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GUIDE FOR SOIL SURVEYS FOR RIVER VALLEY PROJECTS

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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GUIDE FOR SOIL SURVEYS FOR RIVER VALLEY PROJECTS

Preliminary Investigation and Collection of Data Sectional Committee, BDC 47

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 1

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GUIDE FOR SOIL SURVEYS FOR RIVER VALLEY PROJECTS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 2 December 1969, after the draft finalized by the Preliminary Investigation and Collection of Data Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Soils differ widely from place to place. Soil surveys are, therefore, carried out to determine the nature, distribution and extent of different soils existing in various regions. Since the type of cultivation and the management practices for efficient agriculture depend on the nature of the soil and in order to cultivate scientifically, it is essential to determine various factors, such as the nature of the soil with respect to its moisture retentivity, requirement of water and fertilizers and type of crop most suitable for a particular soil.

0.3 Properties of soil may change after the introduction of an irrigation system in the region due to the development of salinity, alkalinity, water logging, etc. An exhaustive soil survey should, therefore, be conducted during the planning stage of a river valley project with particular emphasis to the suitability of soils for irrigation, reclamation, drainage and also in command areas where water is to be used for irrigation after impounding in a reservoir or running a canal.

0.4 Soil surveys of the catchment and command areas help in formulating measures for mitigating reservoir siltation, prevention of soil erosion and suggesting remedial measures for drainage and water logging problems. Soil surveys should provide for examination of the physical, chemical and engineering properties of the soil. From agricultural point of view the studies help in determining the availability of plant foods in the soil and the need for correcting the deficiencies. Thus, soil surveys furnish information required not only for agricultural purposes but also for reclamation and conservation purposes and for engineering construction activities, like the highways, railways, etc. In this guide it is intended to describe briefly the general principles or guidelines as regards to soil surveys that are carried out for river valley projects. For detailed procedures the 'Soil survey manual (*revised*)', published by the All India Soil and Land Use

Survey Organization may be referred. For conducting rapid pre-irrigation soil survey to determine the feasibility of a river valley project the 'Manual for pre-irrigation soil survey, volumes I and II', published by the Central Water and Power Commission (Water Wing), may be referred.

0.5 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices followed in the field in this country.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard lays down the guidelines for carrying out soil surveys for river valley projects.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS : 2809-1964† and the following definitions shall apply.

2.1 Acid Soil — A soil that gives an acid reaction (below *p*H 7·0).

2.2 Alkali Soil — A soil which has either so high a degree of alkalinity (*p*H 8·5 or higher) or so high a percentage of exchangeable sodium (15 percent or higher ESP), or both, that the growth of most crop plants is reduced.

2.3 Base Status — The extent to which a material or soil component (clay or humus) is saturated with exchangeable bases (cations) other than hydrogen. This is expressed as a percentage of the total base or cation exchange capacity of the material.

2.4 Class — A group of soils having a definite range in a property or attribute, such as acidity, slope, texture, structure, land capability, degree of erosion, or drainage.

2.5 Classification — The assignment of objects or units to groups within a system of categories distinguished by their properties. In the classification

*Rules for rounding off numerical values (*revised*).
†Glossary of terms and symbols relating to soil mechanics.

of soils, the fundamental unit is a soil type. Similar soil types are grouped to form a series. Series are grouped into families, families into great soil groups, these into suborders, and suborders into orders (of which there are three : zonal, azonal and intrazonal).

2.6 Land Classification — The classification of units of land for the purpose of showing their relative suitabilities for some specific use.

2.7 Mapping Units — Classificational units that are shown on the maps. The kind of such units shown on the maps depends upon the scale of maps. In reconnaissance surveys these units may be series or association of series, while in detailed surveys they will include types and phases of such soils.

2.8 *p*H Soil — An index of the acidity or alkalinity of a soil in terms of the logarithm of the reciprocal of the hydrogen ion concentration.

2.9 Ped — An individual natural soil aggregate. Refers to aggregate of primary soil particles into compound particles which are separated from adjoining aggregates by surfaces of weakness.

2.10 Photo Tone — Relative intensity of the darkness of the photo images and their shades on the photographs.

2.11 Soil Horizon — One of the layers of the soil profile, distinguished principally by its texture, colour, structure and chemical content.

2.12 Soil Monolith — Refers to soil profiles collected in an undisturbed manner to act as visual aids in soil study and identification or for display.

2.13 Soil Morphology — The constitution of the soil body as expressed in the kind, thickness and arrangement of the horizons in the profile, and in the texture, structure, consistence, porosity and colour of each horizon. In other words, soil morphology is the property of the soil body or any of its parts.

2.14 Soil Phase — The sub-division of a soil type having variations in characteristics not significant to the classification of the soil in its natural landscape, but significant to the use and management of the soil. Examples of the variations recognized by phases of soil types include difference in slope, stoniness and erosion.

2.15 Soil Profile — Vertical section of a soil, showing the nature and sequence of the various layers, as developed by deposition or weathering or both.

2.16 Soil Series — A group of soils that have soil horizons similar in their differentiating characteristics and arrangement in the profile, except for the texture of the surface soil, and are formed from a particular type of parent material. Soil series is an important category in detailed soil classification.

2.17 Soil Types — A subgroup or category under the soil series based on the texture of the surface soil. A soil type is a group of soils having horizons similar in differentiating characteristics and arrangement in the soil profile, and developed from a particular type of parent material. The name of a soil type consists of the name of the soil series plus the textural class name of the surface soil. Thus, Ooty silt loam is the name of a soil type within the Ooty series.

2.18 Taxonomic Soil Unit — Refers to unit of classification related to soils. These could be 'soil series' or 'soil types'.

2.19 Water Table — The upper surface of ground water; elevations at which the pressure in the water is zero with respect to the atmospheric pressure.

3. STANDARD SOIL SURVEY

3.1 Use of Base Maps — Standard soil surveys may be carried out at varying intensities depending on the nature of utilization of the soil. Mapping may be done on varying scales and the mapping legends vary from narrowly to broadly defined units. Soil morphology shall be given utmost consideration in mapping differentiated soils. Soil survey shall be carried out making use of base maps on scales ranging from 1 : 50 000 to 1 : 4 000. The smaller scale maps are the Survey of India topographical maps and the large scale maps are cadastral village maps. Air photographs in scales of 1 : 15 000 to 1 : 60 000 as available may be used as base maps since they help to increase accuracy of observations and location of soil boundaries and other features, besides helping to speed up the work. The choice of scale of base maps used shall depend upon the type of survey which in its turn will reflect the purpose and objective of the survey.

3.2 Type of Data to be Collected — The topographic and vegetation condition of the terrain should be noted. Soil samples on both profile and surface basis should be collected for laboratory examination and confirmation of the field observations. The soil samples for laboratory examination of engineering properties shall be collected in accordance with IS : 2132 - 1963*.

3.2.1 The *p*H value, available and total plant nutrients, base status, soluble salt contents, permeability and other engineering properties may be determined for interpretation of the behaviour of the soils under varied uses.

*Code of practice for thin-walled tube sampling of soils.

4. TYPES OF SOIL SURVEYS

4.1 Rapid Reconnaissance Survey — In the case of all project planning including irrigation projects, the feasibility studies require general information regarding the soil conditions, terrain features, and other disadvantageous features which militate against the success of the project. For such purposes a rapid reconnaissance survey, combined with studies on the soil characteristics may be adequate. In such surveys base maps in the scales ranging between 1 : 60 000 and 1 : 250 000 may be adequate for the purpose. The soil sampling shall be limited to studies on the variability of the soils, their depth characteristics, the occurrence of harmful factors, like salinity, alkalinity, etc, and delineation of the approximate extent of these features. The soil map prepared from such a rapid reconnaissance survey should indicate the extent and limits of the above features and such other observations that may be made to suit the requirements of such a survey.

4.2 Reconnaissance Survey — Reconnaissance soil surveys help to fix the nature of soils occurring in the area and also to determine the areas suitable for more intensive development or to recognize the areas which require attention or amelioration because of their suffering from erosion, salinity, alkalinity, and such factors affecting their use. Reconnaissance surveys shall furnish the information to precede detailed surveys. The scale of mapping shall be 1 : 50 000 using topo sheets of the Survey of India as base maps. The field work shall involve studies of soil profiles at intervals of 3 to 6 km or shorter intervals depending upon the soil heterogeneity. Auger sampling for every 0·25 to 1 km shall be carried out to study the variations in profile characters. Profiles showing similar horizon characters within narrowly defined limits may be grouped together into 'series'. The 'series' shall form the unit for mapping of soils in this type of survey. The soil series may be named after the place (location, village or town) near where the typical soil profile representative of the series was first recognized or described. The determination of soil ('series' or the 'association of series') boundaries in such surveys may be made partly by traversing and largely by extrapolation.

4.3 Detailed Survey — In this type of survey, maps in adequately large scale may be used to permit demarcation of soil phases and details of soil and terrain. In this type, the mapping units are narrowly defined to indicate variations in surface texture, soil depth, erosion, salinity, alkalinity, slope features or any other factors significant for land use or land development. Cadastral maps with village as a unit may be used. Aerial photographs in the scale of 1 : 10 000 to 1 : 15 000 may also be used. Studies of soils shall be similar as in reconnaissance survey, but at much closer intervals. Also the boundary delineated should be made by close traverse.

5. SOIL MAPS

5.1 Use of Soil Maps — A soil map is prepared after a soil survey and is intended to show the distribution of soils, their types and other mapping units decided upon. From such soil maps, interpreted single characteristic maps, or land use maps or maps showing engineering properties may be prepared. The single characteristic maps may include such properties as slope, erosion, nutrient status, salinity, drainage, etc.

5.2 Equipment — The following are some of the important equipment that may be required for soil survey:

a) Augers of various types;
b) Tape, spade, pick-axe, etc;
c) Abney level;
d) Compass;
e) Lables, bags for collecting samples;
f) Munsell colour chart;
g) Base maps and field note books;
h) Indicators for *p*H measurement and hydrochloric acid;
j) Soil monolith boxes, such as
   1) macromonolith (wooden frame $150 \times 15 \times 7.5$ cm); and
   2) micromonolith (plywood boxes with adjustable partitions $30 \times 7.5 \times 3.75$ cm).

6. METHODS OF SOIL SURVEY

6.1 Traversing for Reconnaissance Soil Survey — The field operations include preliminary study of the soils of the area, the preparation of the mapping legend and identification of the soils. The mapping unit in this case is the soil series. In areas of complex geological formation and in highly undulating terrain where soil characters change abruptly within small distances, the delineation of boundaries between different identified series becomes a matter of difficulty, and their mapping as separate units presents cartographic difficulties. In such situations, it is necessary to delineate them in 'associations' of series. The reconnaissance soil survey should be carried out on topo sheet (1 : 50 000) of the Survey of India or similar base maps, including air photographs.

6.1.1 Soil profiles may be located at intervals of 3 to 6 km depending upon soil heterogeneity and these should be examined. Soil monoliths should be collected for typical profiles for record and correlation purposes.

The traverses for identification of soils and for plotting boundaries may be spaced at greater intervals than in the detailed soil surveys. Under certain conditions of field work, especially in pre-irrigation surveys the adoption of grid method for locating the augering sites may be useful. Grid squares of extent ranging from 1 to 8 km^2 depending upon the nature of terrain may be suitable. During traverses for marking boundaries of soil units, the available roads and paths should be followed. Observations in regard to depth, texture and terrain feature shall be recorded at every 1 km, and such observations may also be made at 0·25 to 0·5 km.

6.2 Traversing for Detailed Soil Survey — The reconnaissance survey should precede a detailed survey, as this furnishes adequate basic information about the nature and kind of soils occurring in an area and adequate background information becomes available in respect of the problems of erosion, cropping and their relationship with the utilization of soil and land resources. Detailed survey aims at bringing out details in respect of soil and terrain features and such comprehensive data could be used for proper interpretation to guide different technical classifications, including engineering properties.

6.2.1 The mapping legend is narrowly defined which includes the taxonomic soil unit (series), the surface texture, soil depth, slope and erosion features of the terrain. The base maps used in such surveys may be of scale 1 : 15 000 to 1 : 4 000. These may be cadastral maps or aerial photographs.

6.2.2 In proceeding with the operations of the detailed soil mapping, the field party should traverse the land on foot and depending on soil heterogeneity examine auger samples at intervals of 100 to 200 m. The profiles for detailed soil examination should be located at intervals of 1 to 2 km or where changes of soil are noted. The delineation of soil boundaries demarcating soil units should be made in the field with reference to fixed points on the map. Additional information, like drains, *NULLAS*, sand dunes, wet spots, etc, should be indicated on the map by conventional symbols.

6.2.2.1 The soil boundaries should be drawn through observations made continuously in the course of the traverse.

6.3 Field Party for Soil Survey — A field party should consist of the following:

a) Soil surveyor,

b) Field assistant,

c) Tracer,

d) *KHALASI*, and

e) Jeep driver (with a jeep).

6.3.1 *Rates of Field Work by Reconnaissance and Detailed Surveys* — In plain areas, a field party should cover per day about 4 km^2 by reconnaissance survey or about 800 km^2 for a working year of 200 field days. In respect of detailed survey a party should cover 0·8 km^2 per day in plain areas and about 0·4 km^2 in hilly terrain. Thus, the annual outturn may be 160 km^2 in favourable terrain and only 65 to 80 km^2 in difficult terrain.

7. SOIL CHARACTERISTICS

7.1 In a soil survey the following characteristics of the soil shall be determined and recorded horizon-wise:

a) Soil reaction (*p*H),
b) Carbonate content,
c) Soil texture,
d) Soil colour,
e) Soil structure,
f) Soil consistency, and
g) Cementation.

7.2 Soil Reaction — Soil reaction is an important characteristic in soil studies because of its intrinsic importance in various phases of soil development. It has a large influence on microbiologic activities, availability and uptake of various plant nutrients, and the reaction of applied fertilizers to the soil. The intensity of soil acidity or alkalinity is expressed as *p*H value. A *p*H value of 7 implies neutral characteristic. Values lower than 7 indicate acidity and higher ones alkalinity. Soils with *p*H value round about neutrality are usually the best for agricultural purposes. The *p*H value shall be determined in accordance with IS : 2720 (Part XXVI)-1967*.

7.2.1 Ranges of *p*H values are classified as follows:

	*p*H *Value*		*p*H *Value*
a) Extremely acidic	below 4·5	f) Neutral	6·6-7·3
b) Very strongly acidic	4·5-5·0	g) Mildly alkaline	7·4-7·8
c) Strongly acidic	5·1-5·5	h) Moderate alkaline	7·9-8·4
d) Medium acidic	5·6-6·0	j) Strongly alkaline	8·5-9·0
e) Slightly acidic	6·1-6·5	k) Very strongly alkaline	9·1 and higher

7.2.2 In the field *p*H value of soil may be determined by the colorimetric method. Indicators that have different colours at different *p*H values are

*Methods of test for soils: Part XXVI Determination of *p*H value.

commonly used in the field. The indicators commonly used and their *p*H ranges are as follows:

Indicator	*p*H *Range*
Brom-cresel green	3·8-5·6
Chlorophenol red	5·2-6·8
Bromthymol blue	6·0-7·6
Phenol red	6·8-8·4
Cresel red	7·2-8·8
Thymol blue	8·0-9·6

7.2.3 Universal indicator solutions may also be used for obtaining approximate *p*H values.

7.3 Carbonate Content — The presence of free carbonates in the soil and parent material shall be tested with 10 percent hydrochloric acid conforming to IS : 265-1962*. While testing very dry soil, the emission of air bubbles should not be confused for effervescence. The reaction shall be recorded as slight, strong, or violent effervescence. It may be noted whether the effervescence is due to the presence of fragments of limestone, or concentration of lime, or due to the fine earth itself. The calcium carbonate content in the soil shall be determined in accordance with IS : 2720 (Part XXIII)-1966†. The pattern of free carbonates in the soil profile and in the parent material is a useful criterion for deciding between soil series. Where the presence of carbonates is doubtful or where quantitative results are required, soil samples may be sent to the laboratory for carbonate determination.

7.4 Soil Texture — The soil classification may be made in the field by feel of the soil with fingers and, if necessary, supplemented by examination under a hand-lens. This requires skill and experience, but sufficient accuracy may be obtained if the soil surveyor frequently checks his inference with that of laboratory test results. The feel for moist soil is different from that of dry soil. Frequently clay particles are grouped into small hard aggregates that give a feel of silt or sand when dry. Because of differences in relative size within the clay fraction itself, soil horizons of similar total clay content vary in physical properties. Variations in the kind of clay or other constituents give the soil hardness suggesting a high amount of clay. The soil must be well moistened and rubbed vigorously between the fingers for a proper classification of texture by feel. The field identification procedure for sand, sandy loam, loam, silt loam, clay loam, sandy clay and clay is given in Appendix A.

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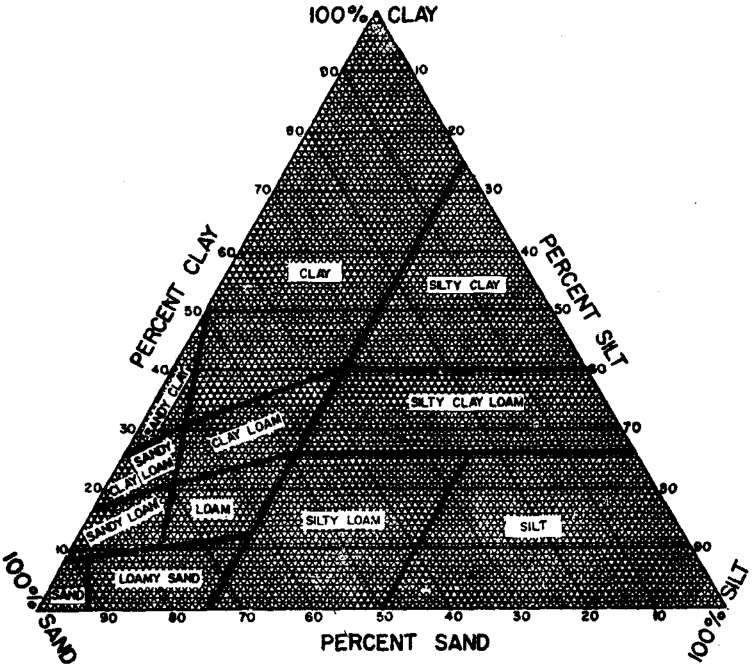
*Specification for hydrochloric acid (*revised*).

†Methods of test for soils : Part XXIII Determination of calcium carbonate.

7.4.1 More dependable definitions of soil texture are those based on grain size analysis (mechanical analysis) carried out in the laboratory in accordance with IS : 2720 (Part IV) - 1965* and interpreted from the triangular texture diagram (*see* Fig 1). Even while soil survey is in progress samples of soil horizons of doubtful texture should be forwarded to the laboratory and given high priority for examination so that the results may be sent back to the field at once to serve as guides.



NOTE — The upper limit of silt specified as 0·02 mm in this standard is for classification of soils for agricultural purposes only. For other engineering classifications, IS : 1498-1959 'Classification and identification of soils for general engineering purposes' shall be followed.

FIG. 1 TRIANGULAR TEXTURE DIAGRAM BASED ON FRACTIONS WITH EFFECTIVE DIAMETERS OF 0·002, 0·02 AND 2·0 mm FOR THE UPPER LIMITS OF THE CLAY, SILT AND SAND FRACTIONS, RESPECTIVELY

7.5 Soil Colour — Colour is the most obvious and easily determined of all soil characteristics. From soil colour one may infer about a soil, such as its

*Methods of test for soils : Part IV Grain size analysis.

nature, its organic matter content, state of hydration of the iron oxide, etc. Soil colours are most conveniently determined by comparison with colour chart. Munsell colour chart shall be used in classifying soil colours. It consists of a number of colour chips systematically arranged with notations on cards in a loose-leaf book. The arrangement is by hue, value, and chroma, the three simple variables that combine to give all colours. The hue is the dominant spectral colour and a function of wavelength. Value refers to the relative lightness of colour and is a function of the total amount of light. Chroma is the relative purity or strength of the spectral colour and increases with decreasing greyness.

7.5.1 In the Munsell colour chart, all colours in a given card are of a constant hue, designated by the symbol in the upper right-hand corner of the card. Vertically, the colours become successively lighter and their value increases. Horizontally, the colour increases in chroma to the right. The value and chroma of each colour in the chart is printed immediately beneath the colour. The first number is the value, and the second is the chroma.

7.5.2 The nomenclature for soil colour consists of two complementary systems. They are the names of colour and the Munsell colour notation. Neither of these alone is adequate for all purposes. The Munsell notations should be employed in all descriptions to supplement the colour names. This affords greater precision as a convenient abbreviation in field descriptions, for expression of the specific relations between colours and for statistical treatment of colour data. The Munsell notation is useful for international correlation, since no translation of colour names is needed.

7.6 Soil Structure — Soil structure refers to the aggregation of primary soil particles into compound particles or clusters of primary particles. There are four primary types of soil structures as given below:

a) *Platy* — The particles are arranged around a plane, generally horizontal.

b) *Prismlike* — The particles are arranged around a vertical line and bounded by relatively flat vertical surfaces. There are two sub-types:

   1) *Prismatic* — without rounded upper ends, and

   2) *Columnar* — with rounded caps.

c) *Blocklike or Polyhedral* — The particles are arranged around a point and bounded by flat or rounded surfaces, which are casts of the moulds formed by the faces of surrounding peds. There are two sub-types:

   1) *Angular blocky* — bounded by planes intersecting at relatively sharp angles, and

2) *Sub-angular blocky* — having mixed rounded and plane faces with vertices mostly rounded.

d) *Spheroidal or Polyhedral* — The particles are arranged around a point and bounded by curved or very irregular surfaces. Spheroidal is sub-divided into granular, relatively non-porous and crumb and very porous.

7.6.1 Ped is a natural structural aggregate in soils (*see* **2.9**). Each type of structure includes peds that vary in shape, and detailed soil descriptions may require supplemental statements about the shape of the individual peds.

7.6.1 Grade of structure represents the degree of aggregation. In the field, grade of structure may be determined by noting the durability of the aggregates and the proportions between aggregated material and the rest that result when the material is displaced or gently crushed. Grade of structure changes with the moistening of the soil. If grade is designated at an unstated moisture content, it is assumed that the soil is nearly dry or only very slightly moist, which is commonly that part of the range in soil moisture in which soil structure is most strongly expressed.

7.6.2.1 Old road cuts are not suitable places to determine grade of structure, but they afford a clue to the type of structure present.

7.6.2.2 The following terms are used in describing the grades of structure:

a) *Structureless* — It represents the condition in which there is no observable aggregation or no definite orderly arrangement of natural lines of weakness. It may be said to be massive if coherent and single grain if non-coherent.

b) *Weak* — It represents the degree of aggregation characterized by poorly formed indistinct peds that are barely observable in place. When disturbed, soil material that has this grade of structure breaks into a mixture of few wholesome peds, broken peds and much unaggregated material. If necessary for comparison purposes, this grade may be further divided as very weak and moderately weak.

c) *Moderate* — It represents the grade of structure characterized by well formed distinct peds that are moderately durable and evident but not distinct in undisturbed soil. Soil material of this grade, when disturbed, breaks down into a mixture of many distinct wholesome peds, some broken peds, and little unaggregated material.

d) *Strong* — It represents the grade of structure characterized by durable peds that are quite evident in undisplaced soil, that adhere weakly to one another, that withstand displacement and become separated when the soils are disturbed. When removed from the profile, soil material of this grade of structure consists very largely of entire peds and includes few broken peds and little or no unaggregated material. If necessary for comparison, this grade may be sub-divided as moderately strong and very strong. Examples of strong grade of structure are in the granular type.

7.7 Soil Consistency — Soil consistency comprises the attributes of soil material that are expressed by the degree and kind of cohesion or by the resistance to deformation or rupture. Every soil material has consistency irrespective of whether the mass be large or small in natural condition or greatly disturbed, aggregated or structureless, moist or dry. Although consistency and structure are interrelated, structure deals with the shape, size and definition of natural aggregates that result from variations in the forces of attraction within a soil mass, whereas consistency deals with the strength and nature of such forces themselves.

7.7.1 Although evaluation of consistency involves some disturbance, unless otherwise stated, descriptions of consistency customarily refer to that of soil from undisturbed horizons.

7.7.2 The various terms used in describing the property of consistency are given in Appendix B.

7.8 Cementation — Cementation of soil material refers to a hard consistency caused by some cementing substance other than clay minerals, such as calcium carbonate, silica, or oxides or salts of iron and aluminium. Typically the cementation is altered little by moistening; the hardness persists 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 cementation that is pronounced when dry but become weak when wet. Some layers, cemented with calcium carbonate, soften with wetting. The degree of cementation is expressed as given in **7.8.1** to **7.8.3**.

7.8.1 *Weakly Cemented* — Cemented mass is brittle and hard but can be broken in the hand.

7.8.2 *Strongly Cemented* — Cemented mass is brittle and harder that may be broken in the hand but is easily broken with a hammer.

7.8.3 *Indurated* — Very strongly cemented; does not soften under prolonged wetting and is so extremely hard that for breakage, a sharp blow with a hammer is required.

8. STUDY OF SOIL PROFILE

8.1 After reconnaissance of the area, a suitable site representing the normal conditions prevailing in the area shall be selected for profile examination. While digging the pit, care shall be taken to expose the vertical face to sunlight and the soil excavated from the pit shall be thrown on either side. The pit may be 1·2 m wide and 1·8 m deep. In case of soils which are very shallow with hard bedrock or high subsoil water level and uniformity of the soil has been established by auger bores and other studies, profiles may not be dug to the requisite 1·8 m depth. The characteristics of the soil in the exposed profile should be studied horizon-wise and observations should be recorded.

9. CLASSIFICATION OF SOILS

9.1 After the field work is over, an expert on the subject shall study the data collected and the information furnished in the map. He shall also study the laboratory test results and demarcate the land according to the findings of the soil survey. The following factors shall be taken into account in the classification of soils pertaining to an area:

a) Consideration of erosion;

b) Considerations of slope of the land;

c) Development of the soil, such as zonal (well developed), intrazonal (more or less developed) and azonal (not well developed);

d) Soil series;

e) Type of soil;

f) Suitability of land use, whether suited for agricultural purposes or not (*see* Appendix C); and

g) Suitability of the soil for irrigation (*see* **9.2** and **9.2.1**).

9.2 In the classification of soils and lands for irrigation suitability, the following data shall be collected:

a) Effective soil depth and texture of surface soils;

b) Content of coarse fragments, such as gravels, cobbles, stones, *KANKAR*, etc;

c) Permeability;

d) Available water holding capacity;

e) Salinity up to 1·8 m depth according to the natural horizons or for every 0·3 m;

f) Alkalinity determined by exchangeable sodium percentage (ESP);

g) Slope of terrain;

h) Depth of water table; and

j) Availability of outlets for surface and sub-surface drainage.

9.2.1 Irrigation capability may be decided by consideration of soil characteristics and land features. The criteria for classifying lands into irrigability classes as suited to semi-arid and arid regions are given in Table 1. In this classification, four classes (Classes 1 to 4) of irrigable soils/lands are recognized. Class 5 relates to lands considered temporarily non-irrigable but which could become irrigable with correction and amendments. Class 6 relates to lands which are not fit for irrigation (*see* Appendix D).

10. MAPPING

10.1 It is essential to indicate the soil classification on a map. The following points shall be kept in view in this connection:

a) Whether the relative positions of the cultural features, physical features, drainage and soil boundaries, etc, agree to the geodetic control established;

b) Whether sufficient number of controls have been established to check the accuracy of the said details; and

c) Whether topographic features running from one sheet to the adjoining sheet are in complete agreement and properly oriented.

11. AERIAL PHOTOGRAPHS AND THEIR CHARACTERISTICS

11.1 Aerial Photographs — Aerial photographs are pictures taken by an aerial camera fitted into a plane flying under certain specific conditions of flight.

11.2 Types—Aerial photographs are of two main types:

a) Oblique photographs, and

b) Vertical photographs.

11.3 Characteristics of the Two Types of Photographs

11.3.1 Oblique photographs are taken with camera pointed down at an angle such that the longitudinal axis of the camera forms an angle of less than 90° with the ground. Although oblique photographs serve many purposes and are useful in reconnaissance surveys as an aid to the identification of boundaries, they are not readily converted into maps, and are not so satisfactory for soil mapping as the vertical pictures.

11.3.2 Vertical photographs are taken with fixed level camera pointed straight down from the aircraft so that the longitudinal axis of the camera

TABLE 1 CRITERIA FOR CLASSIFYING LANDS INTO IRRIGABILITY CLASSES AS SUITED TO SEMI-ARID AND ARID REGIONS

(*Clause* 9.2.1)

SL No.	PROPERTIES	IRRIGABLE SOIL/LAND CLASSES				PROVISIONALLY NON-IRRIGABLE UNCLASSIFIED CLASS 5	NON-IRRIGABLE CLASS 6
		Class 1	Class 2	Class 3	Class 4		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1)	Effective soil depth (useful to crops)	More than 90 cm	45 to 90 cm	22·5 to 45 cm	7·5 to 22·5 cm	—	Less than 7·5 cm
2)	Texture of surface	Sandy loam to clay loam inclusive	Loamy sand; clay	Sand; clay	Sand; clay	—	Any texture
3)	Soil permeability (of least permeable layer) (*see* Note 1)	5 to 50 mm/h	1·3 to 5 mm/h; 50 to 130 mm/h	0·3 to 1·3 mm/h; 130 to 250 mm/h	Less than 0·3 mm/h; Greater than 250 mm/h	—	Not applicable
4)	Available water holding capacity to depth of 90 cm	12 cm or more	9 to 12 cm	6 to 9 cm	2 to 6 cm	—	Less than 2 cm
5)	Coarse fragments, such as cobbles and stones greater than 75 mm size	Less than 5 percent	5 to 15 percent	15 to 35 percent	35 to 65 percent	—	More than 65 percent
6)	Gravel and *KANKAR* (25 to 75 mm size)	Less than 15 percent	15 to 35 percent	35 to 55 percent	55 to 70 percent	—	More than 70 percent
7)	Rock outcrops (distance apart in m)	40	20	15	5	—	Less than 5
8)	Salinity (in saturation extract) E. C. × 10^3 (*see* Note 2)	Less than 4 millimhos	4 to 8 millimhos	8 to 12 millimhos	12 to 16 millimhos	—	More than 16 millimhos
9)	Salt affected (visual), (percent of area affected)	Less than 20 percent	Less than 20 percent	20 to 50 percent	20 to 50 percent	—	More than 50 percent
10)	Severity of alkali problem	ESP less than 15 percent	ESP less than 15 percent	ESP more than 15 percent	ESP more than 15 percent	—	ESP more than 15 percent
11)	Sub-soil or substrata drainage characteristics	Lower sub-soil is at least moderately permeable or a permeable layer of atleast 150 mm thickness occurs immediately below the soil but within 3 m (sand, gravel)		No moderately permeable sub-soil or other permeable layer of atleast 150 mm thickness occurs within depth of 3 m		—	Same as for Classes 3 and 4
12)	Soil erosion status	Effects of sheet and rill erosion are reflected in effective soil depth, available moisture holding capacity and in some other factors shown above, moderately or severely gullied soils may be classified based on local experience					
13)	Slope of terrain	Less than 1 percent	1 to 3 percent	3 to 5 percent	5 to 10 percent	Class 5 includes lands which are temporarily non-irrigable, but irrigable with corrections of adverse properties. Further investigations needed	Class 6 includes lands which do not meet the minimum requirements for the other land classes and are not suitable for irrigation or small isolated tracts not susceptible to delivery of irrigation water
14)	Surface grading (*see* Note 3)	No restrictions or very moderate restrictions	Moderate restrictions	Moderately severe restrictions	Severe restrictions		
15)	Outlets	Suitable outlets available	Suitable outlets available	Suitable outlets available	No drainage outlets available		
16)	Depth of water table	More than 5 m	3 to 5 m	1·5 to 3 m	1·5 m and below		
17)	Surface drainage (*see* Note 4)	—	—	—	—		
18)	Sub-surface drainage (*see* Note 5)	—	—	—	—		

NOTE 1 — Soil permeability, as a criteria, is not applicable to deep black soils because of their unique properties. Deep black soils (Vertisols) which are inherently slowly to very slowly permeable due to expanding 2 : 1 lattice type minerals do not qualify for irrigability soil Class 1. They would qualify for being placed in Classes 2, 3 and 4.

NOTE 2 — For salinity determination, 1 : 2 soil to water ratio may be adopted and the conductivity figures (E.C. × 10^3) corresponding to each range given in item (8) of Table 1 are as below:

Salinity in 1:2 dilution	Less than 1 millimho	1 to 1·5 millimhos	1·5 to 2·5 millimhos	2·5 to 3 millimhos	More than 3 millimhos

NOTE 3 — The restrictions are in terms of the quantity of earthwork excavation needed for cut and fill. Specifications in regard to the quantities would require to be developed for each area depending on the nature of earth material and the economics of the operation required.

NOTE 4 — Surface drains involving moderate lengths of shallow drains are required for unit area under Classes 1 and 2. For Classes 3 and 4, specifications would need to be drawn up as suited for each area.

NOTE 5 — Sub-surface drains are not needed for Classes 1 and 2, or else the lands are situated within reasonably short length of natural drainage (*NULLA* or river). Specifications in regard to sub-surface drains will require to be drawn up for Classes 3 and 4. Class 4 may need pumping out drainage water.

As in the Original Standard, this Page is Intentionally Left Blank is perpendicular to the horizontal plane of the ground. In general, single lens vertical photographs which are taken in a series of independent overlapping exposures are recommended for soil survey. They have convenient size for field use and map constructions, permit of stereoscopic study, give complete details of ground features and also have satisfactory ranges of scale.

12. AERIAL PHOTO INTERPRETATION IN SOIL SURVEY

12.1 Aerial Photo Interpretation — This covers recognition, identification, systematic analysis and classification of physical and cultural characteristics of the earth's surface as pictured on the photographs and the scientific deductions of the above aspects.

12.1.1 *Recognition and Identification* — Air photo recognition is the direct classification of a directly visible object within a known category upon detection in the photo image. Photo identification is then defined as the classification of a directly visible object or element by means of information.

12.1.2 *Analysis* — Analysis is the process of delineating groups of objects or of elements which have a separate individuality for the photo interpretation.

12.1.3 *Classification* — Classification includes the description of the individual objects delineated by analysis, their arrangement into a pertinent system for use in the field investigations, and the codification necessary to express their system. Thus, classification establishes the identity of the objects differentiated by analysis.

12.1.4 *Deduction* — Deduction is a more complicated process which is largely based on converging evidence. The evidence is derived from partially visible objects or from elements which give only partial indications on the nature of certain correlative indications.

12.2 Limitations of Aerial Photographs in Soil Survey — Aerial photographs are only pictures of the earth's surface (but not of the soil) which is a three dimensional piece of landscape having specific physical, chemical and biological characteristics. For mapping soils, it is necessary to study the soils to the entire depth to know the arrangement and characteristics of the different soil horizons which reflect the overall effect of genetic processes. The morphological, physical and chemical characteristics of soil profiles will help soil classification into various taxonomic and mapping units which are shown in a soil map.

12.2.1 Since soil surveyors require data like the morphological, physical and chemical characteristics of the different soil horizons, which are not readily available on aerial photographs, the conventional field study of soil profiles and field investigations which are essential for soil classification and mapping should not be by-passed by the use of aerial photo interpretations.

12.2.2 However, a large number of soil mapping units shown on a soil map may be interpreted and estimated with a combination of photo interpretation and field observations. The following soil mapping units given in **12.2.2.1** to **12.2.2.3** may be interpreted subject to the limitations indicated against them.

12.2.2.1 *Soil series* — These are distinguished on the basis of internal characteristics of the soil profile and cannot always be expected to be seen or distinguished on aerial photographs. In some cases if they are clearly related to any of the elements of the landscape clearly visible on air photos, these may be identified.

12.2.2.2 *Soil slope classes* — With adequate experience in photo interpretation and local knowledge of the terrain mapped, soil slope classes may be evaluated and separated through photo interpretation and a minimum of field work.

12.2.2.3 *Soil texture* — Broad variations in surface soil texture may be discerned by the study of photo tone but the exact soil texture has to be determined in the field. Generally, heavier the soil, darker would be the photo tone. But variations of air photo tone are influenced by soil colour and soil moisture. Therefore, any deductions made from air photo tone without a good knowledge of the local conditions of the terrain may lead to erroneous conclusions.

12.3 Importance of Aerial Photographs in Soil Survey — In spite of many limitations, aerial photographs are useful for soil mapping. In a normal soil survey, majority of the observations made in the field without air photos are needed for locating the soil boundaries, and a few of the observations are used to describe the soils. Although air photo interpretation may have limited application in the study of the soils, it is very useful in reducing the time spent for locating the soil boundaries which are the most laborious and time-consuming part of the soil survey. Therefore, once all the soil characteristics have been observed in the field, aerial photographs and interpretation of these photographs will help considerably in the manner described in **12.3.1** and **12.3.2**.

12.3.1 The aerial photographs help to locate and plot accurately the soil boundaries. This is made possible by the several relationships existing between soil mapping units and landscape units which are visible on air photos and which have to be judged and established by the soil surveyor. These relationships may be found only by experienced soil surveyor trained in the techniques of photo interpretation.

12.3.2 Considerable time is saved in the field by reducing the number of observations and traverses which would otherwise be required for locating the soil boundaries.

12.4 Approach of Photo Interpretation — Aerial photo interpretation in soil survey should be made in an orderly and scientific manner. The various techniques and methods used should provide data which are accurate and reproducible. The two main trends of photo interpretation used in soil survey are briefly described in **12.4.1** and **12.4.2**.

12.4.1 The analytical approach of photo interpretation consists of a systematic analysis on air photos of the individual elements of the landscape, such as landform, slope, drainage, vegetation and land use, visible on the photographs and which are supposed to be related directly or indirectly to the soil mapping units. The result is a photo analytical map with lines and symbols indicating landscape units. This photo analytical map serves as a guide for the preparation of a final soil map. The mapping of the soils in the field is done in a conventional way but all the photo interpretation lines which during the field investigations are found to be useful soil boundaries shall be examined in detail. The photo analytical map should be converted by subsequent field work and necessary corrections and additions of soil data should be incorporated into final soil map. This approach is useful particularly in the case of detailed soil survey.

12.4.2 The physiographic approach would be where the terrain is analyzed and classified making use of the science of geography, geomorphology and geology. This approach requires thorough knowledge of these sciences and is useful in the case of reconnaissance soil survey.

12.5 Photo Material Required for a Soil Survey

12.5.1 The photo material required for a soil survey shall be as follows:

a) Copies of the photo index,

b) One set of glossy contact prints on single or double weight paper,

c) One or two sets of semi-matt or matt contact prints on double weight paper,

d) For detailed soil survey, sometimes one set of enlargement of alternate photographs on semi-matt or matt on double weight paper may be required (*see* Note),

e) One set of glossy photo mosaic on double weight paper at the scale of contact prints (*see* Note), and

f) Some semi-matt or matt photo mosaic on double weight paper at the scale of contact prints.

NOTE — The glossy contact prints are for stereoscopic study. The semi-matt or matt prints and the semi-matt or matt mosaics are used in the field. The glossy mosaic is used for the final soil map.

12.6 Instruments Required for Photo Interpretation — The instruments which will be needed for photo interpretation are as follows:

a) Pocket stereoscopes;
b) Mirror stereoscopes with parallax bar;
c) Scanning stereoscope;
d) Sketchmaster;
e) Radial line plotter;
f) Simple instruments for the construction of planimetric map from aerial photographs; and
g) Simple measuring devices, such as perspex scale and dot counter.

APPENDIX A

(*Clause* 7.4)

FIELD IDENTIFICATION OF SOILS BY FEEL

A-1. DETAILS OF IDENTIFICATION

A-1.1 The method for identification of soils by feel is described in **A-1.1.1** to **A-1.1.7**.

A-1.1.1 *Sand* — Sand is loose and single-grain. The individual grains may be readily seen or felt. Dry sand may be held in hand under pressure and when this pressure is released, the grains fall apart. Moist sand may stay even after release of pressure, but will crumble if touched or disturbed.

A-1.1.2 *Sandy Loam* — A sandy loam is a soil containing greater proportion of sand but which has enough silt and clay to make it somewhat cohesive. The individual sand grains may readily be seen and felt. Squeezed when dry, it will form a cast but will readily fall apart. But if squeezed when moist, a cast may be formed that will endure careful handling without breaking.

A-1.1.3 *Loam* — A loam is a soil having a relatively even mixture of different grades of sand, silt and clay. It is mellow, somewhat gritty to feel, yet fairly smooth and slightly plastic. Squeezed when dry, it will form a cast that will endure careful handling. When squeezed moist, the cast formed may be handled quite freely without breaking.

A-1.1.4 *Silt Loam* — A silt loam is a soil having a moderate amount of the fine grades of sand and only a small amount of clay; over half of the particles being silt. When dry it may appear cloddy (often crumbly) but the lumps may be readily broken and when pulverized it feels soft. When wet the soil readily runs together and puddles. Either dry or moist it will form casts that may be handled freely without breaking but when squeezed between thumb and finger, it will not ribbon but will give a broken appearance.

A-1.1.5 *Clay Loam* — A clay loam is a fine textured soil which usually breaks into clods or lumps that are hard when dry. When the moist soil pinched out between the thumb and finger it will form a thin 'ribbon' which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.

A-1.1.6 *Sandy Clay* — This is a mixed type of soil in which the sand and clay fractions will be in equal proportions. When dry the soil forms irregular clods which are quite hard and do not easily break or crumble. When wet it becomes plastic but no ribbon will be formed when pinched between the thumb and fingers. The soil gives a distinctly gritty and sticky feeling.

A-1.1.7 *Clay* — A clay is a fine textured soil that usually forms very hard lumps or clods when dry and is quite plastic and usually sticky when wet. When the moist soil is pinched out between the thumb and fingers it will form a long, flexible 'ribbon'. Some fine clays, very high in colloids are friable and lack plasticity under all conditions.

APPENDIX B

(*Clause* 7.7.2)

TERMS RELATING TO CONSISTENCY

B-1. DETAILS OF TERMS

B-1.1 Consistency When Wet — Consistency when wet is determined at or slightly above field capacity and is expressed either in terms of stickiness or plasticity.

B-1.2 Stickiness — Stickiness is the quality of adhesion to other objects. For field evaluation of stickiness, soil material is pressed between thumb and finger and its adherence noted. Degrees of stickiness are described in **B-1.2.1** to **B-1.2.4**.

B-1.2.1 *Non-sticky* — After release of pressure, practically no soil material adheres to thumb or finger.

B-1.2.2 *Slightly Sticky* — After pressure, soil material adheres to both thumb and finger but comes off rather clearly.

B-1.2.3 *Sticky* — After pressure, soil material adheres to both thumb and finger and tends to stretch.

B-1.2.4 *Very Sticky* — After pressure, soil material adheres strongly to both thumb and forefinger and is decidedly stretched when they are separated.

B-1.3 Plasticity — Plasticity is the ability to change shape continuously under the influence of an applied stress and to retain the impressed shape on removal of the stress. For field determination of plasticity, roll the soil material between thumb and finger and observe whether or not a wire or thin rod of soil may be formed. The degree of resistance to deformation at or slightly above field capacity is expressed as given in **B-1.3.1** to **B-1.3.4**.

B-1.3.1 *Non-plastic* — Soil cannot be drawn into a wire form.

B-1.3.2 *Slightly Plastic* — Soil may be drawn into a wire form but soil mass is easily deformable.

B-1.3.3 *Plastic* — Soil may be drawn into a wire form but moderate pressure is required for deformation of the soil mass.

B-1.3.4 *Very Plastic* — Soil may be drawn into a wire form but much pressure is required for deformation of the soil mass.

B-1.4 Consistency When Moist — Consistency when moist is determined at a moisture content approximately midway between air dry and field capacity. At this moisture content, most soil materials exhibit a form of consistency characterized by (a) tendency to break into smaller masses rather than into powder, (b) some deformation prior to rupture, (c) absence of brittleness, and (d) ability of the material after disturbance to join again when pressed together. The resistance decreases with moisture content, and accuracy of field descriptions of this consistency is limited by the accuracy of estimating moisture content. To evaluate this consistency, select and attempt to crush in the hand a mass that appears slightly moist.

B-1.5 Loose — Non-coherent.

B-1.6 Friable — Soil material crushes easily under gentle to moderate pressure between thumb and forefinger, and joins when pressed together.

B-1.7 Very Friable — Soil material crushes under very gentle pressure between thumb and forefinger, and joins when pressed together.

B-1.8 Firm — Soil material crushes under moderate pressure between thumb and forefinger but resistance is distinctly noticeable.

B-1.9 Very Firm — Soil material crushes under strong pressure barely crushable between thumb and forefinger.

B-1.10 Extremely Firm — Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger and cannot be broken apart bit by bit.

B-1.11 Consistency When Dry — The consistency of soil materials when only dry is characterized by rigidity, brittleness, maximum resistance to fragments with rather sharp edges, and inability of the crushed material to join again when pressed together.

B-1.12 Soft — Soil mass is very weakly coherent and fragile, breaks into powder or individual grains under very slight pressure.

B-1.13 Slightly Hard — Weakly resistant to pressure, easily broken between thumb and forefinger.

B-1.14 Hard — Moderately resistant to pressure; can be broken in the hand without difficulty but is barely breakable between thumb and forefinger.

B-1.15 Very Hard — Very resistant to pressure, can be broken in the hand only with difficulty, not breakable between thumb and forefinger.

B-1.16 Extremely Hard — Extremely resistant to pressure, cannot be broken in the hand.

APPENDIX C

[*Clause* 9.1, *Item* (f)]

LAND USE CAPABILITY

C-1. LAND SUITED FOR CULTIVATION

C-1.0 The land is categorized under four different classes as given in **C-1.1** to **C-1.4**.

C-1.1 Class I Land — This is very good land that may be cultivated safely with ordinary good farming methods. It is nearly level land (slope less than one percent) and has deep, productive, easily worked soils and is subject to only slight erosion. It is well drained and is suited for intensive cropping. The land is suited for a wide variety of crops. For continued good production, these lands require the use of fertilizers, green manure crops and crop rotation.

C-1.2 Class II Land — This is good land that may be cultivated with easily available practices. Some of the limitations of this class of land are gentle slope, moderate susceptibility to erosion, moderate depth, moderate overflow and moderate wetness. Each of these limitations requires special methods for correction, such as contour bunding, strip cropping, contour tillage, crop rotations that include grasses or legumes, drainage and the application of fertilizers and manures.

C-1.3 Class III Land — This class of land has restricted use for cultivation. The land is moderately good and may be used for cropping provided intensive management measures are taken. This kind of land is characterized by one or more of the following limitations:

a) Moderate steep slope,
b) High susceptibility to erosion,
c) Moderate overflow,
d) Slow sub-soil permeability,
e) Excessive wetness,
f) Shallow depth,
g) Hard pan or clay pan,
h) Sandy or gravelly with low moisture capacity, and
j) Low inherent fertility.

C-1.4 Class IV Land — This class of land has very restricted use for cultivation and needs special care in handling and management. The variety of crops that may be grown is limited. Its cropping use is restricted by slope, erosion, unfavourble soil characteristics and adverse climate.

C-2. LAND UNSUITED FOR CULTIVATION

C-2.0 The land is categorized under four different classes as given in **C-2.1** to **C-2.4**.

C-2.1 Class V Land — This land is not suited for cultivation but is suited for pasture and grassland. Cultivation may not be feasible because of one or more factors, such as wetness, stoniness or some other limitations. Land is nearly level and not subject to more than slight wind or water erosion. It occurs in many swampy areas that cannot be drained easily.

C-2.2 Class VI Land — This land is subject to moderate limitations under grazing or forestry use. It is too steep, subject to erosion, shallow, wet or dry but with careful management may be made suitable either for grazing or forestry. Gullies in such areas should be controlled by diversion of water, provision of contour furrows or ridges.

C-2.3 Class VII Land — This land is very steep, eroded, stony, rough, shallow, dry or swampy and is recommended particularly in humid regions only for forestry and wood land and not pasture.

C-2.4 Class VIII Land — This land includes such areas as marshes, deserts, deep gullies, rocky escarpments and very steep, rough stony, barren land. It is suited only for wild life, recreation of water-shed protection uses.

APPENDIX D

(*Clause* 9.2.1)

IRRIGATION CAPABILITY CLASSES

D-1. CLASSIFICATION

D-1.1 From the point of irrigation capability, soils/lands should be classified into six classes as given in **D-1.1.1** to **D-1.1.6**.

D-1.1.1 *Class 1* — The soil is quite suitable for irrigation having good texture, adequate depth and good available moisture holding capacity. The soil has low salinity and alkalinity problems. The land slope and features are favourable with the water table at satisfactory level. Drainage conditions are satisfactory. The needs for levelling and land-forming are minimum.

D-1.1.2 *Class 2* — Soil in this group is moderately suitable for irrigation farming with limited hazards. The texture of the soil is within the satisfactory range and the soil is moderately deep. The permeability and the available water holding capacity of the soil are moderately good. Saline and alkaline conditions are satisfactory. The slope of land and nature of terrain offers moderate limitations. The drainage restrictions and need for levelling and land-forming are moderate.

D-1.1.3 *Class 3* — These soils are suitable for limited irrigation and cropping suitability is also limited. The texture of soil may vary between extremes of sand and clay under moderate depth. Water holding capacity is moderate. Soluble soils and exchangeable sodium are moderately high. Internal permeability is fair. The slope of land and terrain features offer more severe restrictions compared to Class 2.

D-1.1.4 *Class 4* — The soils in this class are shallow and the texture may range between the extremes of sand and clay. Soil permeability may also vary within wide range depending upon texture of the least permeable layer. The water holding capacity is low and the salinity is high and the exchangeable sodium percentage is more than 15 percent. The terrain features offer more severe restrictions which limit the use of the lands for irrigation agriculture. Drainage difficulties are severe.

D-1.1.5 *Class 5* — These include lands which will require additional economic and engineering studies to determine the irrigability. Such lands are classed as temporarily non-irrigable, pending execution of reclamation or corrective works.

D-1.1.6 *Class 6* — The specification of soil and terrain features fall outside those for Classes 1 to 4. Because of the severe restrictions irrigation is uneconomic or wasteful. These lands are to be considered as non-irrigable because the soil and land conditions do not meet the minimum requirements of the next higher class recognized in a particular survey. This class may also include small areas of arable lands lying within larger bodies of non-arable lands.

(*Continued from page* 1)

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