between thumb and forefinger. If it forms a cast that holds together slightly, proceed to A2. If the cast falls apart when pressure is released, it is probably coarse textured (sand or loamy sand). Check this by pressing when moist. If the cast formed can be transferred from one hand to another, proceed to A2. If it can not, it is coarse (sand, loamy sand).

A2 If the cast formed of dry soil can be transferred from one hand to another, proceed to A3. If it cannot, it is probably moderately coarse textured (sandy loam; fine sandy loam). Check this moist. If the cast of moist soil can be handled readily without breaking, proceed to A3. If it can be tansferred form one hand to the other, but cannot readily be picked up intact, it is moderately coarse (sandy loam; fine sandy loam).

A3 Squeeze the fully moist (not wet) soil between thumb and forefinger with a shearing stress. If the soil forms a thin smooth "ribbon" that will bear its own weight, proceed to A4. If it forms a rough "ribbon" that breaks under its own weight it is medium textured (loam).

A4 Roll the fully moist soil into a worm-like roll about 6mm (1/4 inch) in diameter between the palms of the hands. If the roll can bear its own weight when it is flexed (shake while holding one end), proceed to A5. If the roll breaks easily when flexed, it is moderatley fine (clay loam).

A5 If the roll does not break when flexed, it is fine textured (sandy clay).

B Sand grains cannot be felt distinctly as a major part of the mass (one may feel a few sand grains). Proceed to B1.

B1 Shear the fully moist (but not wet) soil between thumb and forefinger. If it forms a slick unbroken "ribbon" proceed to B2. If it forms a broken rough ribbon it is medium textured (silt, silt loam or very fine sandy loam).

(By carefully feeling for slight abrasiveness the very fine sandy loam can be detected. Pulverized when dry, silt feels soft and floury; silt loam has a similar feeling but sand grains may also be apparent. Very moist silt feels soapy. Silt has a gritty feel when chewed between the teeth).

B2 Roll the fully moist soil between palms of the hands. If the roll bears its own weight readily when flexed, proceed to B3. If it breaks, it is moderately fine (silty clay loam).

B3 If the roll bears its own weight when flexed, it is fine textured (clay or silty clay).

(Most clay is quite plastic and usually sticky when wet. Clay is not gritty when chewed between the teeth. Some fine clays very high in colloids are friable and lack plasticity in all moisture conditions).

APPENDIX J

SOIL STRUCTURE

TYPES, KINDS AND CLASSES OF SOIL STRUCTURE

(from Walmsley *et al.*, 1980)

TYPE	KIND	CLASS	SIZE
Blocklike-soil particles arranged around a point and bounded by flat or rounded surfaces	Angular blocky (ABK): peds bounded by flattened, rectangular faces intersecting at relatively sharp angles	VF: very fine angular blocky	<5
		F: fine angular blocky	5-10
		M: medium angular blocky	10-20
		C: coarse angular blocky	20-50
		VC: very coarse angular blocky	>50
	Subangular blocky (SBK): peds bounded by slightly rounded, subrectangular faces with vertices[2] of their intersections mostly subrounded	VF: very fine subangular blocky	<5
		F: fine subangular blocky	5-10
		M: medium subangular blocky	10-20
		C: coarse subangular blocky	20-50
		VC: very coarse subangular blocky	>50
	Granular (GR): Spheroidal peds bounded by curved or very irregular faces that do not adjoin those of adjacent peds	VF: very fine granular	<1
		F: fine granular	1-2
		M: medium granular	2-5
		C: coarse granular	5-10
		VC: very coarse granular	>10
Platelike-soil particles arranged around a horizontal plane and and generally bounded by relatively flat horizontal surfaces	Platy (PL): Peds flat or platelike; horizontal planes more or less developed	VF: very fine platy	<1
		F: fine platy	1-2
		M: medium platy	2-5
		C: coarse platy	5-10
		VC: very coarse platy	>10
Prismlike-soil particles arranged around a vertical axis and bounded by relatively flat vertical surfaces	Prismatic (PR): Vertical faces of peds well defined and vertices[2] angular (edges sharp); prism tops essentially flat	VF: very fine prismatic	<10
		F: fine prismatic	10-20
		M: medium prismatic	20-50
		C: coarse prismatic	50-100
		VC: very coarse prismatic	>100
	Columnar (COL): Vertical edges near top of columns not sharp (vertices[2] subrounded); column tops flat, rounded, or irregular	VF: very fine columnar	<10
		F: fine columnar	10-20
		M: medium columnar	20-50
		C: coarse columnar	50-100
		VC: very coarse	>100
Structureless-no observable aggregation of primary particles or no definite orderly arrangement around natural lines of weakness	Single grained (SGR):	loose, incoherent mass of individual primary particles, as in sands	
	Massive (MA):	amorphous; a coherent mass showing no evidence of any distinct arrangement of soil particles; separates into clusters of particles, not peds	
Cloddy (CDY): not a structure; used to indicate the condition of some ploughed surfaces; grade, class, and shape too varied to be described in standard terms.			

1. The size limits refer to measurements in the smallest dimension of platy, prismatic, and columnar peds and to the largest of the nearly equal dimensions of blocky and granular peds.
2. Definition of vertex (plural, vertices): The intersection of two planes of a geometrical figure.

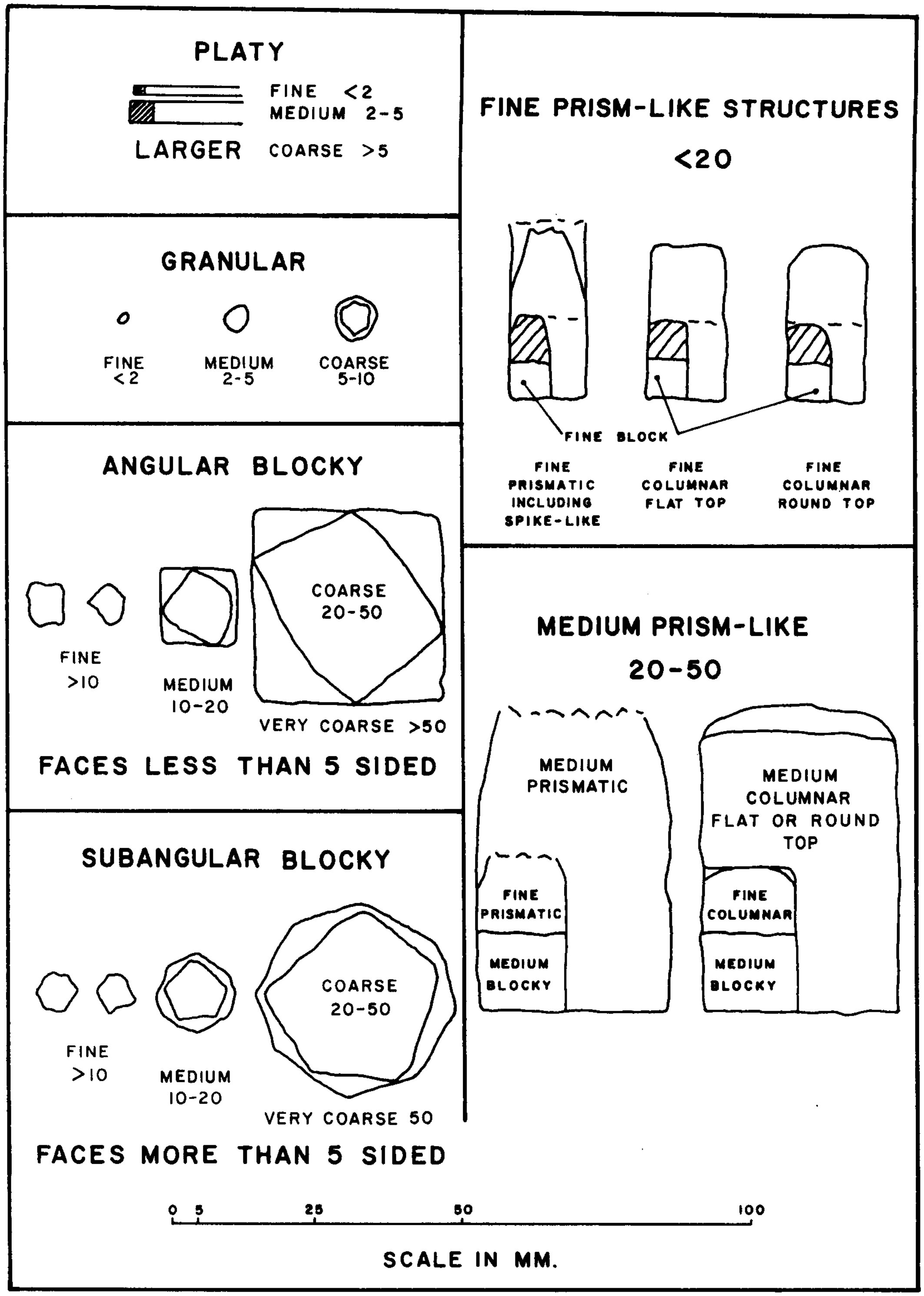

Figure 6. Diagrammatic representation of soil structure.