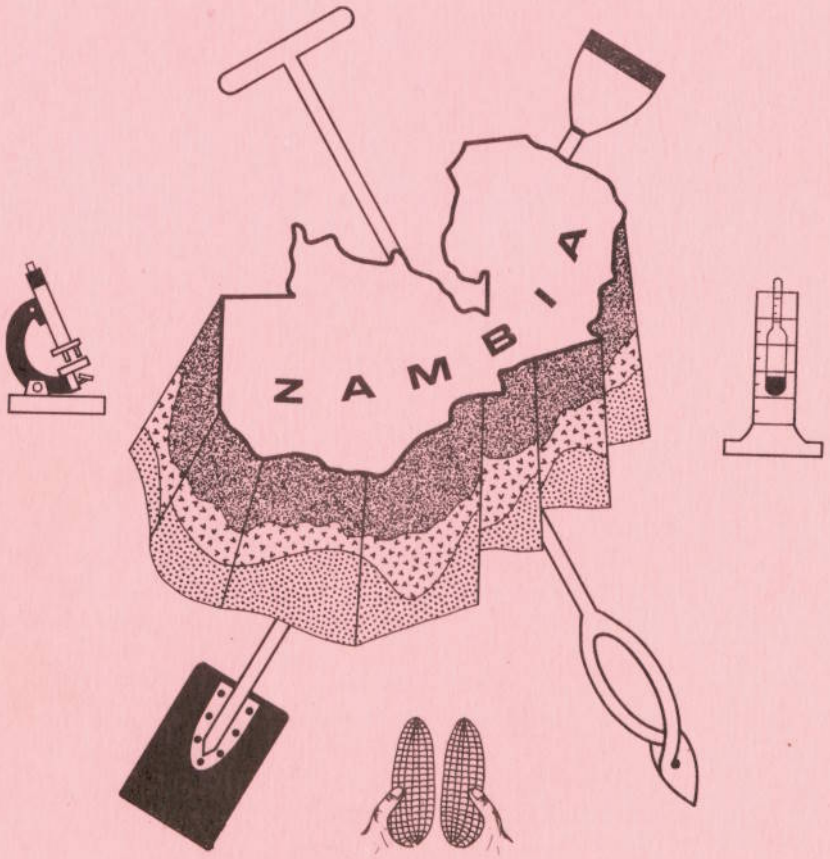
REPUBLIC OF ZAMBIA

MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

TECHNICAL GUIDE No. 18

FIELD GUIDE FOR SOIL SURVEYORS

BY PETER WOODE



SOIL SURVEY UNIT
RESEARCH BRANCH
DEPARTMENT OF AGRICULTURE
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FIELD GUIDE FOR SOIL SURVEYORS.

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CONTENTS

INTRODUCTION.

This guide is a collection of the various guidelines, tables, checklists, and identification charts that are commonly required by a soil surveyor. It is not meant to replace any of the sources from which many these data were drawn, but merely to bring together into one reference book the most commonly needed material.

In order to avoid lengthy deliberations, some of the definitions given here have been simplified. It is stressed that when carrying out a formal profile description the definitions given here may be insufficient. In such cases reference must be made to the profile description manual.

The first draft of this guide was circulated amongst the Soil Survey Unit in 1985, and the second draft in 1986. Suggestions for improvements and additions were made by many members of the unit. Some suggestions involved changes in existing recommendations (noteably the land capability system). These were not acted upon because it was not the author's mandate to change systems. However, many of the suggestions were taken up, and thanks are due to all who took the time to reply.

Sample field sheets, application forms for soil analyses, and application forms for soil surveys are included. If printed copies of these forms are not available, these samples may be copied onto stencil in the provinces. The land capability field sheets are for the use of planning staff when carrying out land capability surveys. For soils surveys, the soil survey sheets should always be used. It is not the intention that both sheets are used on the same survey.

Some of the entries such as the drainage tables, the time estimates, and the norms for analytical data, are still evolving. Suggestions for upgrading these will always be gratefully received.

The following members of the Soil Survey Unit were responsible for certain sections: Mr. Chris Van Der Meeren for the Soil Survey Information Sheet; Mr. Barry Dalal-Clayton for the Geomorphic Legend; Mr. Jim Cheatle for the analytical data norms and relationships; Mr. Wietze Veldkamp for the key to the soil series; Mr. Otto Spaargaren for the forms for soil analyses. The illustrations were drawn by Mr. Joseph Chisanga. Many others contributed in many ways.

The remainder of the guide is the work of the author. It was typed on an Amstrad word processor by the author. The calculations of time estimates, and the diagrams of structure classes, area coverage estimations, and descriptions of mottles were produced by BASIC programs written by the author.

SURVEY PLANNING.

Although the actual operations for the different survey levels are different, a common approach should be made to all surveys. These are summarised in the following list, which is a framework to be modified to suit specific cases:

1. Open a file and fill in a "survey information sheet".

2. Complete an application form for private applications.

3. Clarify the aims of the survey, and decide upon the type and level of survey.

4. Order air photos and mosaics well in advance.

5. Obtain topographic and geological maps.

6. Search for previous survey and related data for the area.

7. For State Land, obtain boundary data from the Survey Dept. or the Planning Section.

8. Obtain Meteorological data.

9. Make a time estimate and budget, and inform the applicant, Soil Correlator, and Senior Soil Surveyor about the proposed date of the survey.

10. File air photos in order run by run; check for quality and correct coverage; base line air photos.

11. Plot flight lines onto topographic maps.

12. Carry out initial API and make API legend.

13. Visit the survey area; carry out a few spot augerings and draft field legend; locate camp site; consult local farmers; inform local officials about the survey.

14. a) Exploratory and reconnaissance surveys: Decide on pilot areas or representative catenas for initial investigations.

    b) Semi-detailed and detailed surveys: Plan provisional location of traverses or observation sites.

15. Check field equipment against check list.

16. Check condition of vehicle.

17. Commence field work with reconnaissance observations.

18. Reconnaissance surveys: survey pilot areas at higher level and refine legend.

19. Open and describe preliminary profiles.

20. Consult Soil Correlator and set up soil legend.

21. Revise traverse or observation site location plan.

22. Commence main auger observation work.

23. Every day: file field sheets, plot position of observations, update legend, carry out API.

24. Open, describe and sample profiles.

25. Discuss with Land Evaluator and Soil Correlator whether a field trip with either of them is necessary to examine the soil profiles and land characteristics.

26. If relevant, take topsoil samples for fertility analysis, and carry out soil physical tests (infiltration etc.).

27. Revise API and interpret draft soil map whilst in the field.

28. Prepare preliminary report as soon as field work is complete and before commencing on any other survey.

29. At all times file all data and keep the file tidy and up to date.

EQUIPMENT CHECKLIST.

SURVEY

Barrel augers
Dutch augers
Sand augers
Back pack
Clip board
Cyclometer
Chain & arrows
Colour book
Field sheets
Profile guidelines
Profile sheets
Technical guides
Chinagraphs
Pencils, pens
Rubbers
Protractors
Set squares
Rulers
Mirror stereoscope
Pocket stereoscopes
Masking tape
Compass
2 - 3m tape measure
Clinometer
Abney level
Water bottles
Geological hammer
pH papers
Distilled water
Dilute HCl in bottle
Plastic bags
Labels & string
Profile pick
Hand lens
Maps
Air Photos in bag
Mosaics
Correlation boxes
Proportional dividers
Scale ruler
Auger extensions
Satelite images
Altimeter
Sand ruler

CAMP

Tents
Tent poles
Tent guy ropes
Tent pegs
Fly sheets
Ground sheets
Camp beds
Mattresses
Wash/bath stands
Plastic bowls
Buckets
Shower bucket
Water heating drum
Tilley lamp
Spare mantles
Spirit
Parafin
Hurricane lamps
Washing line
Chairs
Tables
Mosquitoe nets
Water containers
Water filters
Water coolers
Kitchen box
Cooking utensils
Pots & pans
Plates & mugs
Spades/shovels
Hoes
Axes
Slashers
Sickles
Picks/Mattocks
Pangas
First aid kit
Snake bite kit

ESSENTIAL BOOKS

Tech. Guide No. 11
Tech. Guide No. 13
Tech. Guide No. 14
Tech. Guide No. 15
Tech. Guide No. 17
Tech. Guide No. 18
"FAO legend"
"Keys to Soil Taxonomy"
"Know Your Trees"
"Field Guide to Rocks & Minerals"

VEHICLE

Fuel drums
Jerry cans
Drum pump
Filter funnel
Patches
Solution
Tyre levers
Heavy hammer
Valve key
Foot or hand pump
Tool kit
Engine oil
Brake fluid
Jack (vehicle)
Winch
Tow rope
Spare fuel filter
Wheel brace
Spare fan belt
Spare wheel
Fuses (esp winch on LR)
Service manual
High lift jack

PERSONAL

Food
Protective clothing
Boots/strong shoes
Hat
Reading matter
Toilet paper
Matches
Pocket knife
Torch
Malaria tablets
Asprins or Panadols
Spare pen
Raincoat
Bedding
Bible

CHARACTERISTICS OF DIFFERENT SURVEY LEVELS

DETAILED SURVEYS

MAP SCALE (Final)	:	1:20,000 and greater
FIELD MAP SURVEY	:	Often required
IDEAL AIR PHOTO SCALE	:	1:10,000 - 1:20,000
SATELITE IMAGES	:	Not used
OBSERVATION PATTERN	:	Rigid grid
OBSERVATION DENSITY	:	Less than 10 ha / observation More than 10 observations / square kilometre
TYPICAL TRAVERSE SPACING	:	100 - 400 metres
TYPICAL OBSERV. SPACING	:	50 - 200 metres
PROFILE DESCRIPTIONS	:	1/minor map unit, at least 2/major map unit
ANALYTICAL REQUESTS	:	Specialised, for crop requirements etc.
SOIL PHYSICAL TESTS	:	Always done, at least 1/ major arable map unit
FERTILITY SAMPLES	:	At least 1/arable map unit
MAPPING METHODOLOGY	:	Soil boundaries mapped in field
FIELD MAP TYPE	:	Enlarged air photos, or field surveyed map
FINAL MAP TYPE	:	Orthophoto
MAP UNIT CLASSIFICATION	:	Phase/sub-phase of soil series/land eval. units
SMALLEST UNIT ON MAP	:	1.5 ha
NARROWEST UNIT ON MAP	:	40 metres
TYPICAL AREA COVERED	:	100 - 1,000 ha
TYPICAL WORK RATES*	:	100 ha - 7 weeks 500 ha - 12 weeks 1,000 ha - 17 weeks

USES OF SURVEY :

1. Irrigation scheme planning.
2. Farm planning where soil pattern complex.
3. Research stations or plots.
4. Other high cost enterprise planning.

MAJOR STAGES OF SURVEY :

1. Prepare a base map - either enlarged AP or may require field survey.
2. Air photo interpretation. Scale may be too large for meaningful stereo interpretation. Combine with relevant topographic / geological units.
3. Reconnaissance field work. Auger observations in all major units interpretated above. Preliminary soil legend prepared.
4. Plan observation grid layout.
5. Main auger survey. Often requires accurate pegging of observation sites prior to survey. Refine legend. Preliminary map made by encircling observation points with same soils. Refine from interpreted map and then by making further auger observations to "follow" boundaries on the ground.
6. Open, describe and sample profiles to fully characterise map units and finalise legend.
7. Take fertility samples and carry out physical tests.

* Work rates do not include final report preparation.

CHARACTERISTICS OF DIFFERENT SURVEY LEVELS

SEMI-DETAILED SURVEYS

MAP SCALE (Final)	:	1:50,000
FIELD MAP SURVEY	:	Not usually required - air photos used
IDEAL AIR PHOTO SCALE	:	1:20,000 - 1:40,000
SATELITE IMAGES	:	Not usually used
OBSERVATION PATTERN	:	Usually flexible grid. Occassionally rigid grid or free survey
OBSERVATION DENSITY	:	15 - 100 ha / observation 6 - 1 observations / square kilometre
TYPICAL TRAVERSE SPACING	:	500 metre - 1 kilometre
TYPICAL OBSERV. SPACING	:	300 metre - 1 kilometre
PROFILE DESCRIPTIONS	:	1 - 2 per soil series
ANALYTICAL REQUESTS	:	Usually for classification. Rarely specialised
SOIL PHYSICAL TESTS	:	Sometimes carried out
FERTILITY SAMPLES	:	1 / major arable mapping unit
MAPPING METHODOLOGY	:	Most boundaries located by API and confirmed in field. Some located in field
FIELD MAP TYPE	:	Aerial photos. Occassionally 1:50,000 sheets
FINAL MAP TYPE	:	Orthophoto or 1:50,000 base map
MAP UNIT CLASSIFICATION	:	Series/associations of soils/land eval. units
SMALLEST UNIT ON MAP	:	10 ha
NARROWEST UNIT ON MAP	:	100 metres
TYPICAL AREA COVERED	:	500 - 20,000 ha
TYPICAL WORK RATES*	:	1,000 ha - 6 weeks 10,000 ha - 14 weeks 20,000 ha - 22 weeks

USES OF SURVEY :

1. Feasibility studies.
2. Regional land use planning.
3. Farm boundary decisions.
4. Farm planning for rainfed agriculture.
5. Location of potential sites for irrigation and other high cost enterprises. These potential sites will then be surveyed at a detailed level.

MAJOR STAGES OF SURVEY :

1. Air photo interpretation. Delineation of land elements and significant geological boundaries, etc. Most boundaries that appear on the final map are plotted at this stage, but there is little soil information in the API legend.
2. Reconnaissance field work. Observations in all major API units and along representative catenas. Basic soil legend developed at this stage. Observation pattern planned. May open preliminary profiles.
3. Main auger survey. Refine legend. Revise API boundaries, add field observed boundaries, complete draft soil map.
4. Open, describe and sample profiles to fully characterise map units and finalise soil legend.
5. If relevant, take fertility samples and/or carry out physical tests.

* Work rates do not include final report preparation.

CHARACTERISTICS OF DIFFERENT SURVEY LEVELS

RECONNAISSANCE SURVEYS

MAP SCALE (Final)	:	1:100,000 - 1:250,000
FIELD MAP SURVEY	:	Not required
IDEAL AIR PHOTO SCALE	:	1:80,000
SATELITE IMAGES	:	Used in conjunction with air photos
OBSERVATION PATTERN	:	Free survey
OBSERVATION DENSITY	:	200 - 2,000 ha / observation 0.5 - 0.05 observations / square kilometre
TYPICAL TRAVERSE SPACING	:	Not relevant
TYPICAL OBSERV. SPACING	:	Not relevant
PROFILE DESCRIPTIONS	:	1 per major series
ANALYTICAL REQUESTS	:	For classification
SOIL PHYSICAL TESTS	:	Not carried out
FERTILITY SAMPLES	:	Rarely taken
MAPPING METHODOLOGY	:	API / satelite image interp. with field checks
FIELD MAP TYPE	:	Topographic sheets or satelite images
FINAL MAP TYPE	:	Topographic map base
MAP UNIT CLASSIFICATION	:	Sub-group level
SMALLEST UNIT ON MAP	:	40 - 250 ha
NARROWEST UNIT ON MAP	:	200 - 500 metres
TYPICAL AREA COVERED	:	50,000 - 500,000 ha
TYPICAL WORK RATES*	:	50,000 ha - 7 weeks 250,000 ha - 17 weeks 500,000 ha - 29 weeks

USES OF SURVEY :

1. Overview of soil and land resources in a region.
2. Selection of potential areas for development. These areas will then be surveyed at a more detailed level.

MAJOR STAGES OF SURVEY :

1. Interpretation of geological / topographic / exploratory survey data.
2. Air photo or satelite image interpretation.
3. Compilation into preliminary field map and interpretation legend.
4. Carry out pilot surveys at a more detailed survey level to establish soil relationships in map units.
5. Compile the field legend
6. Free survey field work - check boundaries and revise map and legend.
7. Open, describe and sample profiles to fully characterise map units and finalise soil legend.

* Work rates do not include final report preparation.

CHARACTERISTICS OF DIFFERENT SURVEY LEVELS

EXPLORATORY SURVEYS

MAP SCALE (Final)	:	1:500,000 - 1:10,000,000
FIELD MAP SURVEY	:	Not required
IDEAL AIR PHOTO SCALE	:	1:80,000
SATELITE IMAGES	:	Major remote sensing tool
OBSERVATION PATTERN	:	Free survey
OBSERVATION DENSITY	:	15,000 - 40,000 ha / observation
TYPICAL TRAVERSE SPACING	:	Not relevant
TYPICAL OBSERV. SPACING	:	Not relevant
PROFILE DESCRIPTIONS	:	1 / dominant and co-dominant soil type
ANALYTICAL REQUESTS	:	For classification
SOIL PHYSICAL TESTS	:	Not carried out
FERTILITY SAMPLES	:	Not taken
MAPPING METHODOLOGY	:	Landscape units are interpretated from satelite images, geological and other maps. Field work characterises these units.
FIELD MAP TYPE	:	Satelite images
FINAL MAP TYPE	:	Topographic map base
MAP UNIT CLASSIFICATION	:	Higher order units
SMALLEST UNIT ON MAP	:	4,000 ha
NARROWEST UNIT ON MAP	:	2 km
TYPICAL AREA COVERED	:	2,000,000 ha
TYPICAL WORK RATE*	:	2,000,000 ha / year

USES OF SURVEY : Broad overview of land resources nationwide.

MAJOR STAGES OF SURVEY :

1. Compilation of existing soils information.
2. Interpretation of maps, air photos and satelite images.
3. Synthesis map of landscape units and field legend compiled.
4. Free field survey to characterise the composition of the landscape units.
5. Profiles described in dominant and co-dominant soils.

* Work rates do not include final report preparation.

SITE EVALUATION.

Site evaluations are usually carried out on small areas of land that can be examined in one day. The area covered depends upon access, uniformity, vegetation cover, and land use.

Usually a site evaluation covers a field or fields on a farm. Each area that the farmer defines as a management unit is treated seperately. If the farmer intends to divide his area into small fields that will be managed seperately, then a seperate evaluation is carried out on each field. If, however, he intends to treat a large tract of land as a single management unit, then the whole area should be evaluated as one.

1. Carry out an initial API. Relate this to your previous knowledge of the area, or of similar areas in other localities. This requires experience, so that a site evaluation cannot be entrusted to inexperienced staff.

2. On site, check the surface characteristics: erosion, surface drainage problems, gravelly or stoney topsoil, frequent rock outcrops, excessive termite mounds, etc..

3. Measure the average site slope and compare it with the texture of the topsoil. If the topsoil texture is sandy clay or heavier and the slope is more than 5%, or if the topsoil texture is sandy clay loam or lighter and the slope is more than 3%, then the site is unsuitable for most arable use without the construction of soil conservation measures.

4 Auger at several places to ascertain the uniformity of the site. If the average soil depth is less than 50cm deep over rock, or is less than 30cm deep over gravel, then the site is probably unsuitable for arable use.

5. Determine the drainage characteristics of the site.

6 Dig at least one mini pit and determine the dominant soil series.

7. Take composite samples of both topsoil (0-20cm) and upper subsoil (30-40 cm), from at least 30 sub-samples and send them for fertility analyses.

8. If irrigation is to be used, evaluate the proposed water source.

9. On the basis of the above data, in conjunction with a knowledge of the agro-ecological zone and the soil series, find the land evaluation ratings for the intended crops under the proposed level of land use.

10. Write a short report specifying the main characteristics of the land and soil, and giving cropping and management recommendations. A site evaluation does not involve mapping.

SURVEY INFORMATION SHEET

This sheet should be used to open the file for each survey undertaken.

Name of farm or area	:
Farm number	:
Registered owner of land	:
Type of rights held to land	:
Location	:
District	:
Province	:
Chief	:
Address	:
Telephone number	:
Area (hectares)	:
Survey requested by	:
Reason for survey	:
Date requested	:
Date field work commenced	:
Date field work completed	:
Survey level	:
Survey scale	:
Surveyor(s)	:
Survey unit	:
Air photo flight	:
Air photo runs and numbers	:
Topographic sheet numbers	:
Geological report numbers	:
Landsat coverage	:
Previous surveys	:
Other background information	:
Report title	:
Report number	:
Date completed	:

		tick	
Maps:	Location	( )	Scale :
	Geology	( )	Scale :
	Vegetation	( )	Scale :
	Physiography	( )	Scale :
	Land use	( )	Scale :
	Land capability	( )	Scale :
	Irrigability	( )	Scale :
	Soils	( )	Scale :
	Land evaluation	( )	Scale :

Time requirements:	Estimated	Actual
Pre-field	days:	days:
Field	days:	days:
Draft maps	days:	days:
Preliminary report	days:	days:
Final report	days:	days:

No. of field staff (specify) :
No. of field teams :
No. of casual field workers :

No. of kilometres run :

Subsistence allowance paid :
Lunch allowance paid :
Fuel and lubrication costs :
Photographic costs :
Report costs :
Other costs :
TOTAL COST :
Cost per hectare :

Accessibility of survey area :
Scale of base map :
Quality of base map :
Type of field map :
Average observation density :
No. of auger observations :
No. of profiles :
Profile numbers :
No. of mapping units :
Physical tests :
No. of fertility samples :

REMARKS:

TIME ESTIMATES FOR SOIL SURVEYS (days).

DETAILED SURVEYS. (Map scales 1:20,000 - 1:5,000)

	Area of survey x 100 ha									
	1	2	3	4	5	6	7	8	9	10
PRE-FIELD										
Information gathering	2	2	2	2	2	2	2	2	2	2
Air photo interpretation[1]	1	1	1	1	1	1	1	1	1	1
Preparations for field[3]	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
Miscellaneous[2]	1	1	1	1	1	1	1	1	1	1
FIELD WORK										
Setting up/breaking camp	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2
Prelim. reconnaissance[4]	0-1	0-1	0-1	0-1	0-1	0-1	1	1	1	1
Base map preparation	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2
Auger survey[5]:										
400m x 200m grid:										
25 sites / day	1	1	2	2	3	3	4	4	5	5
20 sites / day	1	1	2	3	3	4	4	5	6	6
15 sites / day	1	2	3	3	4	5	6	7	8	8
200m x 100m grid:										
25 sites / day	2	4	6	8	10	12	14	16	18	20
20 sites / day	3	5	8	10	13	15	18	20	23	25
15 sites / day	3	7	10	13	17	20	23	27	30	33
100m x 50m grid:										
25 sites / day	8	16	24	32	40	48	56	64	72	80
20 sites / day	10	20	30	40	50	60	70	80	90	100
15 sites / day	13	27	40	53	67	80	93	107	120	133
Profile descriptions[5]	4	4	5	5	5	5	5	6	6	6
Fertility samples[5]	0-2	0-3	0-3	0-4	0-4	0-4	0-4	0-4	0-4	0-4
Physical tests	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Travel to & from camp[6]	2-3	2-5	2-7	2-9	2-11	2-12	3-14	3-16	3-17	3-19
Miscellaneous[2]	----- 25% of total field work-----									
POST-FIELD										
Draft maps	2	3	3	4	4	4	5	5	6	6
Draft prelim. report	3	3	4	4	4	4	4	5	5	5
Check, correct, compile	1	1	1	1	1	1	1	1	1	1
Miscellaneous[2]	2	2	2	2	2	2	3	3	3	3
Complete final report	--- 1½ x field work (min 20, max 130 days) ---									

NOTES

[1] Based on 10 photos/day, each covering 3,500ha (1:30,000).
[2] Miscellaneous is a 25% contingency to include non-survey duties.
[3] 2 days if camping, 1 day if not camping.
[4] Omit if auger survey is less than 4 days.
[5] Divide by number of field teams.
[6] Total field days divided by 10 if camping.

TIME ESTIMATES FOR SOIL SURVEYS (days).

SEMI-DETAILED SURVEYS. (Map scales 1:50,000 - 1:30,000)

	Area of survey x 1000 ha									
	1	2	3	4	5	10	20	30	40	50
PRE-FIELD										
Information gathering	2	2	2	2	2	2	2	2	2	2
Air photo interpretation[1]	1	1	1	1	1	1	1	1	1	2
Preparations for field[3]	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
Miscellaneous[2]	1	1	1	1	1	1	1	1	1	2
FIELD WORK										
Setting up/breaking camp	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2
Prelim. reconnaissance[4]	0-1	0-1	0-1	0-1	0-1	1	1	2	2	3
Auger survey[5]:										
1000m x 1000m grid:										
20 sites / day	1	1	2	2	3	5	10	15	20	25
15 sites / day	1	1	2	3	3	7	13	20	27	33
10 sites / day	1	2	3	4	5	10	20	30	40	50
500m x 1000m grid:										
20 sites / day	1	2	3	4	5	10	20	30	40	50
15 sites / day	1	3	4	5	7	13	27	40	53	67
10 sites / day	2	4	6	8	10	20	40	60	80	100
300m x 600m grid:										
25 sites / day	2	4	7	9	11	22	44	67	89	111
20 sites / day	3	6	8	11	14	28	56	83	111	139
15 sites / day	4	7	11	15	19	37	74	111	148	185
Profile descriptions[5]	4	4	4	4	5	5	6	7	8	9
Fertility samples[5]	0-4	0-4	0-4	0-4	0-4	0-4	0-4	0-4	0-4	0-4
Soil physical tests	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Travel to & from camp[6]	2	2-3	2-3	2-4	2-4	3-7	3-11	4-16	5-21	6-26
Miscellaneous[2]	----- 25% of total field work -----									
POST-FIELD										
Draft maps	2	2	2	2	3	3	4	5	6	7
Draft prelim. report	3	3	3	3	4	4	5	6	7	8
Check, correct, compile	1	1	1	1	2	2	3	4	4	4
Miscellaneous[2]	2	2	2	2	2	2	3	4	4	5
Complete final report	--- 1½ x field work (min 20, max 130 days) ---									

NOTES

[1] Based on 10 photos/day, each covering 3,500ha (1:30,000).
[2] Miscellaneous is a 25% contingency to include non-survey duties.
[3] 2 days if camping, 1 day if not camping.
[4] Omit if auger survey is less than 4 days.
[5] Divide by number of field teams.
[6] Total field days divided by 10 if camping.

TIME ESTIMATES FOR SOIL SURVEYS (days).

RECONNAISSANCE SURVEYS. (Map scales 1:250,000 - 1:100,000)

	Area of survey x 1000 ha									
	5	10	50	100	150	200	250	500	750	1000
PRE-FIELD										
Information gathering	3	3	3	4	4	5	5	7	9	10
Air photo interpretation[1]	1	1	2	3	5	7	8	17	20	20
Preparations for field[3]	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2
Miscellaneous[2]	2	2	2	2	3	4	4	7	8	8
FIELD WORK										
Setting up/breaking camp	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2
Prelim. reconnaissance[4]	0	0-1	0-2	1-3	1-3	2-3	2-3	3	3	3
Pilot area surveys	1	1	2	4	6	8	10	20	30	40
Auger survey[5]:										
1250ha / observation:										
20 sites / day	1	1	2	4	6	8	10	20	30	40
15 sites / day	1	1	3	5	8	11	13	27	40	53
10 sites / day	1	1	4	8	12	16	20	40	60	80
750ha / observation:										
20 sites / day	1	1	3	7	10	13	17	33	50	67
15 sites / day	1	1	4	9	13	18	22	44	67	89
10 sites / day	1	1	7	13	20	27	33	67	100	133
250ha / observation:										
25 sites / day	1	2	10	20	30	40	50	100	150	200
20 sites / day	1	3	13	27	40	53	67	133	200	267
15 sites / day	2	4	20	40	60	80	100	200	300	400
Profile descriptions[5]	4	4	4	4	4	5	6	11	15	15
Fertility samples[5]	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-3	0-4	0-4
Soil physical tests	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Travel to & from camp[6]	2	2	2-4	2-7	2-9	3-12	3-15	5-28	7-41	9-53
Miscellaneous[2]	----- 25% of total field work -----									
POST-FIELD										
Draft maps	2	2	2	2	3	4	5	10	15	15
Draft prelim. report	5	5	5	5	5	6	6	6	9	10
Check, correct, compile	1	1	1	1	1	1	1	2	3	4
Miscellaneous[2]	2	2	2	2	2	3	3	5	7	7
Complete final report	--- 1½ x field work (min 20, max 130 days) ---									

NOTES

[1] Based on 10 photos/day, each covering 3,500ha (1:30,000).
[2] Miscellaneous is a 25% contingency to include non-survey duties.
[3] 2 days if camping, 1 day if not camping.
[4] Omit if auger survey is less than 4 days.
[5] Divide by number of field teams.
[6] Total field days divided by 10 if camping.

AVERAGE TIME ESTIMATES FOR SOIL SURVEYS.

DETAILED SURVEYS. (Map scales 1:20,000 - 1:5,000)

Time estimates for typical detailed surveys under camping conditions, with 1 field team, using a 200m x 100m grid, observing 20 sites / day, including base map preparation, fertility sampling, and soil physical tests.

		Area of survey x 100 ha									
		1	2	3	4	5	6	7	8	9	10
PRE-FIELD	(days)	6	6	6	6	6	6	6	6	6	6
FIELD WORK	(days)	23	29	34	39	43	45	50	54	58	61
POST-FIELD	(days)	8	9	10	11	11	11	13	14	15	15
PRELIMINARY REPORT	(days)	37	44	50	56	60	62	69	74	79	82
	(weeks)	7	9	10	11	12	12	14	15	16	16
FINAL REPORT	(days)	72	88	101	115	125	130	144	155	166	174
	(weeks)	14	18	20	23	25	26	29	31	33	35

SEMI-DETAILED SURVEYS. (Map scales 1:50,000 - 1:30,000)

Time estimates for typical semi-detailed surveys under camping conditions, with 1 field team, using a 600m x 300m grid, 20 sites / day, including fertility sampling, but excluding soil physical tests.

		Area of survey x 1000 ha									
		1	2	3	4	5	10	20	30	40	50
PRE-FIELD	(days)	6	6	6	6	6	6	6	6	6	8
FIELD WORK	(days)	18	23	26	31	36	55	95	135	175	216
POST-FIELD	(days)	8	8	8	8	11	11	15	19	21	24
PRELIMINARY REPORT	(days)	32	37	40	45	53	72	116	160	202	248
	(weeks)	6	7	8	9	11	14	23	32	40	50
FINAL REPORT	(days)	59	72	79	92	107	155	246	290	332	378
	(weeks)	12	14	16	18	21	31	49	58	66	76

RECONNAISSANCE SURVEYS. (Map scales 1:250,000 - 1:100,000)

Time estimates for typical reconnaissance surveys under camping conditions, with 1 field team, with an observation density of 750ha/obs., 15 sites / day, excluding fertility sampling and soil physical tests.

		Area of survey x 1000 ha									
		5	10	50	100	150	200	250	500	750	1000
PRE-FIELD	(days)	8	8	9	11	14	18	19	33	39	40
FIELD WORK	(days)	12	12	19	29	38	48	57	104	151	192
POST-FIELD	(days)	10	10	10	10	11	13	14	23	34	36
PRELIMINARY REPORT	(days)	30	30	38	50	63	79	90	160	224	268
	(weeks)	6	6	8	10	13	16	18	32	45	54
FINAL REPORT	(days)	50	50	67	94	120	151	176	290	354	398
	(weeks)	10	10	13	19	24	30	35	58	71	80

SIMPLIFIED DEFINITIONS OF MASTER HORIZONS.

H - Organic surface horizon; Saturated with water for long periods.

O - Organic surface horizon; Not saturated with water for long periods.

A - Mineral surface horizon; Has accumulation of humified organic matter.

E - Leached mineral horizon with high sand / silt and low iron content.

B - Mineral horizon with illuvial concentrations of clay, iron, or humus, or with structure. Mottles are not diagnoistic of a B horizon.

C - Mineral horizon of structureless material with no characteristics of the other master horizons; includes gravely material.

R - Rock too hard to dig.

SUFFIXES

a - highly decomposed organic material

b - buried horizon

c - concretions

d - dark coloured surface horizon

e - organic material of intermediate decomposition

f - slightly decomposed organic material

g - gleying (mottles or grey colours)

h - accumulation of organic matter

i - albic (whitish, bleached) materials

j - sulphides (smell of "rotten eggs")

k - accumulation of calcium carbonate

m - cemented or indurated

n - accumulation of sodium

o - residual accumulation of iron and aluminium oxides

p - ploughed

q - accumulation of silica

r - weathered or soft bedrock

s - non-residual accumulation of iron and aluminium oxides

t - accumulation of illuvial clay (cutans)

u - unspecified

v - vertic properties (cracking clay)

w - alteration in situ (development of colour or structure)

x - plough "pans"

y - presence of gypsum crystals

z - plinthitic (iron-rich, hardens irreversibly on wetting & drying)

DEFINITIONS OF DRAINAGE CLASSES.

VERY POORLY DRAINED

Soils that are wet to the surface for most of the year. These soils usually occupy level or depressed sites, and are frequently ponded.

POORLY DRAINED

Soils that are wet at or near the surface most of the growing season.

IMPERFECTLY DRAINED

Soils that are wet close to the surface during the growing season for long enough to markedly restrict crop growth.

MODERATELY WELL DRAINED SOILS

Soils that are wet within the rooting zone during the growing season for long enough to adversely affect crop growth.

WELL DRAINED

Soils that retain optimum amounts of moisture for crop growth, and are not wet close enough to the surface or for long enough during the growing season to adversely affect crop yeilds.

SOMEWHAT EXCESSIVELY DRAINED

Soils with a low water holding capacity from which water is removed rapidly. They often have little horizon differentiation, are sandy and very porus.

EXCESSIVELY DRAINED

Soils with a low water holding capacity from which water is removed very rapidly. They are often shallow, on steep slopes, or very porus.

FLOW CHARTS FOR THE DETERMINATION OF DRAINAGE CLASSES.

NOTES: 1. Wherever ground water data is available it should be used directly for determining the drainage class. Elsewhere, these flow charts may be used, EXCEPT IN WESTERN PROVINCE. They are a good guide for most of Zambia, but exceptions may occur, in which case field judgement must be used.
2. Colours and textures are those dominant in the control section.
3. Mottles must be AT LEAST common, medium, distinct.
4. N/S = Not Significant.

HUE : 10R / 2.5YR / 5YR
CHROMA: any

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
N/S	N/S	N/S	S or LS	Slope >8%	Excessive
				Slope <8%	Somewhat Excessive
			SL and heavier	N/S	Well

HUE : 7.5YR
CHROMA: 4 or more

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
None	N/S	N/S	N/S	N/S	Well
At any depth above 90 cm	N/S	N/S	N/S	Chroma of mottles >3	Well
				Chroma of mottles <3	Moderate

HUE : 7.5YR
CHROMA: 3 or less

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
None	N/S	Interfluve with forest veg.	N/S	N/S	Well
		Lower slope with sparse veg. or drainage line	S or LS	N/S	Well
			SL and heavier	N/S	Moderate
60-90cm	N/S	N/S	N/S	N/S	Moderate
0-60cm	N/S	Interfluve	N/S	N/S	Imperfect
		Drainage line	N/S	N/S	Poorly

FLOW CHARTS FOR THE DETERMINATION OF DRAINAGE CLASSES.

NOTES: 1. Wherever ground water data is available it should be used directly for determining the drainage class. Elsewhere, these flow charts may be used, EXCEPT IN WESTERN PROVINCE. They are a good guide for most of Zambia, but exceptions may occur, in which case field judgement must be used.
2. Colours and textures are those dominant in the control section.
3. Mottles must be AT LEAST common, medium, distinct.
4. N/S = Not Significant.
5. DSWT = Dry Season Water Table.

HUE : 10YR
CHROMA: 4 or more

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
None	N/S	Interfluve with forest veg.	N/S	N/S	Well
		Interfluve with sparse veg. on lower slope	S or LS	N/S	Well
			SL or heavier	Depth ≤60cm over laterite	Moderate
				Other	Well
		Lower slope or drainage line with grassland	N/S	N/S	Moderate
60-90cm	N/S	N/S	N/S	Chroma of mottles >3	Well
				Chroma of mottles ≤3	Moderate
0-60cm	None	Interfluve with forest veg.	N/S	Chroma of mottles >3	Moderate
				Chroma of mottles ≤3	Imperfect
		Lower slope or drainage line with grassland	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly
	Yes	N/S	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly

FLOW CHARTS FOR THE DETERMINATION OF DRAINAGE CLASSES.

NOTES: 1. Wherever ground water data is available it should be used directly for determining the drainage class. Elsewhere, these flow charts may be used, EXCEPT IN WESTERN PROVINCE. They are a good guide for most of Zambia, but exceptions may occur, in which case field judgement must be used.
2. Colours and textures are those dominant in the control section.
3. Mottles must be AT LEAST common, medium, distinct.
4. N/S = Not Significant.
5. DSWT = Dry Season Water Table.

HUE : 10YR
CHROMA: 3 or less

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
None or below 60cm	N/S	Interfluve with forest veg.	N/S	N/S	Well
		Interfluve with sparse veg. on lower slope	S or LS	N/S	Well
			SL or heavier	Depth <60cm over laterite	Imperfect
				Other	Moderate
		Lower slope or drainage line with grassland	N/S	DSWT >30cm	Poorly
				DSWT <30cm	V. Poorly
	Yes	N/S	N/S	DSWT >30cm	Poorly
				DSWT <30cm	V. Poorly
0-60cm	None	Interfluve with forest veg.	N/S	N/S	Imperfect
		Lower slope or drainage line with grassland	N/S	DSWT >30cm	Poorly
				DSWT <30cm	V. Poorly
	Yes	N/S	N/S	DSWT >30cm	Poorly
				DSWT <30cm	V. Poorly

FLOW CHARTS FOR THE DETERMINATION OF DRAINAGE CLASSES.

NOTES: 1. Wherever ground water data is available it should be used directly for determining the drainage class. Elsewhere, these flow charts may be used, EXCEPT IN WESTERN PROVINCE. They are a good guide for most of Zambia, but exceptions may occur, in which case field judgement must be used.
2. Colours and textures are those dominant in the control section.
3. Mottles must be AT LEAST common, medium, distinct.
4. N/S = Not Significant.
5. DSWT = Dry Season Water Table.

HUE : 2.5Y
CHROMA: 4 or more

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
None	N/S	N/S	S or LS	N/S	Well
			SL or heavier	N/S	Moderate
60-90cm	N/S	N/S	N/S	N/S	Moderate
0-60cm	None	Interfluve with forest veg.	N/S	Chroma of mottles >3	Moderate
				Chroma of mottles ≤3	Imperfect
		Lower slope or drainage line with grassland	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly
	Yes	N/S	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly

HUE : 2.5Y
CHROMA : 3 or less

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
N/S	None	Interfluve with forest veg.	N/S	N/S	Imperfect
		Lower slope or drainage line with grassland	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly
	Yes	N/S	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly

FLOW CHARTS FOR THE DETERMINATION OF DRAINAGE CLASSES.

NOTES: 1. Wherever ground water data is available it should be used directly for determining the drainage class. Elsewhere, these flow charts may be used, EXCEPT IN WESTERN PROVINCE. They are a good guide for most of Zambia, but exceptions may occur, in which case field judgement must be used.
2. Colours and textures are those dominant in the control section.
3. Mottles must be AT LEAST common, medium, distinct.
4. N/S = Not Significant.
5. DSWT = Dry Season Water Table.

HUE : 5Y / N/-
CHROMA: 3 or more

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
None or below 30cm	None	Interfluve with forest veg.	N/S	N/S	Imperfect
		Lower slope or drainage line with grassland	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly
	Yes	N/S	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly
0-30cm	N/S	N/S	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly

HUE : 5Y / N/-
CHROMA: 2 or less

MOTTLES (DEPTH)	RRCs	VEGETATION & POSITION	SUBSOIL TEXTURE	OTHER	DRAINAGE CLASS
N/S	None	Interfluve with forest veg.	N/S	N/S	Imperfect
		Lower slope or drainage line with grassland	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly
	Yes	N/S	N/S	DSWT >30cm	Poorly
				DSWT ≤30cm	V. Poorly

DESCRIPTION OF SOIL TEXTURE CLASSES.

1. SANDY SOILS - Those with a significant amount of grittiness.

Non-cohesive; particles do not stick together or only do so very slightly; does not form threads ..... **SAND**

Slightly cohesive; can be moulded into a thick thread but cannot support its own weight ..... **LOAMY SAND**

Slightly cohesive; can be MOULDED into a thick thread that supports itself, but cannot be ROLLED into a thread ..... **SANDY LOAM**

Moderately cohesive; rolls into a thread that forms a U shape before breaking; although cohesive, it is easy to work and is grittty; may take a slight polish ..... **SANDY CLAY LOAM**

Strongly cohesive; sticky; rolls into a thread that forms a U shape before breaking; takes a polish; stiff to work, but sand can be clearly felt ..... **SANDY CLAY**

2. CLAYEY SOILS - Those which are not gritty, but are cohesive and take a polish. Clay coheres (sticks to itself) so your fingers remain relatively clean.

Slightly smooth; slightly soapy; moderately sticky; the ball of soil deforms readily; rolls into a thread that almost forms a ring before breaking ..... **CLAY LOAM**

Moderately smooth and soapy; extremely sticky; difficult to deform the ball of soil; rolls into a thread that almost forms a ring before breaking; takes a polish ..... **SILTY CLAY LOAM**

Cohesive; rolls into a thread that forms a stable ring without cracking; takes a high degree of polish; stiff to work ..... **CLAY**

Like clay (above) but also soapy ..... **SILTY CLAY**

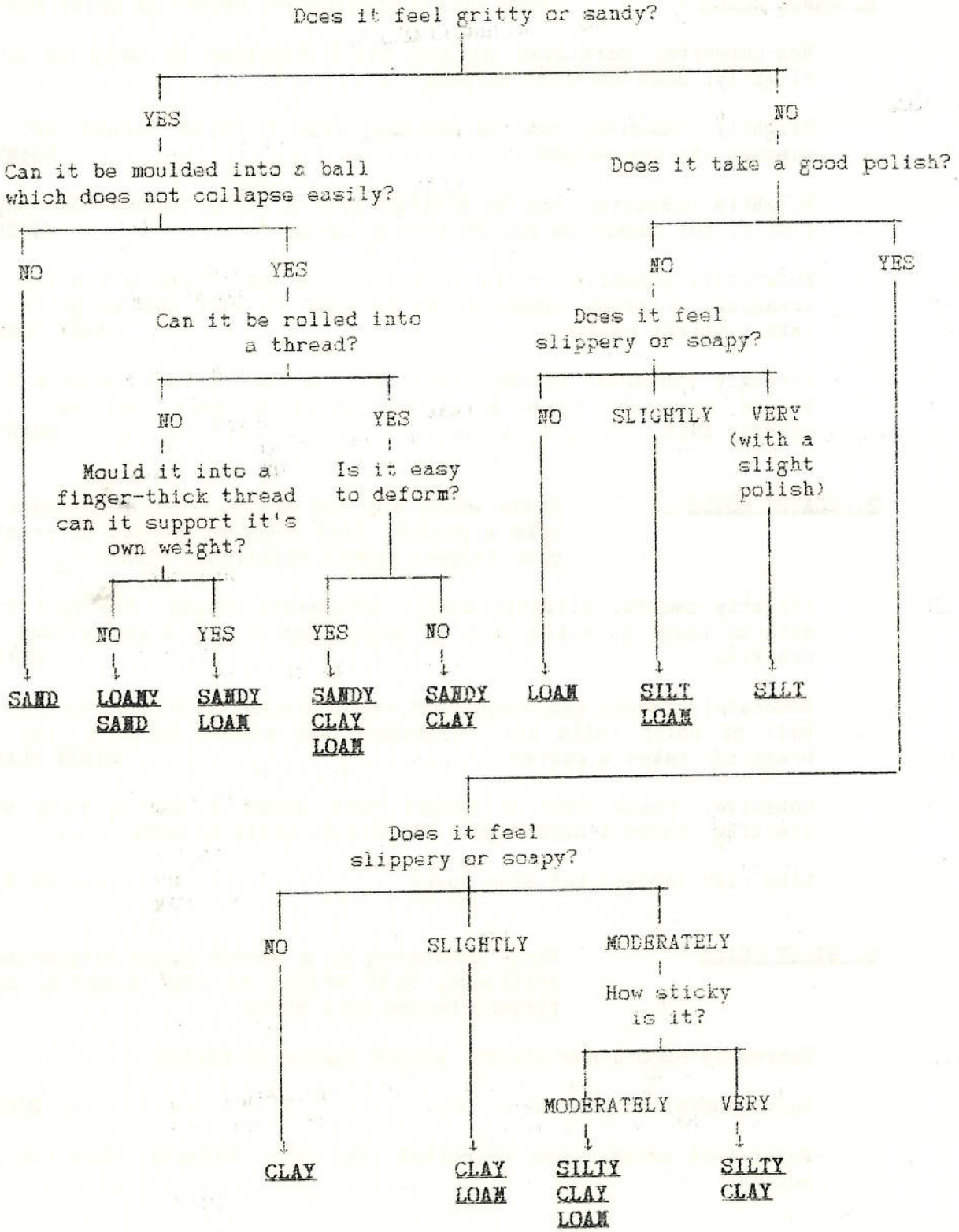
3. SILTY SOILS - Those dominated by a smooth soapy slipperiness or silkiness. Silt sticks to your fingers, so your fingers become very dirty.

Extremely smooth and sticky; slight degree of polish ..... **SILT**

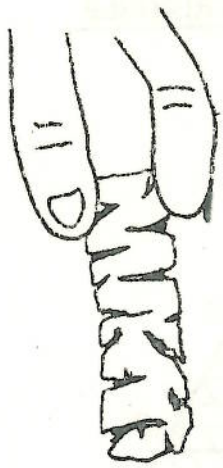
Very smooth; no polish ..... **SILT LOAM**

Moderately smooth; can be rolled into short threads; does not take a polish ..... **LOAM**

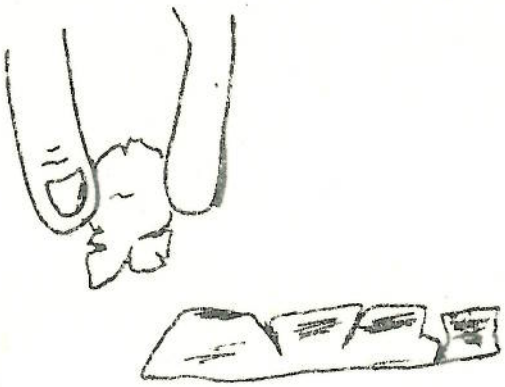
ASSESSMENT OF SOIL TEXTURE.



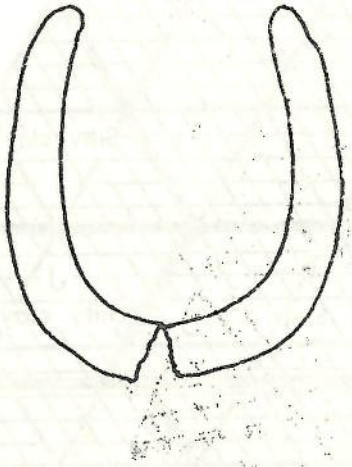
ASSESSMENT OF SOIL TEXTURE



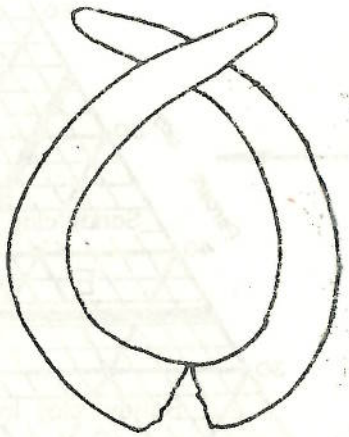
SANDY LOAM



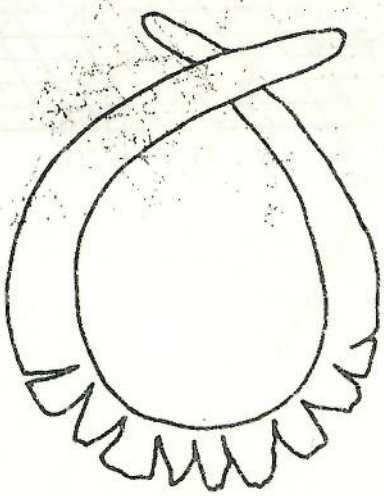
LOAMY SAND



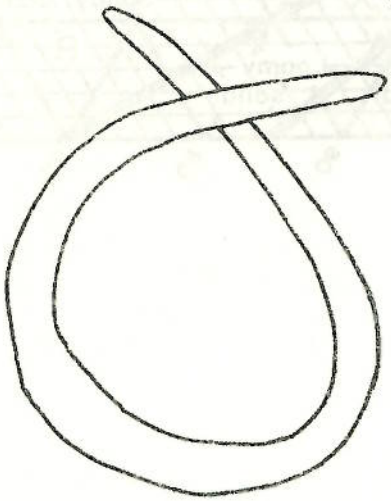
SANDY CLAY LOAM/LOAM



CLAY LOAM/SILTY CLAY LOAM

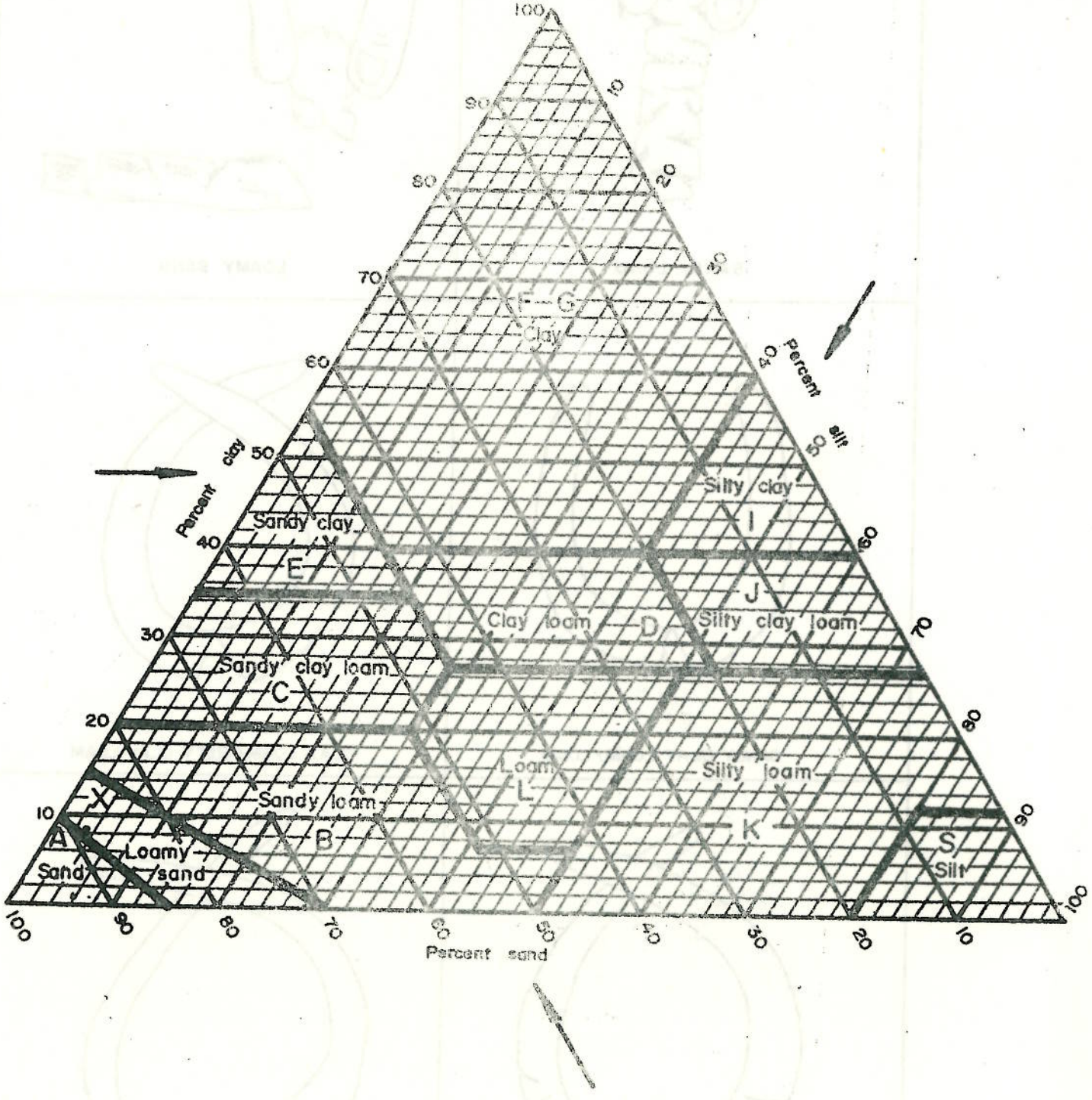


SANDY CLAY



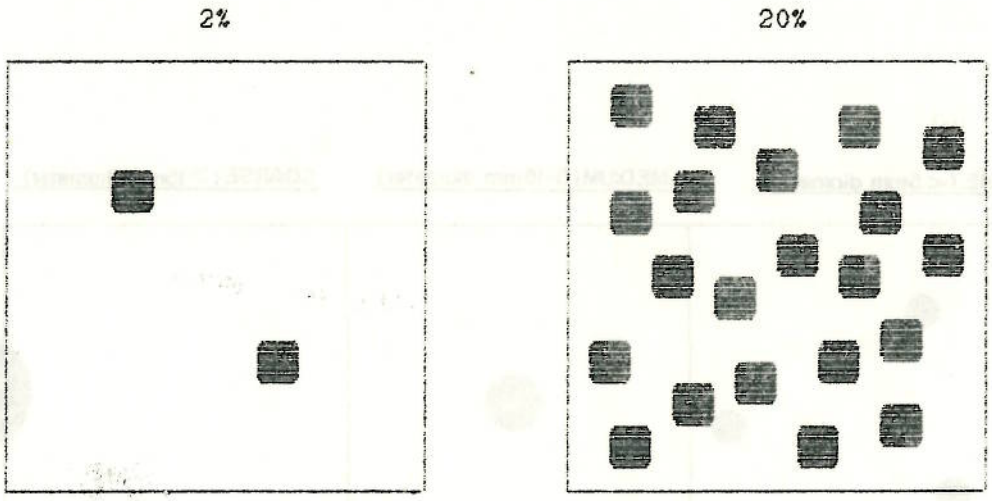
CLAY/SILTY CLAY

THE TEXTURE TRIANGLE



DESCRIPTION OF MOTTLES

ABUNDANCE



Few - Less than 2% of surface area.

Common - 2 to 20% of surface area.

Many - More than 20% of surface area.

SIZE

Fine - Less than 5mm diameter .....

Medium - 5 to 15mm diameter.

Coarse - More than 15mm diameter .....

CONTRAST

Faint - Difficult to see.

Distinct - Readily seen.

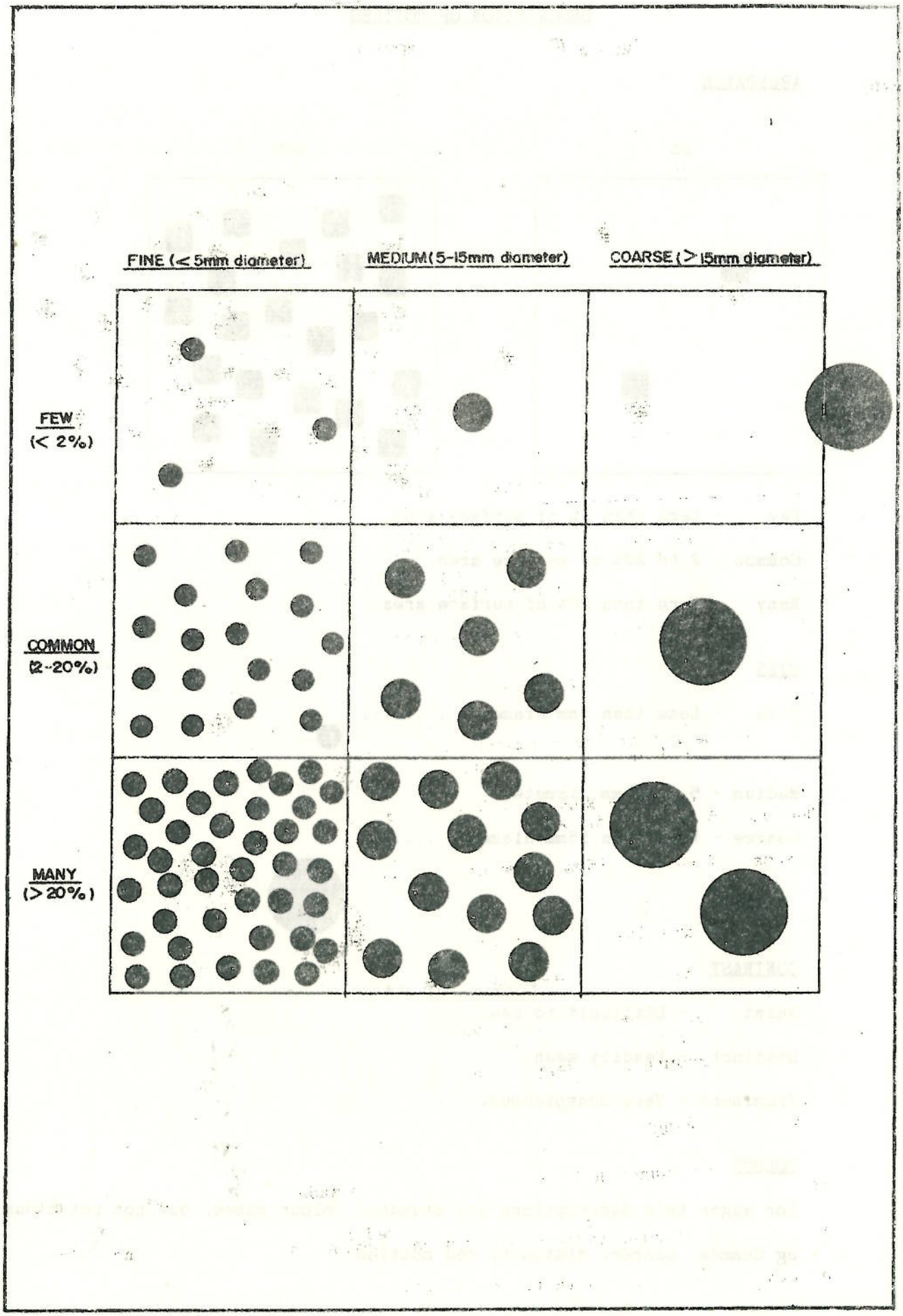
Prominent - Very conspicuous.

COLOUR

For auger hole descriptions use standard colour names, but not notations.

eg Common, coarse, distinct, red mottles.

DESCRIPTION OF MOTTLES



DESCRIPTION OF SOIL STRUCTURE.

Structure is described in terms of GRADE (or strength), CLASS (or size), and TYPE.

GRADES OF STRUCTURE

STRUCTURELESS	No peds observable in place or after breaking.
WEAK	Peds barely observable in place. Breaks into few entire peds, many broken peds, and much unaggregated material.
MODERATE	Peds evident, but not distinct in place. Breaks into many entire peds, some broken peds, and little unaggregated material.
STRONG	Peds distinct in place. Breaks into many entire peds, few broken peds, and little or no unaggregated material.

CLASSES OF STRUCTURE

See charts on pages 31 to 33.

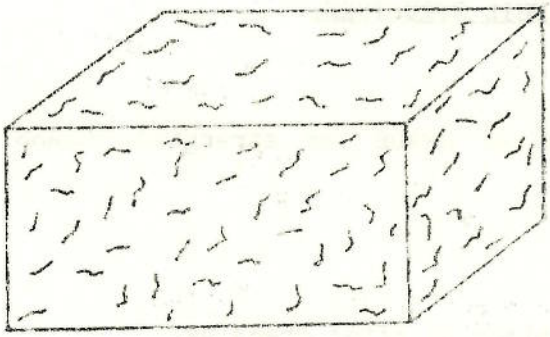
TYPES OF STRUCTURE

See drawings on page 30.

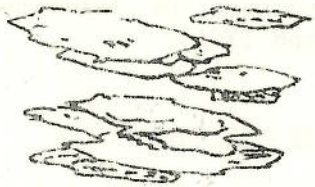
SINGLE GRAIN	Structureless and non-coherent.
MASSIVE	Structureless but coherent.
PLATY	The peds are flat and platelike.
PRISMATIC	Vertical columns with indistinct tops.
COLUMNAR	Vertical columns with rounded tops.
GRANULAR	Almost spherical peds with irregular faces.
CRUMB	Small, soft, porous, rounded peds.
ANGULAR BLOCK	Blocklike with sharp corners.
SUBANGULAR BLOCKY	Blocklike with rounded corners.

eg "Weak, fine, subangular blocky structure."

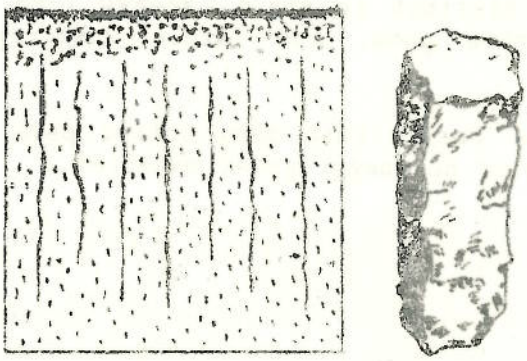
TYPES OF SOIL STRUCTURE



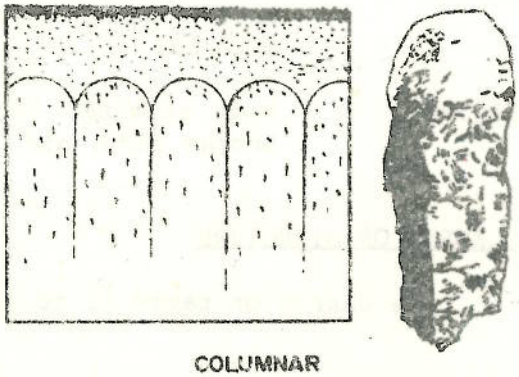
MASSIVE



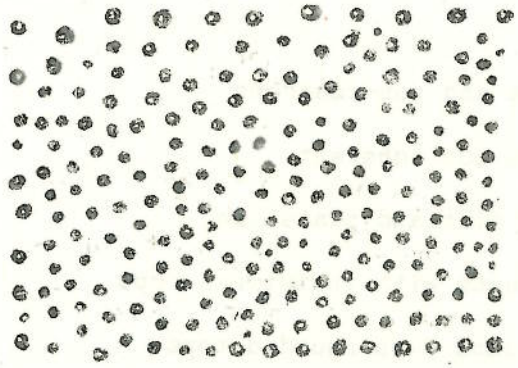
PLATY



PRISMATIC

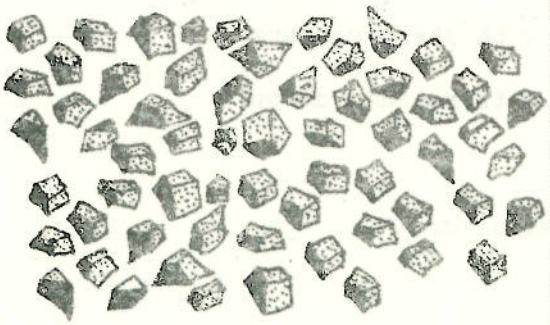


COLUMNAR

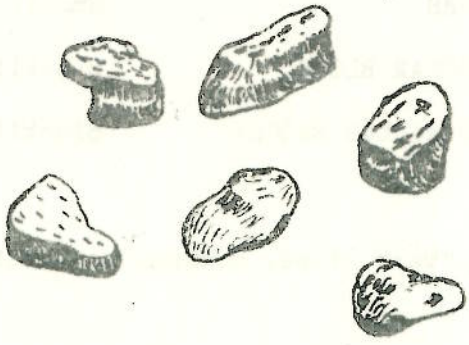


GRANULAR

CRUMB



ANGULAR BLOCKY



SUBANGULAR BLOCKY

CLASSES OF STRUCTURE.

	GRANULAR & CRUMB	PLATY
Very fine (<1mm)		
Fine (1-2mm)		
Medium (2-5mm)		
		
		
Coarse (5-10mm)		
		
		
		
Very Coarse (>10mm)		
		

CLASSES OF STRUCTURE.

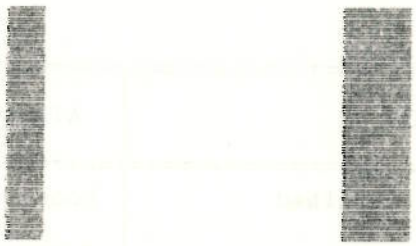
ANGULAR AND SUBANGULAR

Very fine (<5mm)	
Fine (5-10mm)	
Medium (10-20mm)	
Coarse (20-50mm)	 

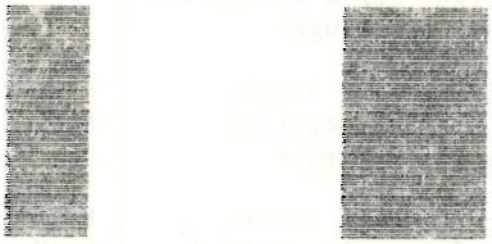
CLASSES OF STRUCTURE.

PRISMATIC AND COLUMNAR

Very fine (<10mm)

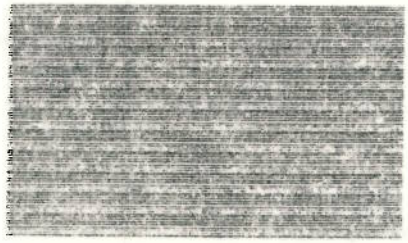


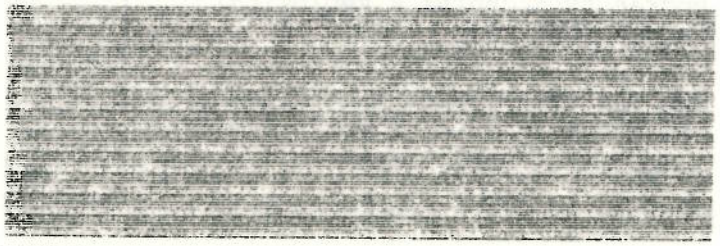
Fine (10-20mm)



Medium (20-50mm)

Coarse (50-100mm)





DESCRIPTION OF CONSISTENCE.

At augerhole observations only the moist consistence is usually recorded. The consistence classes are as follows:

DESCRIPTION	AIR-DRY	FIELD CAPACITY	CEMENTED MATERIAL
No specimen can be obtained	Loose	Loose	
The specimen crushes or breaks when a very slight force is applied by the thumb and forefinger	Soft	Very friable	
The specimen crushes or breaks when a slight force is applied by the thumb and forefinger	Slightly hard	Friable	
The specimen crushes or breaks when a moderate force is applied by the thumb and forefinger	Moderately hard	Moderately firm	
The specimen crushes or breaks when a strong force is applied by the thumb and forefinger	Hard	Firm	Weakly cemented
The specimen cannot be crushed or broken by the thumb and forefinger but can be crushed or broken by squeezing slowly between the hands	Very hard	Very firm	Moderately cemented
The specimen cannot be crushed or broken in hands, but can be broken or crushed underfoot by applying weight slowly	Extremely hard	Extremely firm	Cemented
The specimen cannot be crushed underfoot but can be crushed or broken by dropping a geological hammer from 20cm			Strongly cemented
The specimen cannot be crushed or broken by dropping a geological hammer from 20cm			Indurated

MUNSELL SOIL COLOUR NAMES

10R

	/1	/2	/3	/4	/6	/8
6/	reddish grey	pale red	pale red	pale red	light red	light red
5/	reddish grey	weak red	weak red	weak red	red	red
4/	dark reddish grey	weak red	weak red	weak red	red	red
3/	dark reddish grey	dusky red	dusky red	dusky red	dark red	dark red
2/	reddish black	very dusky red				

2.5YR

	/0	/2	/4	/6	/8
6/	grey	pale red	light reddish brown	light red	light red
5/	grey	weak red	reddish brown	red	red
4/	dark grey	weak red	reddish brown	red	red
3/	very dark grey	dusky red	dark reddish brown	dark red	
2/	black	very dusky red	dark reddish brown		

5YR

	/1	/2	/3	/4	/6	/8
8/	white	pinkish white	pink	pink		
7/	light grey	pinkish grey	pink	pink	reddish yellow	reddish yellow
6/	light grey	pinkish grey	light reddish brown	light reddish brown	reddish yellow	reddish yellow
5/	grey	reddish grey	reddish brown	reddish brown	yellowish red	yellowish red
4/	dark grey	dark reddish grey	reddish brown	reddish brown	yellowish red	yellowish red
3/	very dark grey	dark reddish brown	dark reddish brown	dark reddish brown		
2/	black	dark reddish brown				

7.5YR

	/0	/2	/4	/6	/8
8/	white	pinkish white	pink	reddish yellow	
7/	light grey	pinkish grey	pink	reddish yellow	reddish yellow
6/	grey	pinkish grey	light brown	reddish yellow	reddish yellow
5/	grey	brown	brown	strong brown	strong brown
4/	dark grey	brown	brown		
3/	very dark grey	dark brown			
2/	black	very dark brown			

10YR

	/1	/2	/3	/4	/6	/8
8/	white	white	very pale brown	very pale brown	yellow	yellow
7/	light grey	light grey	very pale brown	very pale brown	yellow	yellow
6/	grey	light brownish grey	pale brown	light yellowish brown	brownish yellow	brownish yellow
5/	grey	greyish brown	brown	yellowish brown	yellowish brown	yellowish brown
4/	dark grey	dark greyish brown	brown	dark yellowish brown		
3/	very dark grey	very dark greyish brown	dark brown	dark yellowish brown		
2/	black	very dark brown				

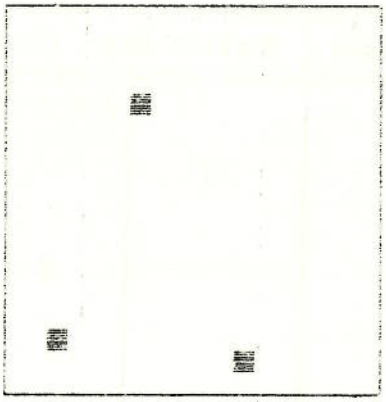
2.5Y

	/0	/2	/4	/6	/8
8/	white	white	pale yellow	yellow	yellow
7/	light grey	light grey	pale yellow	yellow	yellow
6/	light grey	light brownish grey	light yellowish brown	olive yellow	olive yellow
5/	grey	greyish brown	light olive brown	light olive brown	
4/	dark grey	dark greyish brown	olive brown		
3/	very dark grey	very dark greyish brown			
2/	black				

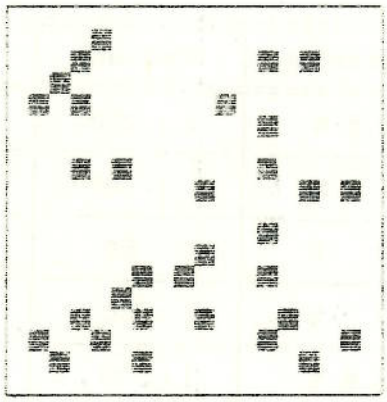
5Y

8/	white	white	pale yellow	pale yellow	yellow	yellow
7/	light grey	light grey	pale yellow	pale yellow	yellow	yellow
6/	light grey	light olive grey	pale olive	pale olive	olive yellow	olive yellow
5/	grey	olive grey	olive	olive	olive	
4/	dark grey	olive grey	olive	olive		
3/	very dark grey	dark olive grey				
2/	black	black				
	/1	/2	/3	/4	/6	/8

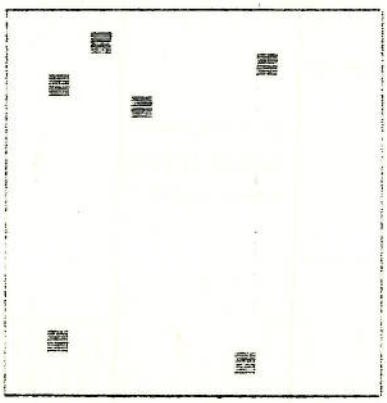
AREA COVERAGE ESTIMATION.



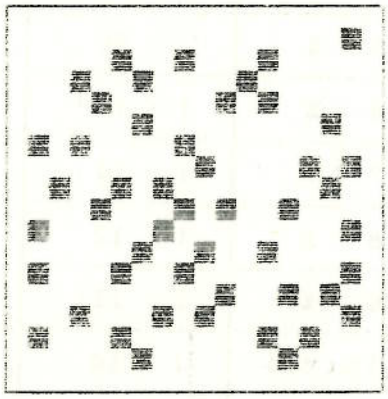
1 %



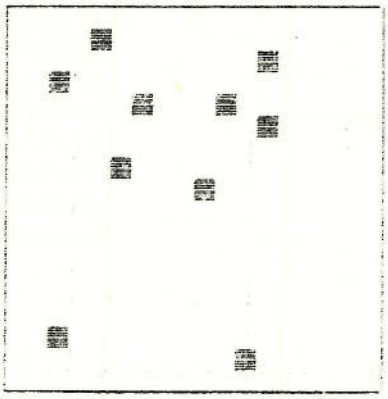
10 %



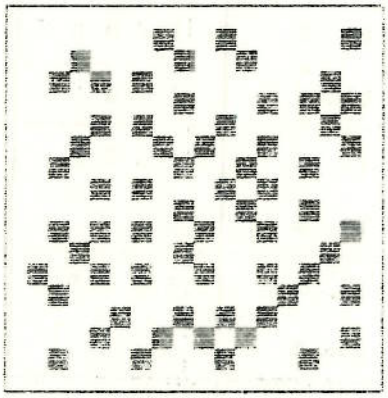
2 %



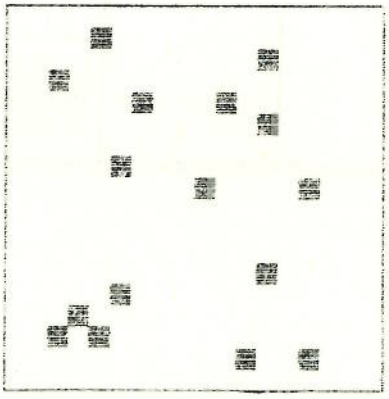
15 %



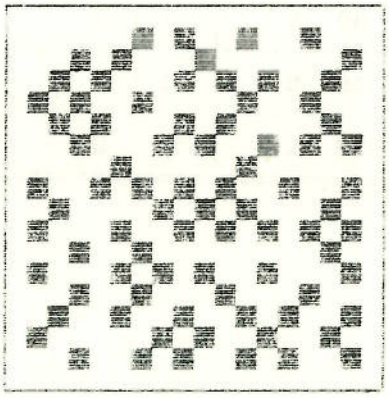
3 %



20 %



5 %



25 %

APPROXIMATE SLOPE CONVERSIONS.

Percentage	Gradient	Degrees	LC Class	Profile Desc. Class	
0.5 %	1 : 200	0° 15'	O	1	
1 %	1 : 100	0° 30'			2
2 %	1 : 50	1° 00'	A		
3 %	1 : 35	1° 30'			
3.5 %	1 : 30	2° 00'	B	3	
4 %	1 : 25	2° 30'			
5 %	1 : 20	3° 00'			
6 %	1 : 16	3° 30'	C		4
7 %	1 : 14	4° 00'			
8 %	1 : 12	4° 30'			
9 %	1 : 11	5° 00'	D	5	
10 %	1 : 10	5° 30'			
10.5 %	1 : 9.5	6° 00'			
11 %	1 : 9	6° 30'			
12 %	1 : 8	7° 00'			
13 %	1 : 7.5	7° 30'	E		6
14 %	1 : 7	8° 00'			
15 %	1 : 6.5	8° 30'			
20 %	1 : 5	11° 00'			
25 %	1 : 4	14° 00'	F	7	
30 %	1 : 3	17° 00'			
45 %	1 : 2	24° 00'			
>45 %	>1 : 2	>24° 00'		8	

APPROXIMATE SLOPE CONVERSIONS.

To convert GRADIENTS to PERCENTAGES.

Percentage = gradient x 100

eg to convert 1 : 50 to a percentage:

Percentage = 1 / 50 x 100 = 2%

To convert PERCENTAGES to GRADIENTS.

Gradient = 1 : (100 / percentage)

eg to convert 4% to a gradient:

Gradient = 1 : (100 / 4) = 1 : 25

To convert DEGREES to GRADIENTS.

Gradient = 1 : (60 / degrees)

eg to convert 6° to a gradient:

Gradient = 1 : (60 / 6) = 1 : 10

To convert GRADIENTS to DEGREES.

Degrees = gradient x 60

eg to convert 1 : 120 to degrees:

Degrees = (1 / 120) x 60 = 0.5° = 30'

To convert PERCENTAGES to DEGREES.

Degrees = (percentage / 100) x 60

eg to convert 5% to degrees:

Degrees = (5/100) x 60 = 3°

To convert DEGREES to PERCENTAGES.

Percentage = (degrees x 100) / 60

eg to convert 3° to a percentage:

percentage = (3 x 100) / 60 = 5%

COMPASS BEARINGS.

1. CONVERSIONS FOR 400 DEGREE COMPASSES.

To convert bearings measured on a 360 degree compass or protractor to bearings based on a 400 degree circle (grades):

Divide by 360 and multiply by 400

or multiply by 1.1

To convert bearings measured on a 400g compass or protractor to bearings based on a 360 degree circle:

Divide by 400 and multiply by 360

or multiply by 0.9

2. BACK BEARINGS.

1) 360 degree compasses:

If the foreward bearing is less than 180° then add 180°

If the foreward bearing is more than 180° then subtract 180°

2) 400 grade compasses:

If the foreward bearing is less than 200g then add 200g

If the foreward bearing is more than 200g then subtract 200g.

UTM MAP REFERENCES.

1. Take the grid zone designation, given in the map legend.

   eg In the example overleaf, the grid zone designation is 36L

2. Take the 100km square identification, also given in the map legend.

   eg In the example overleaf, the 100km square identification is TA

3. Take the west (left hand) edge of the square in which the point lies. Read the figures printed against this line on the north (top) or south (bottom) margin. Pay no attention to the smaller figures - only take the large figures.

   eg In the example overleaf, the grid line at the west edge of the square in which point X lies is numbered 26.

4. Estimate tenths eastwards (to the right) from the west (left hand) edge of the square in which the point lies to the point.

   eg In the example overleaf, point X lies approximately 3 tenths in from the west edge of the square.

5. Take the south (bottom) edge of the square in which the point lies. Read the figures printed against this line on the west (left hand) or east (right hand) margin. Pay no attention to the smaller figures - only take the large figures.

   eg In the example overleaf, the grid line at the south edge of the square in which point X lies is numbered 98.

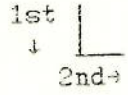
6. Estimate tenths northwards (up) from the south (bottom) edge of the square in which the point lies to the point.

   eg In the example overleaf, point X lies approximately 4 tenths up from the south edge of the square.

36L	TA	26	3	98	4
↑	↑	↑	↑	↑	↑
Grid zone	100km square	vertical grid line number	tenths to right of vertical grid line	horizontal grid line number	tenths up from horizontal grid line

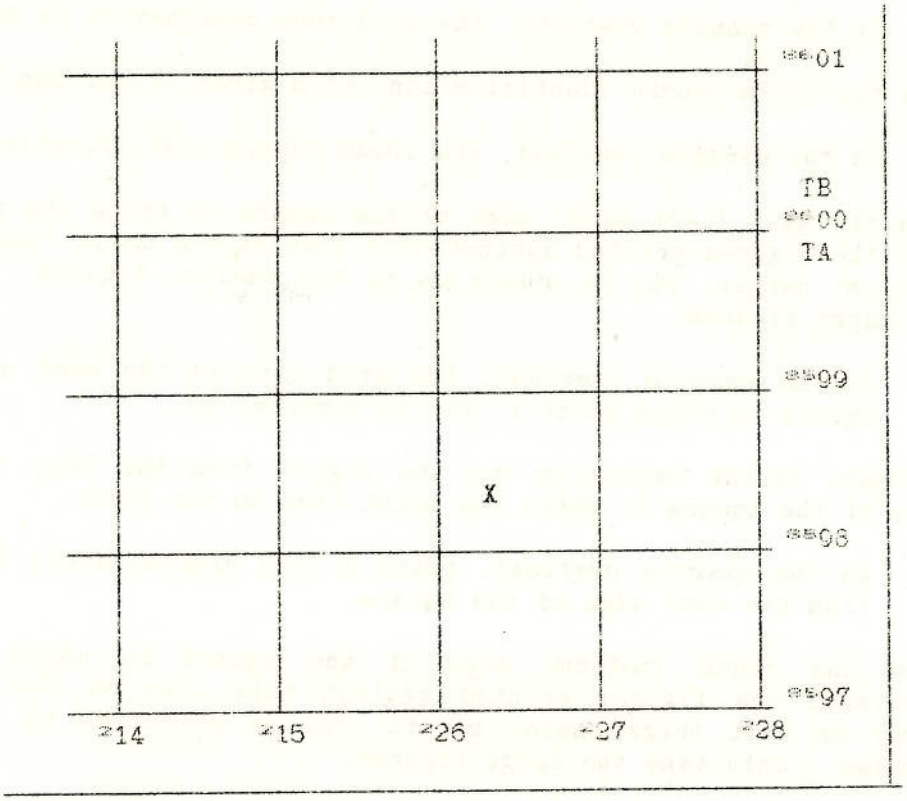
THE CAPITAL "L" RULE

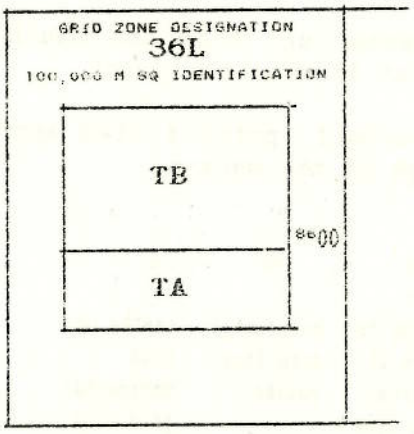
When you write a capital "L", you always write the vertical stroke first, and the horizontal stroke second :



In the same way, when taking a map reference, you always refer to the vertical grid line first, and the horizontal grid line second.

UTM MAP REFERENCES.





EXAMPLE UTM coordinates of point X :

36L TA 263 984

AIR PHOTO INTERPRETATION.

1. Make a print laydown, study topographic maps and landsat images, identify main landscape units. From geological maps, landsat, etc., identify major geological units, colour and tonal changes, drainage patterns etc..

2. Work rapidly through all the photos under the stereoscope. Construct a preliminary legend and delineate major units. Number the units from the top of the landscape downwards.

3. Work through all the photos again more slowly, delineating all boundaries. Refine and expand the legend using the elements listed below. Match up adjacent photos and runs.

The elements used in air photo interpretation are:

a) Geomorphic unit
b) Land element
c) Slope position
d) Meso and micro-relief
e) Slope degree and type
f) Drainage pattern and density
g) Vegetation type and density
h) Probable drainage class
i) Infered erosion
j) Other (inc.unidentified tone, pattern and texture variations)

The API legend is constructed using the layout shown below:

Map Unit	Geomph. Unit	Land Element	Slope Posn.	Mes/Mic Relief	Slope° & type	Drain. pattern	Vegn. type	Drain. class?	Infered Erosion	Other
1										
2										
3										
4										
5										
etc. ↓										

ELEMENTS FOR AIR PHOTO INTERPRETATION.

a) Geomorphic Unit - See legend on page 52.

b) Land Element - See Technical Guide No. 17 for definitions.

Hill / escarpment / ridge / cuesta / tor / inselberg / dome / pediment / piedmont / plain / interfluve / floodplain / levee / oxbow / backswamp / terrace / alluvial fan / swamp / dune / dambo / dilungu / deflation hollow / valley bottom

c) Slope Position

Crest / upper slope / mid slope / lower slope / toe slope / depression / dambo head (broad / uniform) / dambo side / dambo bottom / dambo fringe

d) Meso (>50cm) and Micro (<50cm) Relief

Termite mounds / gullies or rills / gilgai / raised levels / depressions / wind ripples / rock or laterite outcrops / bunds and ridges

e) Slope Degree and Type

Degree : Level / gentle / moderate / steep / very steep
Type : Uniform / Concave / convex / complex

f) Drainage Pattern and Density

Pattern : see drawings on page 47
Density : low / medium / high

g) Vegetation type and density

Type : Forest / woodland / grassland / swamp / agricultural
Density : Dense / medium / sparse

h) Possible Drainage Class - Make an estimate based on experience.

i) Infered Erosion

No erosion / slight erosion / moderate erosion / severe erosion
(No gullies / occasional gullies / frequent gullies)

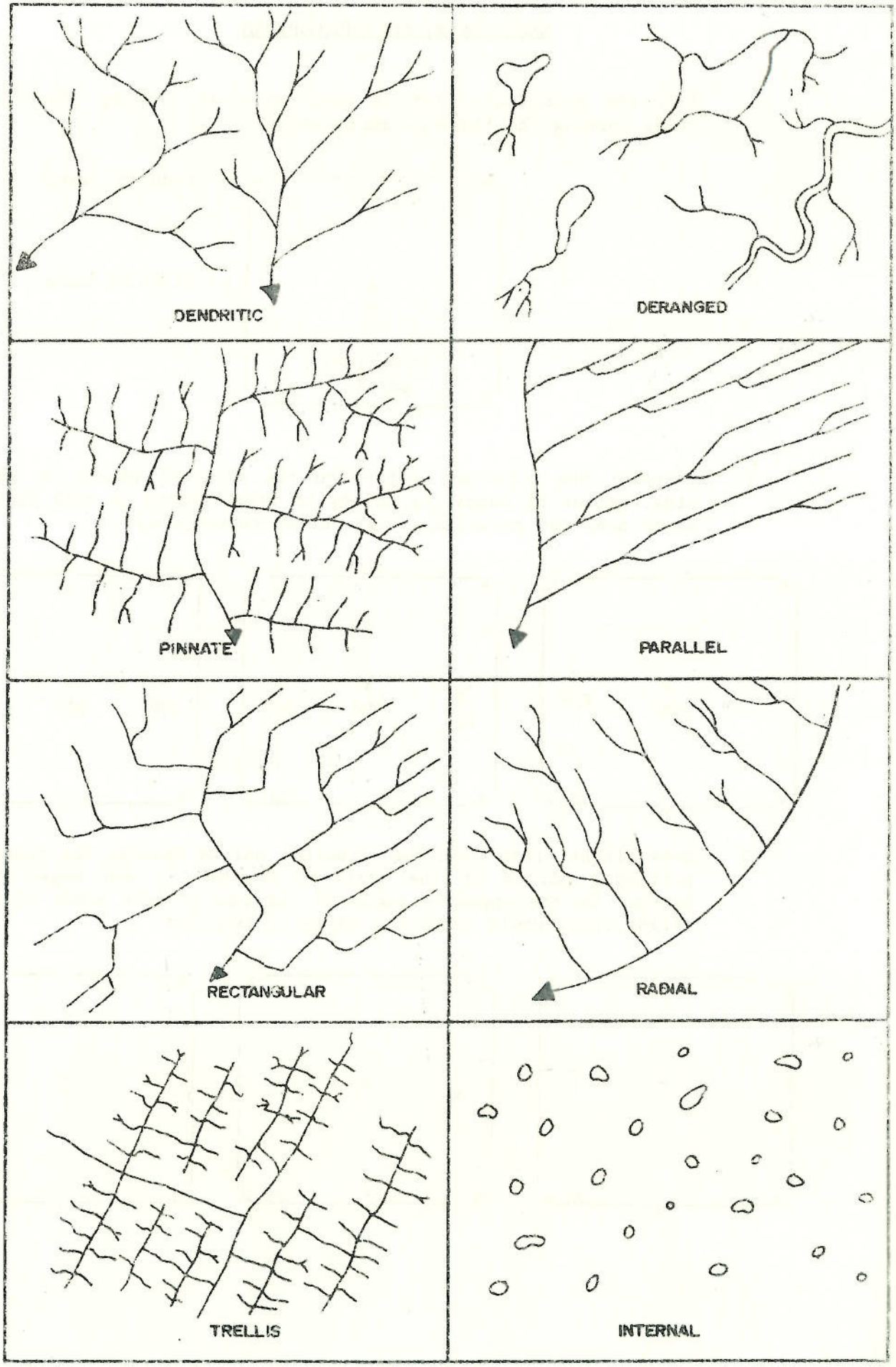
j) Unidentified Tone, Pattern and Texture Variations

Tone : White / light / medium / dark / black
Pattern : Linear / dotted / chequered
Tone : Smooth / fine / medium / coarse / very coarse

k) Other

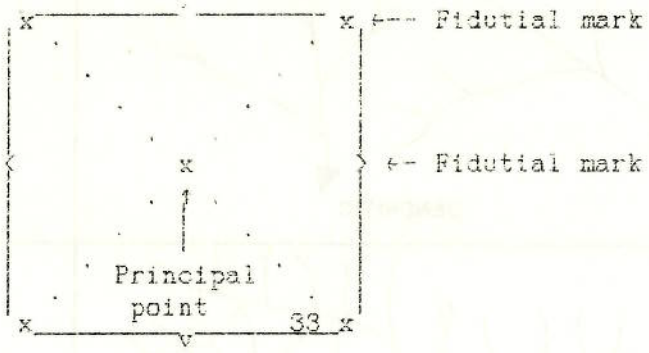
Any visible attributes not covered above.

DRAINAGE PATTERNS

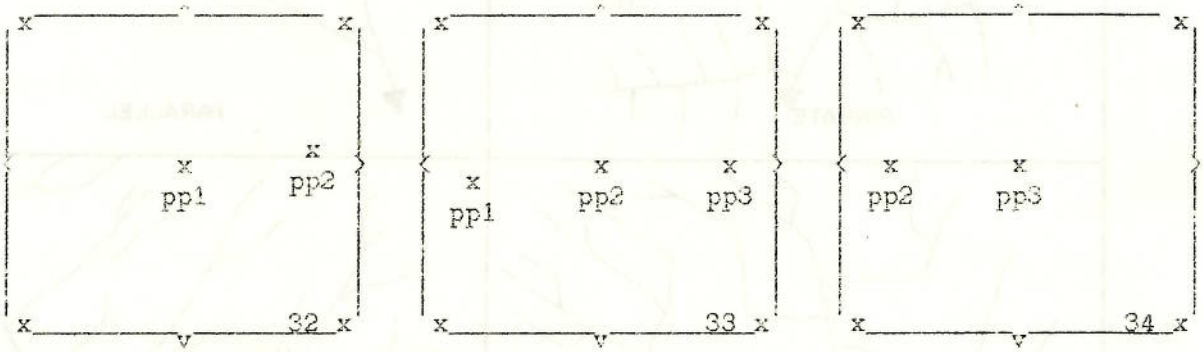


BASE LINING AIR PHOTOGRAPHS.

1. Mark the principal point on each photo by finding where the lines joining the fidutial marks cross.



2. Transfer the principal points to the adjacent photos on each side, either by comparing points of detail found on both photos at or near the principal point, or stereoscopically.



3. Draw flight lines from the principal points through the transfered principal points of the adjacent photos, to the edges of the photos. On the opposite edges of the photos make marks where the flight lines would cross the edges if extended.

USING A STEREOSCOPE FOR RAPID OR OCCASIONAL USE.

1. The two photos should be parallel to one and other and the correct way round..

2. Place the two photographs under the stereoscope with the overlap area on the right photo under the right hand mirror/lens, and the left hand overlap area under the left hand mirror/lens.

3. With a pocket stereoscope the two photos must overlap, with a distance of about 6cm between the two cross marks. To view most of the area, the upper photo must be bent carefully upwards to reveal the area of examination on the lower photo. With a mirror stereoscope the photos should be about 3cm apart.

4. Mark a cross on both photos over the same feature, such as a road corner, village, etc., using a chinagraph pencil.

5. Look through the stereoscope, focussing each eye on the cross marked on the photo beneath that eye.

6. Hold the left hand photo still, and move the right hand photo from side to side until the two crosses coincide, so that an image of a single cross is obtained.

7. One of the photos may have to be turned slightly so that the two images coincide

8. The view is now stereoscopic and hills should be visible rising up out of the photo, with the dambos and valleys seen as depressions in the photos.

9. With practice the use of crosses marked on the photos may be discontinued.

CARE OF STEREOSCOPES AND AIR PHOTOS.

1. Always handle the stereoscope with care. It is a very expensive piece of equipment.

2. Never touch the lenses or mirrors with your fingers. Grease left on the reflecting surfaces can permanently reduce the quality of the image.

3. Always put the instrument away in its box when not in use.

4. Never draw on air photos with ink, ball pen, felt tip pen or pencil. Always use a chinagraph (wax) pencil. For rubbing out use a soft rubber or wash the photo with methylated spirits.

5. Never use selotape on air photos. It strips off the emulsion when it is removed. Instead, always use masking tape.

USING THE MIRROR STEREOSCOPE FOR PROLONGED USE.

1. Preparing the Stereoscope

1. Measure the distance apart of your eyes. Set the lenses of the stereoscope to that distance apart.

2. Mark a straight line on the desk, the width of the stereoscope.

3. Place the stereoscope over the line so that the line is central beneath the instrument.

4. Look down the stereoscope using both eyes. You will probably see two lines.

5. Turn the stereoscope one way or the other until the two lines come together to form a single line.

6. Mark the position of the four legs of the instrument. The stereoscope must always be placed exactly onto these marks in future.

7. Look down the stereoscope and close your right eye.

8. Move a pencil along the line under the left hand mirror, and mark faintly both edges of the field of view. Ignore the second image that is seen to the far left.

9. Measure the half way point between these two marks and mark it clearly on the line.

10. Look down the stereoscope using both eyes. Move a pencil along the line under the right hand mirror until it coincides with the image of the mark in the center of the left hand field of view. Mark that point strongly.

2. Viewing the photographs

1. Base line the air photos.

2. Position the principal point of the left hand photo over the centre point of the left hand field of view marked on your desk.

3. Position the transfered left hand principal point on the right hand photo over the point where the centre of the left hand field of view is seen under the right hand side of the stereoscope, ie the right hand mark along the line.

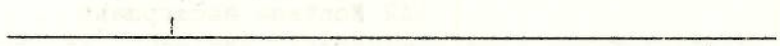
4. Turn both photos until their flight lines and their extended marks on the edges of the photos are aligned along the line marked on your desk. Fix the photographs in position with masking tape at their corners.

The photos are now positioned for effortless stereo viewing, and prolonged interpretation can be carried out with no eye strain.

USING THE POCKET STEREOSCOPE FOR PROLONGED USE.

1. Base line the air photos.

2. Draw a straight line about 10cm long on a piece of paper, and make a mark near one end of the line, as shown below:



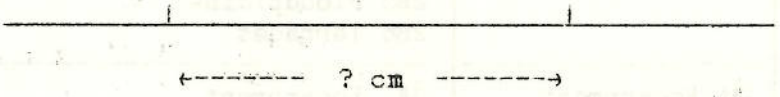
3. Adjust the eye base setting of the stereoscope to suit your eyes.

4. Place the stereoscope over the line with the mark directly beneath the left hand lens.

5. Put a pen or pencil beneath the right hand lens with it's point on the line.

6. Look down the stereoscope and move the pencil from side to side until it coincides with the mark. Mark the line at that point.

7. Measure the distance between the two marks, as shown below:



8. Fasten the left hand photo to your desk using masking tape along the left hand edge only.

9. Lay the right hand photo on top of it, and position it so that the two flight lines lie on the same straight line (use a ruler), and the principal point and transfered principal point are the same distance apart as the marks measured in 6 above.

10. Fasten the right hand photo along its right hand edge with masking tape.

11. Each print can now be lifted and placed on top of the other as required in order to completely examine the entire stereo model.

THE GEOMORPHIC LEGEND.

Map scale 1:5,000,000		Map scale 1:1,000,000
1 Montane Zone	1A Montane Zone	1A1 Montane plateau 1A2 Montane escarpment
2 Central African Plateau	2A Degraded Plateau	2A1 Level to gently undulating plateau 2A2 Dissected plateau 2A3 Hills, ridges, footslopes, and minor escarpments 2A4 Swamps 2A5 Lakes 2A6 Floodplains 2A7 Terraces 2A8 Major dambos
	2B Aggraded Plateau	2B1 Linear dune complex 2B2 Pan complex 2B3 Dilungu 2B4 Slightly dissected plateau 2B5 Floodplains 2B6 Terraces
3 Escarpment	3A Escarpment	3A Escarpment
	3B Escarpment Complex	3B1 Major valley floors 3B2 Hill areas
4 Rift Trough	4A Dissected Trough Floor	4A1 Isolated large hills 4A2 Dissected hilly land
	4B Flat Trough Floor	4B1 Floodplains 4B2 Terraces 4B3 Gently undulating land 4B4 Swamps
	4C Lakes	4C Lakes

See Technical Guide No. 15 for definitions.

TYPICAL RANGES OF ANALYTICAL DATA FOR TOPSOILS.

	TEXTURE			
	S - LS	SL - SCL	CL - C	Vertisols
CEC me%*	1.0 - 6.0	1.6 - 12.5	3.8 - 36.0	14 - 135
BSP %	14 - 100	5 - 100	5 - 100	40 - 100
Ex. Ca me%*	0.2 - 3.1	0.1 - 5.6	0.2 - 25.0	4.0 - 32.0
Ex. Mg me%*	0.0 - 0.9	0.1 - 1.8	0.1 - 15.0	1.5 - 37.0
Ex. K me%*	0.01 - 0.04	0.05 - 0.07	0.06 - 2.30	0.09 - 1.40
pH ($CaCl_2$)	3.7 - 6.5	3.7 - 6.5	3.7 - 7.2	4.6 - 7.2
Avail. P ppm	0 - 20	0 - 20	0 - 30	0 - 40
Org. C %	0.1 - 1.5	0.1 - 2.0	0.1 - 4.0	0.1 - 2.5

* See table at foot of page 54 for conversion to SI units.

pH RELATIONSHIPS.

pH in water is approximately 0.7 to 1.0 units higher than pH in $CaCl_2$.

pH in $CaCl_2$ is approximately 0.1 to 0.4 units higher than pH in KCl.

CEC / ECEC RELATIONSHIPS.

NB These relationships are very approximate.

pH ($CaCl_2$)	< 4.5	4.5 - 5.0	5.1 - 5.5	5.6 - 6.0	>6.0
ECEC >4	x3	x2.5	x2	x1.5	x1
ECEC <4	x2	x2	x1.5	X1.25	x1

eg If pH is 4.6 and ECEC is 4.3,

then approximate CEC is 4.3 x 2.5 = 10.75 ≈ 11

NORMS FOR THE INTERPRETATION OF TOPSOIL ANALYTICAL DATA.

ANALYSIS	RATING	VALUE	INTERPRETATION
CEC me%*	High	>8	Normally well buffered soils
	Low	<2	
BSP %	High	>75	BSP has little bearing on fertility in low CEC soils
	Low	<20	
Ex. Ca me%*	Deficient	<1	Depends on many factors, but where Al satn. >20% or pH<4.6 then Ca status low.
Ex. Mg me%*	Deficient	<0.2	
Ex. K me%*	Deficient (clays)	<0.3	
	(loams)	<0.2	
	(sands)	<0.1	
Ca/Mg ratio	Excessive	>5	Mg deficiency possible
Mg/K ratio	Too low	<3	Mg deficiency possible
	Excessive	>25	K deficiency possible
pH ($CaCl_2$)	Critical (clay/loam)	<4.6	Al toxicity possible
	(sands)	<4.4	Al toxicity possible
Al satn. %	Excessive	>40	Al toxicity likley
Avail. P ppm	Deficient	<7	
	Rich	>15	
Org. C %	Low (clays)	<1.0	
	(loams)	<0.8	
	(sands)	<0.6	

* Analytical results may also be expressed as SI units. The values are the same as the previously used units, except for water retention:

ANALYSIS	Old Units	New (SI) Units
Extractable bases	me %	cmol(p+)/Kg
Cation exchange capacity	me %	cmol(NH_4^+)/Kg
Soluble cations	me %	mmol(p+)/L
Soluble anions	me %	mmol(e^-)/L
Electrical conductivity	mS/cm	dS/M
Water retention	Bars	KPa (1 KPa = 100 bars)
Bulk density	g/cc	Mg/m^3

CALCULATING DERIVED ANALYTICAL DATA.

These calculations will use the following data in the worked examples:

Extractable bases cmol(p+)/Kg					CEC cmol /Kg	P ppm	pH $CaCl_2$	Clay %	Soil water (cm^3/cm^3) KPa	
Ca	Mg	K	Na	Al					10	1500
2.42	1.50	0.51	0.01	0.12	6.92	12	5.6	36	0.247	0.131

TO CALCULATE BSP

1. Add together the exchangable bases
2. Multiply this total by 100.
3. Divide the result by the CEC.

ie $BSP = \frac{(Ca + Mg + K + Na) \times 100}{CEC}$

eg 1. 2.42 + 1.50 + 0.51 + 0.01 = 4.44
2. 4.44 x 100 = 444
3. 444 ÷ 6.92 = 64.16
Result The BSP is 64%

TO CALCULATE ECEC

Add together the exchangable bases and the exchangable aluminium.

ie ECEC = Ca + Mg + K + Na + Al

eg 2.42 + 1.50 + 0.51 + 0.01 + 0.12 = 4.56
Result The ECEC is 4.56 cmol(p+)/Kg

TO CALCULATE ALUMINIUM SATURATION

1. Calculate the ECEC.
2. Multiply the exchangable aluminium by 100.
3. Divide the result by the ECEC.

ie $Al\ satn.\ \% = \frac{Al \times 100}{ECEC}$

eg 1. ECEC is 4.56 (see example above)
2. 0.12 x 100 = 12
3. 12 ÷ 4.56 = 2.63
Result The aluminium saturation is 2.6%

TO CALCULATE CEC/100g clay

1. Multiply CEC by 100.
2. Divide the result by the clay percentage.

ie CEC/100g clay = $\frac{\text{CEC} \times 100}{\text{clay \%}}$

eg 1. 6.9 x 100 = 690
2. 690 ÷ 36 = 19.16
Result The CEC/100g clay is 19 cmol(p+)/Kg clay

TO CALCULATE AVAILABLE WATER CAPACITY (AWC)

1. Subtract the retained soil water at wilting point (1500KPa) from the retained soil water at field capacity (10KPa).
2. Multiply the result by 1000 to convert from cm^3/cm^3 to mm/m.

ie AWC = (Soil water @ Fld. Cap. - Soil water @ Wlt. Pt.) x 1000

eg 1. 0.247 - 0.131 = 0.116
2. 0.116 x 1000 = 116
Result The AWC is 116 mm/m

TO CALCULATE Kg/ha PLANT NUTRIENTS FROM ANALYTICAL DATA

Assumptions: Bulk density = 1.6 g/cc
Plough layer = 15cm
∴ plough layer weighs 2400 tonnes

Kg of element in 1ha topsoil = miliequivalents of element/100g soil (me %)
x equiv. wt. of element
x wt. of 1ha of topsoil (tonnes)
÷ 100

Ca (me %) x 480 = Kg of Ca / ha in top 15cm

Mg (me %) x 290 = Kg of mg / ha in top 15cm

K (me %) x 940 = Kg of K / ha in top 15cm

Na (me %) x 550 = Kg of Na / ha in top 15cm

P (ppm) x 2.4 = Kg of P / ha in top 15cm

NB The equivalent weight is the atomic weight divided by the valency.
me % is the same as cmol/Kg (see table at foot of page 54).

INSTRUCTIONS FOR TAKING SOIL SAMPLES.

FERTILITY SAMPLES (For fertilizer and lime recommendations to farmers)

1. Each sample must be a composite sample comprising at least 30 sub-samples (however small the land) taken at random over the whole area. On large or recently ploughed lands this number must be increased.

2. Each management unit is sampled seperately. If the land is to be farmed as small fields that will be managed seperately, seperate composite samples must be taken from each field. If a large tract of land is to be farmed as a single management unit, then the whole area must be sampled as one.

3. Major changes of soil type within a land and areas of different management or cropping history must be sampled seperately.

4. Samples are best taken during the dry season, although samples only required for pH determination may be taken at any time.

5. Topsoil samples are augered from 0 to 20 cm depth. The sub-samples are thoroughly mixed and divided by quartering until a composite sample of about 1 Kg is obtained.

6. Subsoil samples are augered from 20 to 50 cm depth.

7. The samples are air dried by leaving the sample bags open for a few days. Do not dry soil samples in a room where lime or fertilizer is stored!

8. Label each sample twice - one label inside the bag and one outside.

PROFILE SAMPLES

1. Select the most representative face of the pit.

2. Always take samples from a freshly exposed pit face.

3. Sample from the base of the pit upwards.

4. If a horizon is thicker than 50cm it should be split into equal sections for sampling, each of which should be less than 50cm thick.

5. Each horizon must be sampled throughout its entire depth by cutting a channel from the upper boundary of the horizon to the lower boundary.

6. Each sample should be packed and labeled before collecting the next.

7. Label each sample twice - one label inside the bag and one outside.

KEY TO THE SOIL SERIES.

See Technical Guide No. 14 for full descriptions of the Soil Series.

MODERATELY WELL DRAINED OR BETTER SOILS:

- Sandy soils (sand or loamy sand dominant):
  - Spodic B-hor. & strongly bleached sand in the A-hor.:
    - With albic E-hor. (white dry, dark grey moist):
      - Albic E-hor. extends to below 1.25m depth ..... Client Podzol
      - Albic E-hor. does not extend to below 1.25m depth ..... Kande
    - Without albic E-hor. & with weakly pronounced spodic B-hor., but with humus lamellae in upper B or lower A-hor. ..... Kataba
  - Without spodic B-hor.:
    - Thick dark coloured (chroma ≤ 2) over more than 25cm depth & no clay lamellae in the subsoil & no bleached sand on the topsoil:
      - Loamy topsoil, mod. well drained, with clay in deep subsoil Nsefu
      - Sandy topsoil:
        - Developed on Kalahari sands:
          - Chroma ≤ 2 throughout the upper 1.0m:
            - Umbric A-hor., situated on upland plain ..... Mwanambuyu*
            - No umbric A-hor., pH($CaCl_2$) > 5.5 dominant .. Sesheke II
          - Chroma ≤ 2 over < 1.0m depth ..... Kaoma
        - Not developed on Kalahari sands:
          - 5YR ..... Sasare
          - 7.5YR-10YR, BSP > 50%:
            - Developed on recent alluvium (levee)(fluvisol?) .. Ninga
            - Developed on old alluvium, 10YR only:
              - Average Org. C in upper 50cm > 0.9, pH($CaCl_2$) > 6.5, maybe calcareous in subsoil .. Chama
              - Average Org. C in upper 50cm < 0.9, pH($CaCl_2$) < 6.5, not calcareous ..... Kaoma
    - No thick dark coloured topsoil or the soil has lamellae in the subsoil or the soil has bleached sand in the topsoil:
      - Bleached sand on the topsoil, no spodic B-hor.:
        - Clay lamellae in subsoil, On alluvial fan or river terrace, white mottles in subsoil, topsoil not very white, well oxidised subsoil ..... Sesheke I
        - No lamellae, not on terrace/alluv. fan, less oxidised subsoil:
          - 7.5-5YR ..... Mongu
          - 10YR or yellower:
            - Entirely albic below A-hor. (value ≥6 chroma ≤3) Kanyama
            - Not entirely albic material to 1.0m depth:

* See note on page 67.

-Chroma ≤ 5 in subsoil, very sandy soil ..... Luampa
-Chroma > 6 in the subsoil, slightly loamy . Sikelenge

-No bleached sand on the topsoil:

-With lamellae in the B-hor.:

-7.5-5YR in subsoil ..... Nangweshi
-10YR, On alluvial fan/river terrace, white (silica) mottles in subsoil ..... Sesheke I

-No lamellae:

-5YR or redder dominant:

-Developed on Kalahari sand ..... Milangu*
-Not developed on Kalahari sand ..... Lubwa

-7.5YR or yellower:

-Situated in Kalahari sand area:

-Situated on alluvial terrace:

-pH($CaCl_2$) > 5.0, BSP > 50% ..... Kaoma
-pH($CaCl_2$) < 5.0, BSP < 50% ..... Mushwala

-Situated on upland ..... Kabuyu

-Not situated in Kalahari sand area:

-On levee, loamy topsoil, fluvisol, non-ferric . Mfuwe*

-Located on a slope, no fluvisol:

-Well drained ..... Nachilanga
-Mod. well drained, 10YR, dambo fringe .. Chansonge

-Clayey soils (> 35% clay):

-Non-ferric (CEC/clay > 30 me%):

-7.5-10YR or yellower:

-Calcareous soil, pH($CaCl_2$) > 7.0 ..... Krisifoa
-Non-calcareous, mod. well drained, chroma ≤4, value ≤4 Mwembeshi

-2.5-5YR:

-Clayey topsoil, clay B/A < 1.5 ..... Makeni
-Loamy topsoil, clay B/A > 1.4 ..... Mazabuka

-Ferric (CEC/clay < 30 me%):

-BSP > 20/25%:

-CEC/clay 15 - 30 me%

-2.5YR or redder:

-Clayey topsoil, clay B/A < 1.6 ..... Chelston*
-Loamy topsoil, clay B/A > 1.4 ..... Chipangali

-5-10YR:

-Clayey topsoil, clay B/A < 1.6 ..... Liteta

* See note on page 67.

- Loamy topsoil, clay B/A > 1.5 :
  - Silt/clay < 1.0:
    - Silt/clay < 0.5 ..... Nakambala
    - Silt/clay > 0.5, BSP < 50% ..... Kawama
  - Silt/clay > 1.0 ..... Machiya*
- CEC/clay 6 - 14 me%:
  - 2.5YR or redder:
    - Clay B/A < 1.6, no kandic hor.:
      - Exch. K > 0.5 me% or subsoil pH($CaCl_2$) > 5.3, On basic igneous rocks ..... Malashi
      - Exch. K < 0.5 me%, on limestone or schist .... Mpongwe I
    - Clay B/A > 1.6, clear/doubtful kandic hor. ..... Kalengwa
  - 5-10YR:
    - Abrupt text. change, clay B/A > 2.5, kandic hor., 5-7.5YR:
      - pH($CaCl_2$) in B-hor. > 5.0 ..... Mushemi
      - pH($CaCl_2$) in B-hor. < 5.0 ..... Chifwesa
    - No abrupt text. change:
      - 10YR (7.5YR in deep subsoil or if lateritic gravel is present), mod. well drained ..... Ipafu
      - 5-7.5YR:
        - No kandic or argillic hor., clay B/A <1.5 ... Mutwale
        - With kandic or argillic hor., clay B/A > 1.6:
          - Silt/clay > 0.5, pH($CaCl_2$) > 5.0, argillic hor., loam or clay loam topsoil ..... Kawama
          - Silt/clay < 0.5:
            - pH($CaCl_2$) > 5.2 ..... Mushemi
            - pH($CaCl_2$) < 5.2 ..... Chibesakunda

- BSP < 20/25% :
  - 2.5YR or redder:
    - Silt/clay < 0.28:
      - No kandic hor. (clay B/A < 1.4):
        - pH($CaCl_2$) > 4.5, On limestone, intermediate schist or basic igneous rock ..... Chafukuma
        - pH($CaCl_2$) < 4.5 ..... Katito
      - Doubtful or clear kandic hor. (clay B/A > 1.4) .... Kateshi
    - Silt/clay 0.28 - 0.83:
      - Clayey topsoil, clay B/A < 1.4, no kandic hor.:
        - Non-oxidic:
          - pH($CaCl_2$) > 4.5, On limestone, intermediate schist or basic igneous rock ..... Chafukuma

* See note on page 67.

- -pH($CaCl_2$) ≤ 4.5, on acid rocks ..... Meheba
- -Oxidic (very high iron content), pH($CaCl_2$) > 4.5 Mumena*
- -Sandy clay loam/clay loam topsoil, clay B/A > 1.3, no kandic hor.:
  - -Org. C averaged over upper 50cm > 1.1% ..... Konkola
  - -Org. C averaged over upper 50cm < 1.1% ..... Mulonga
- -Silt/clay ≥ 0.83 ..... Matebo*

-5-10YR:

- -Abrupt text. change in control section:
  - -Clay B/A > 3.2 ..... Chifwesa
  - -Clay B/A < 3.2, text. change from clayey - coarse loamy within 1.0m depth ..... Lubu
- -No abrupt text. change in control section:
  - -10YR:
    - -Well drained, chroma & value ≤ 4 over ≥ 40cm depth, BSP < 10% ..... Samfya
    - -Other soils:
      - - < 40% clay in 0-20cm topsoil ..... Mulobolo
      - - > 40% clay in 0-20% topsoil ..... Mayondo
  - -5-7.5YR:
    - -Silt/clay < 0.28:
      - -No kandic hor., clay B/A < 1.6 ..... Nondo
      - -Clear/doubtful kandic hor., clay B/A >1.7 .. Mufulira
    - -Silt/clay 0.2 - 1.0:
      - -No kandic hor., clay B/A < 1.4, on sedimentary rock ..... Kasempa
      - -Clear/doubtful kandic hor., clay B/A > 1.4, on igneous or metamorphic rock ..... Kawambwa
    - -Silt/clay > 1.0 ..... Nkatongo

-Loamy soils:

- ->35% ironstone gravel throughout, ferric ..... Safeli
- -Fine loamy soils (≥ 20% clay):
  - -Non-ferric (CEC/clay > 28 me%):
    - -Deep dark coloured (chroma ≤ 2) over 1.0 m depth, mod. well drained, 5-10YR ..... Masumba
    - -Dark coloured (chroma ≤ 4 & value ≤ 4) over considerable depth:
      - -Well drained:
        - -10YR, very low BSP ..... Ninge
        - -5-7.5YR ..... Malima*
      - -Mod. well drained, 7.5-10YR ..... Mwembeshi

* See note on page 67.

- -Not dark coloured, situated on upland position ..... Kashinka
- -Ferric (CEC/clay 6 - 28 me%):
  - -BSP > 20/25 % :
    - -10YR:
      - -Calcareous within 50cm depth, silt/clay > 1.0 ... Chernozem
      - -Not calcareous:
        - -Clear kandic hor., mod. well drained, clay B/A >2.5, clay decreases by >20% of max. within 1.5m depth :
          - -CEC/clay < 16 me%, sandy loam topsoil, chroma ≤4 Kado
          - -CEC/clay 16 - 28 me%, sand - loamy sand topsoil, chroma ≥5 ..... Kabwe
        - -No/doubtful kandic hor. (clay B/A < 2.5):
          - -Well - mod. well drained, CEC/clay < 16 me% .. Kahare
          - -Excessively - well drained, CEC/clay > 16 me% Mkushi
    - -2.5YR or redder ..... Tubalenge
    - -5-7.5YR :
      - -Abrupt text. change ..... Milima
      - -No abrupt text. change:
        - - > 25cm sand or loamy sand topsoil ..... Choma
        - - < 25cm sand or loamy sand topsoil :
          - -Silt/clay > 1.0 ..... Machiya*
          - -Silt/clay < 1.0 :
            - -CEC/clay ≤ 16 me% ..... Mikata
            - -CEC/clay > 16 me% ..... Chilimboyi
  - -BSP < 20/25 % :
    - -Abrupt text. change, fine loamy - coarse loamy in 1.0m .. Lubu
    - -No abrupt text. change :
      - -Value ≤ 4 & chroma ≤ 4 over ≥ 40cm depth, BSP ≤ 10% :
        - -2.5-5YR ..... Mberashi
        - -7.5-10YR ..... Nkolemfumu
      - -BSP > 10% :
        - -10YR dominant, well - mod. well drained ..... Mulobolo
        - -7.5YR or redder :
          - -Silt/clay ≥ 0.95 ..... Nkatongo
          - -Silt/clay <0.95 :
            - -Clay B/A < 2.0, sandy loam/sandy clay loam topsoil ≥14% clay in upper 20cm after mixing, no weatherable/weathering rock fragments within 1.5m Misamfu
            - -Clay B/A >2.0, sand/sandy loam topsoil .. Shilende

* See note on page 67.

-Coarse loamy soils (< 20% clay):

-Non-ferric (CEC/clay > 30 me%):

-2.5YR, silt/clay > 5.0 ..... Chinsali

-5-10YR:

-Deep dark coloured (chroma < 2) over 1.0m depth:

-Sandy topsoil, average Org. C in top 50cm < 0.8% Sesheke II

-Loamy topsoil, 5-10YR, average Org. C in top 50cm > 0.8%, mod. well drained ..... Masumba

-Not dark coloured over 1.0m depth, well drained:

-Silt/clay > 1.0:

-Situated on upland ..... Chilanga

-Situated on alluvium ..... Malima*

-Silt/clay < 1.0 ..... Watopa

-Ferric (CEC/clay 6 - 30 me%):

-BSP > 20/25 % :

-Abrupt text. change within 1.0m depth ..... Milima

-No abrupt text. change :

-10YR or yellower:

-Bleached sand on topsoil, subsoil chroma < 4 ... Kanyama

-No bleached sand on the topsoil :

-CEC/clay < 16 me%, well - mod. well drained .. Kahare

-CEC/clay 16 - 30 me%, well drained:

-No/doubtful kandic hor. (clay B/A <2.5)...Chilanga

-Clear kandic hor. (clay B/A > 2.5) ..... Kabwe

-2.5-7.5YR:

- > 25cm sand/loamy sand topsoil ..... Choma

- < 25 cm sand/loamy sand topsoil:

-2.5YR ..... Tubalenge

-5-7.5YR ..... Ifisa

-BSP < 20/25% :

-Abrupt text. change within 1.0m depth ..... Milima

-No abrupt text. change:

-Dark coloured (chroma < 4, value <4) over >40cm, BSP <10%:

-2.5-5YR ..... Mbereshi

-7.5-10YR ..... Nkolemfumu

-Not deep, dark coloured:

-10YR dominant:

-10YR throughout, bleached sandy topsoil ..... Luampa

* See note on page 67.

-Possibly 7.5YR in deep subsoil ..... Ndakale

-2.5-7.5YR :

-Kandic hor. ..... Munkonge

-ABC profile without kandic hor./ AC profile Chinsali

IMPERFECTLY DRAINED SOILS

-Strongly degraded fine loamy to clayey, E-hor., planosol ..... Lochinvar I

-Not strongly degraded or different texture :

-Sandy soils (sand or loamy sand dominant) :

-Fluvisol:

-With clay cover of >25cm ..... Luangwa

-Without clay cover ..... Kalabo

-No fluvisol :

-Bleached sand on topsoil, ferric, developed in Kalahari sand :

-On upper part of seepage zone at edge of floodplain/dambo, umbric A-hor. ..... Litongo-dry

-On level plain, no umbric A-hor. ..... Mulobezi*

-No bleached sand on topsoil, not developed in Kalahari sand :

-Loamy sand texture dominant, BSP < 50% ..... Kansanshila

-Sand texture throughout:

-Alkaline subsoil below 1.0m depth ..... Sesheke II

-No alkaline subsoil ..... Chansonge

-Clayey soils (> 35% clay) :

-Non-ferric (CEC/clay >30 me%) :

-Vertisol (>30% clay in upper 20cm after mixing, >30% clay in upper 50cm, cracks >1cm wide at 50cm depth after long drought) :

-Chroma < 1.5 in upper 30 cm ..... Kafue

-Chroma > 1.5 in upper 30 cm ..... Kembe

-No Vertisol :

-Vertic subsoil with slickensides within 1.0 m depth .... Cheta

-No vertic subsoil :

-Chroma < 4, value < 4, 7.5-10YR ..... Mwembeshi

-2.5 - 5YR ..... Nanga

-Ferric (CEC/clay < 30 me%) :

-CEC/clay > 16 me% ..... Chimsimbe

-CEC/clay < 16 me% :

-BSP > 50% ..... Mwami

-BSP < 50% ..... Kungu

* see note on page 67.

-Loamy soils :

-Silt content ≥ 30% in upper 1.0m :

-Developed on sandstone or quartzite ..... Lukulu

-Developed on limestone, pH($CaCl_2$) > 5.0, Calcic hor., umbric A-hor. ..... Luzongo

-Silt content < 30% :

-Coarse loamy soils (clay < 20%, includes soils with sandy layer overlying fine loamy to clayey textures) :

-Alkaline soil with white sandy E-hor. ..... Sesheke III

-No alkaline soil :

-Abrupt text. change from sandy - fine loamy/clayey, sandy texture over 25cm or more ..... Kafulafuta

-No abrupt textural change ..... Nyenya

-Fine loamy soils (clay ≥20%) :

-Alkaline soil ..... Siatwinda

-No alkaline soil :

-Non-ferric (CEC/clay >30me%) :

-10YR :

-Developed on limestone ..... Mwembeshi

-Not developed on limestone, with plinthite . Nampande

-5-7.5YR:

-Developed in old Luangwa alluvium ..... Chikumba

-Developed on Kafue terrace, 5YR ..... Nanga

-Ferric (CEC/clay >30me%) :

-Silt content >20% throughout ..... Kado

-Silt content <20% :

-Abrupt text. change ..... Munkumpu

-No abrupt text. change ..... Nampande

POORLY AND VERY POORLY DRAINED SOILS

-Strongly degraded fine loamy - clayey soils with continuous greyish silty or fine sandy E-hor., planosol ..... Lochinvar I

-Not strongly degraded, without continuous E-hor. :

-Peat or muck over ≥40cm, histic H-hor. :

- < 100cm peat or muck ..... Sishanjo

- > 100cm peat or muck ..... Liamundi

-Peat or muck over <40cm:

-Sandy soils (sand/loamy sand dominant) :

-Fluvisol :

-With clayey topsoil over ≥25cm depth ..... Luangwa

* See note on page 67.

- -Developed in Kalahari sands, situated on levee .. Sesheke VIII
- -No fluvisol :
  - -Developed in Kalahari sands, mostly umbric A-hor. Litungo-wet
  - -Not developed in Kalahari sands :
    - -Umbric A-hor. ..... Luano III
    - -No umbric A-hor. ..... Muchanga*
- -Clayey soils (>35% clay) :
  - -Vertisol (>30% clay in upper 20cm after mixing, >30% clay in upper 50cm, cracks >1cm wide at 50cm after long drought):
    - -Chroma < 1.5 in upper 30cm ..... Kafue
    - -Chroma > 1.5 in upper 30cm ..... Kembe
  - -No vertisol :
    - -Non-ferric (CEC/clay > 30me%) :
      - -Degraded vertisol with clayey vertic subsoil, but <30% clay in upper 20cm after mixing ..... Bulozi
      - -No vertic subsoil :
        - -Alkaline soil, natric B-hor. with columnar struct. Luona*
        - -No alkaline soil :
          - -Calcareous in subsoil ..... Jivundu
          - -Not calcareous:
            - -Developed on acid rocks ..... Dambo
            - -Not developed on acid rocks :
              - -Developed in alluvium, fluvisol .. Lochinvar II
              - -Developed on schist/limestone ..... Chalimbana
    - -Ferric (CEC/clay < 30me%) :
      - -Peaty and/or silty A-hor., fluvisol ..... Chimbwi
      - -No Peaty A-hor., dambo, maybe plinthite in subsoil Kasakula
- -Loamy soils :
  - -Silt > 30/35% throughout :
    - -Umbric or sometimes mollic A-hor. ..... Kawimbe
    - -Without umbric A-hor:
      - -In Kalahari sand area, BSP < 50% ..... Zambezi
      - -Not in Kalahari sand area :
        - -Developed on schist & limestone ..... Chalimbana
        - -Developed on acid rocks ..... Mupupa*
  - -Silt < 30/35% :
    - -Coarse loamy soils (clay < 20%) :
      - -Alkaline soil, with white sandy E-hor. ..... Sesheke III

* See note on page 67.

- No alkaline soil :
  - Sheet laterite within 60 cm depth ..... Laterite
  - No sheet laterite within 60cm depth :
    - Non-ferric, chroma <2, value <3 for >80cm Black dambo
    - Ferric :
      - Without mollic A-hor. ..... Luano I
      - With peaty or mollic A-hor. ..... Samahima
- Fine loamy soils (clay >20%) :
  - Non-ferric (CEC/clay >30me%) :
    - Alkaline soil, natric B-hor. with columnar struc. Luona*
    - No alkaline soil :
      - Dark (chroma <2, value <3) for >80cm .... Black dambo
      - Not dark coloured over >80cm :
        - Plinthite within 1.2m depth ..... Jimoli
        - No plinthite within 1.2m depth :
          - Developed over limestone or dolomite Chalimbana
          - Developed in alluvial deposits ... Mayukwayukwa*
  - Ferric (CEC/clay <30me%) :
    - With umbric A-hor. ..... Chambishi
    - No umbric A-hor. ..... Kowa

* See note below.

NOTE:

The series names given above are those used in Technical Guide No. 14 (Soil Classification, first approximation). However, the series marked (*) have since been re-named, and the new names are used in Technical Guide No. 17 (Manual for Soil Profile Description) as follows:

Old Names (Tech. Guide 14 & above)	New Names (Tech. Guide 17)
Chelston	Chakunkula
Luona	Lunsemfwa
Machiya	Chilongoshi
Malima	Buleya
Matebo	Chibwaka
Mayukwayukwa	Nkula
Mfuwe	Luangwa
Milangu	Simango
Muchanga	Bangweulu
Mumena	Ingwe
Mulobezi	Ibolelo
Mupupa	Makwi
Mwanambuyu	Lutali

NB The Mpongwe III series has been dropped.

GLOSSARY OF TERMS USED IN SOIL SERIES KEY.

Abrupt textural change: Clear or abrupt horizon boundary & at least 20% (absolute) difference in clay content within 7.5cm vertical distance.

Albic E-horizon: Pale, leached E-horizon below A-horizon.

Albic material: Value (moist) 6 or more & chroma (dry or moist) 3 or less.

Alkaline soil: ESP (exchangeable sodium percentage = Na / CEC x 100) > 15%.

Argillic B-horizon: B-horizon with clay accumulation & cutans.

Calcareous: Reacts (effervesses) with dilute HCl.

Calcic horizon: Accumulation of $CaCO_3$ & silica.

Clayey: More than 35% clay dominant.

Coarse loamy: Less than 20% clay & > 15% sand, but not sand or loamy sand.

Degraded vertisol: Vertic subsoil & clay destruction in the topsoil.

Ferric: Less than 30 me CEC / 100g clay.

Fine loamy: 20 - 35% clay dominant.

Kandic horizon*: Horizon with CEC / 100g clay < 24 & clay increase of ≥20% (relative) within 12cm vertical distance.

Mollic A-horizon: Topsoil with high org. matter, ≥ 25cm thick & BSP ≥ 50%.

Natric B-horizon: Argillic horizon with a high ESP.

Non-ferric: More than 30 me / 100g clay.

Oxidic: Very high iron content in relation to clay content.

Peat: Material with > 12 - 18% organic carbon.

Planosol: Soil with albic E-horizon over a slowly permeable subsoil.

Plinthite: Soft iron-manganese mottles which harden on wetting & drying.

Silty: Less than 15% sand & < 35% clay.

Spodic B-horizon: B-horizon with accumulation of organic matter (humus).

Umbric A-horizon: As mollic A-horizon, but with BSP < 50%.

Vertisol: Soils with > 30% clay in upper 50cm, with cracks 1cm wide at 50cm depth after a long drought period, often with wedge-shaped structure & slickensides in the subsoil.

* This old definition of a Kandic horizon used in the series key differs from the revised definition adopted by Soil Taxonomy.

FIELD ESTIMATION OF TEXTURAL RATIOS AND CHANGES.

These tables give **VERY APPROXIMATE** estimates based on the field texture classes estimated for the two horizons. They are based on mid-range values for the clay content of each textural class, and are intended as a guide for augerhole estimations during the field classification of a site, for later confirmation by laboratory particle size analysis.

FIELD ESTIMATION OF CLAY B/A RATIO

B-hor. field text.	A-horizon field texture (assumed clay content %)											
	S (4)	Si (6)	LS (8)	SL (14)	SiL (14)	L (18)	SCL (28)	SiCL (34)	CL (34)	SC (42)	SiC (48)	C (50)
S	1.0	0.7	0.5	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Si	1.5	1.0	0.8	0.4	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.1
LS	2.0	1.3	1.0	0.6	0.6	0.4	0.3	0.2	0.2	0.2	0.2	0.2
SL	3.5	2.3	1.8	1.0	1.0	0.8	0.5	0.4	0.4	0.3	0.3	0.3
SiL	3.5	2.3	1.8	1.0	1.0	0.8	0.5	0.4	0.4	0.3	0.3	0.3
L	4.5	3.0	2.3	1.3	1.3	1.0	0.6	0.5	0.5	0.4	0.4	0.4
SCL	7.0	4.7	3.5	2.0	2.0	1.6	1.0	0.8	0.8	0.7	0.6	0.6
SiCL	8.5	5.7	4.3	2.4	2.4	1.9	1.2	1.0	1.0	0.8	0.7	0.7
CL	8.5	5.7	4.3	2.4	2.4	1.9	1.2	1.0	1.0	0.8	0.7	0.7
SC	10.5	7.0	5.3	3.0	3.0	2.3	1.5	1.2	1.2	1.0	0.9	0.8
SiC	12.0	8.0	6.0	3.4	3.4	2.7	1.7	1.4	1.4	1.1	1.0	1.0
C	12.5	8.3	6.3	3.6	3.6	2.8	1.8	1.5	1.5	1.2	1.0	1.0

FIELD ESTIMATION OF ABRUPT TEXTURAL CHANGE

Argillic horizon texture	Ochric epiped./albic hor. texture										
	S	Si	LS	SL	SiL	L	SCL	SiCL	CL	SC	SiC
Si											
LS											
SL	ATC	ATC									
SiL	ATC	ATC									
L	ATC	ATC	ATC								
SCL	ATC	ATC	ATC	ATC	ATC						
SiCL	ATC	ATC	ATC	ATC	ATC						
CL	ATC	ATC	ATC	ATC	ATC						
SC	ATC	ATC	ATC	ATC	ATC	ATC					
SiC	ATC	ATC	ATC	ATC	ATC	ATC	ATC				
C	ATC	ATC	ATC	ATC	ATC	ATC	ATC	ATC	ATC		

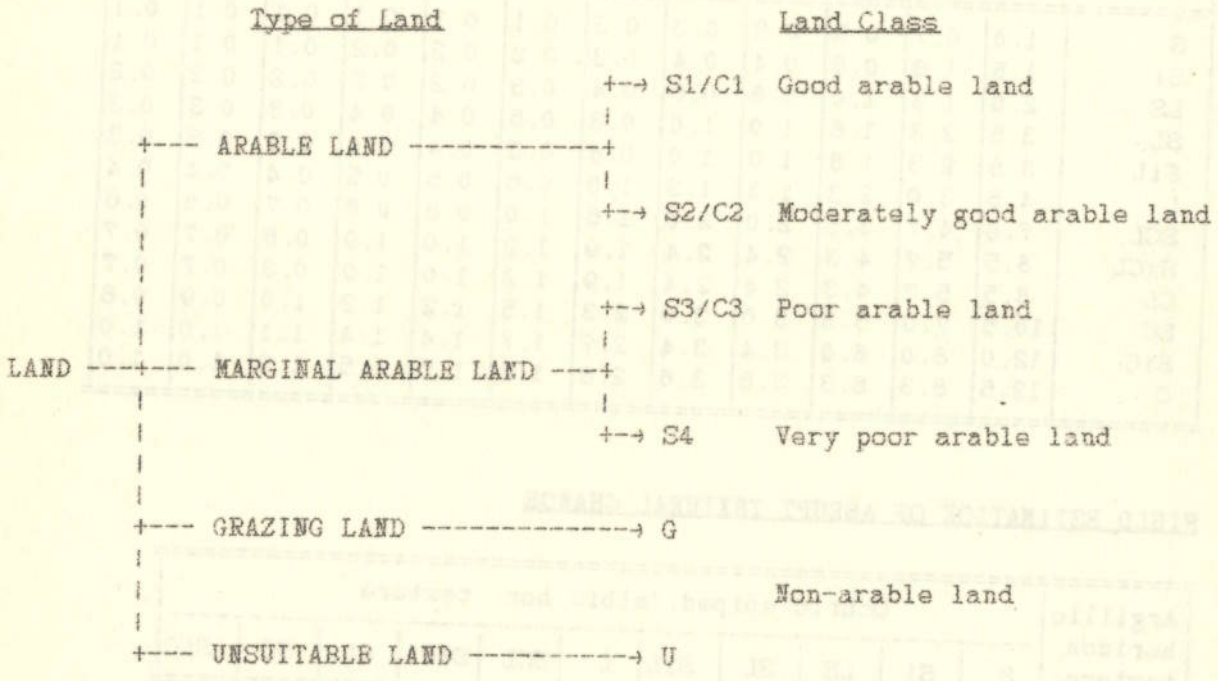
THE TEXTURAL CHANGE MUST OCCUR WITHIN 7.5 cm.

OUTLINE OF THE LAND CAPABILITY SYSTEM.

RESTRICTIONS:

The land capability system must **ONLY** be used when the following conditions apply (thus **NOT** in high rainfall areas or Western Zambia):

a) Plateau conditions
b) Rainfall 800 - 1000mm per year
c) Medium to large scale, rainfed, commercial farming system with good management, including conservation measures, suitable rotation, and adequate use of fertilizers, lime, herbicides and pesticides.

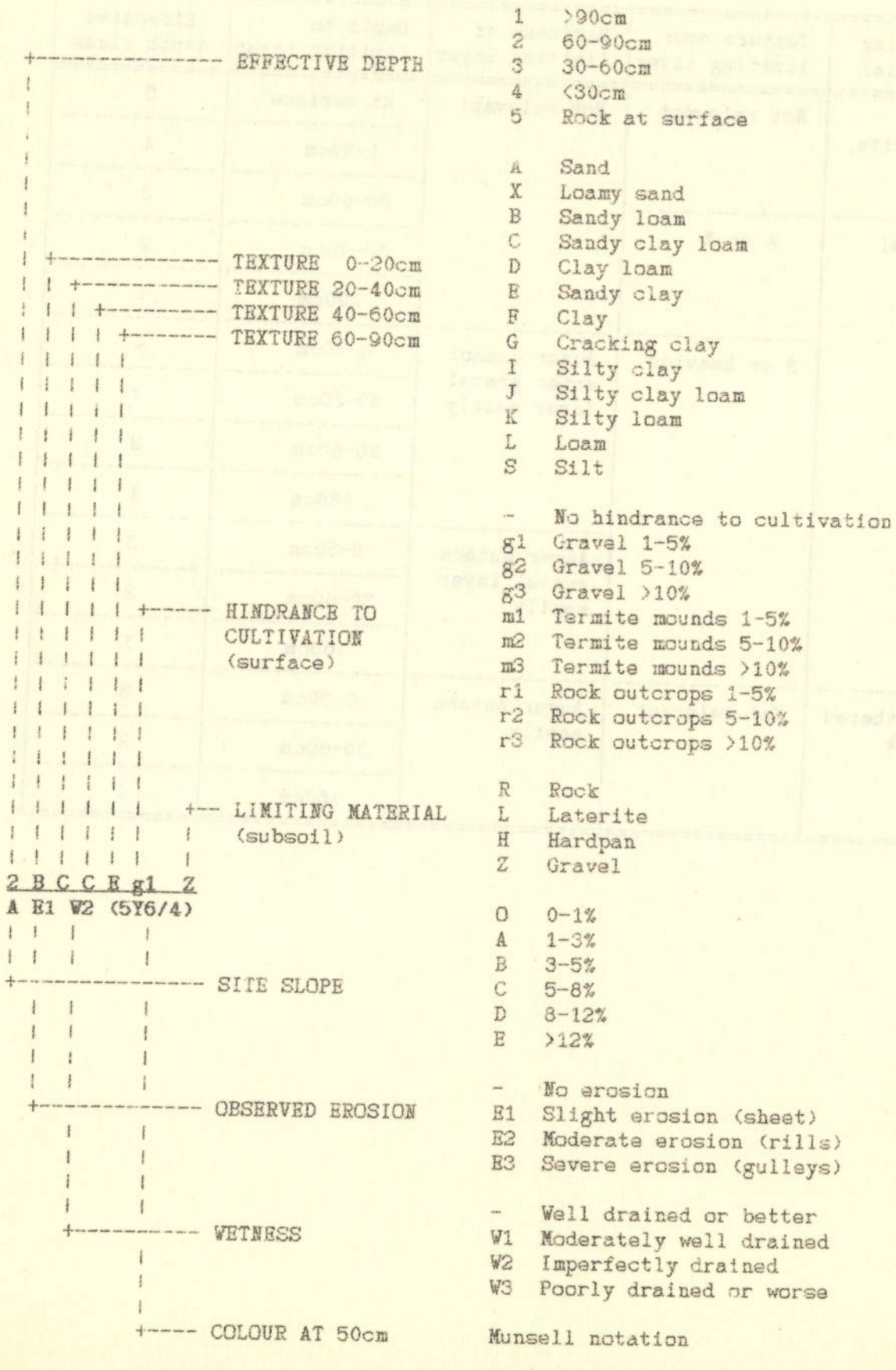


Topsoil textures : A, X, B, L, K, S = "S" soils
Topsoil textures : C, D, E, F, G, I, J = "C" soils

LIMITATIONS FOR LAND SUB-CLASSES:

d - depth
e - erosion
s - slope
t - texture
w - wetness
g - gravely or stoney topsoil)
m - mounds (termiteria)) Hindrances to cultivation
r - rock or laterite outcrops)

THE LAND CAPABILITY CODE.



FLOW CHART FOR LAND CAPABILITY EFFECTIVE DEPTH CLASSES.

Limiting Material	Texture over limiting layer	Hardness of limiting layer	Depth to limiting layer	Effective depth class
Rock, laterite, etc.	Not relevant	Not relevant	At surface	5
			1-30cm	4
			30-60cm	3
			60-90cm	2
			>90cm	1
Gravel	A or X			
	B or heavier	Auger cannot enter gravel layer easily	0-30cm	4
			30-50cm	3
			50-80cm	2
			>80cm	1
		Auger enters gravel layer easily	0-30cm	3
			30-60cm	2
			>60cm	1
Weathered rock	Not relevant	Auger enters easily	0-30cm	3
			30-60cm	2
			>60cm	1

CRITERIA FOR DETERMINING ARABLE LAND CAPABILITY CLASSES.

The following table summarises the criteria for determining the arable land capability class from the land capability code. The same information is repeated in a different format in the tables on pages 74 and 75.

	Arable land				Marginal arable land		
	Good arable land		Moderately good arable land		Poor arable land		Very poor arable land
Clayey - sandy class	C1	S1	C2	S2	C3	S3	S4
Minimum effective depth (cm)	90	90	60	60	30	30	90
Minimum texture topsoil 0 - 20 cm	C	X	C	A	C	A	A*
Minimum texture upper subsoil 20 - 40 cm	C	B	B	X	X	A	A*
Minimum texture lower subsoil 40 - 60 cm	C	C	B	B	X	X	A*
Maximum hindrance to cultivation %	1	1	5	5	10	10	5
Maximum slope class	A	A	B	B	C	C	C
Maximum erosion class	-	-	E1	E1	E2	E2	E2
Maximum wetness class	-	-	W1	W1	W2	W2	W2**

* Not heavier than X, even in 60 - 90 cm depth

** W3 in wet litongo soils

NB Topsoils with textures A, X, B, K, L are included in the S-soils. Heavy clay G, is not accepted in topsoils of C1 and C2.

CRITERIA FOR DETERMINING ARABLE LAND CAPABILITY CLASSES

1. DEPTH

Effective Depth	Class
1	S1/C1
2	S2d/C2d
3	S3d/C3d
4	Gd
5	Ud/Ur

2. HINDRANCE TO CULTIVATION

Hindrance to cultivation	Class
-	S1/C1
m1	S2m/C2m
m2	S3m/C3m
m3	Gm
r1	S2r/C2r
r2	S3r/C3r
r3	Gr
g1	S2g/C2g
g2	S3g/C3g
g3	Gg

3. TEXTURE

See seperate table overleaf

4. SLOPE

Topsoil texture	Slope	Class
A, X, B, C, K, L, S.	O, A	S1/C1
	B	S2s/C2s
	C	S3s/C3s
	D, E	Gs
D, E, F, G, J, I.	O, A	C1
	B, C	C2s
	D	C3s
	E	Gs

5. EROSION

Erosion Factor	Class
-	S1/C1
E1	S2e/C2e
E2	S3e/C3e
E3	Ge

6. WETNESS

Wetness Factor	Class
-	S1/C1
W1	S2w/C2w
W2	S3w/C3w
W3	Gw

NB Topsoil textures A, X, B, L, K, S = "S" soils, eg S2d

Topsoil textures C, D, E, F, G, I, J = "C" soils, eg C2d

LAND CAPABILITY DOWNGRADING FOR SOIL TEXTURE.

3. TEXTURE

Texture 0-20cm	Texture 20-40cm	Texture 40-60cm	Class
A	A	A	S4t
		X+	S3t
	X+	A	S4t
		X	S3t
		B+	S2t
X, B, K, L, S.	A	A	S4t
		X+	S3t
	X	A	S4t
		X	S3t
		B+	S2t
	B+	A	S4t
		X	S3t
		B	S2t
		C+	S1
C, D, E, F, J, I.	A	A+	Gt
	X	A	Gt
		X+	C3t
	B	A	Gt
		X	C3t
		B+	C2t
	C+	A	Gt
		X	C3t
		B	C2t
		C+	C1
G	G	G	C3t

NB + means "and heavier".
eg C+ means "C and heavier".

With shallow soils take the best texture class possible for the group of classes available.

CONVERSION OF LAND CAPABILITY CLASSES TO CROP SUITABILITY RATINGS FOR RAINFED CROPS.

RESTRICTIONS:

The land capability system and these crop suitability ratings must ONLY be used when the following conditions apply (thus NOT in high rainfall areas or Western Zambia):

a) Plateau conditions
b) Rainfall 800 - 1000mm per year
c) Medium to large scale, rainfed, commercial farming system with good management, including conservation measures, suitable rotation, and adequate use of fertilizers, lime, herbicides and pesticides.

Not considered: Slope
Hindrances to cultivation

	Maize	Sorghum	Ground -nuts	Soya beans	Sun- flower	Cotton	Virginia tobacco	Cassava
C1	1	1	2	1	1	1	3	2
C2d	2	1	2	2	2	2	3	2
C2t	2	1	4	2	2	1	4	3
C2w	2	2	3	2	2	2	4	3
C2e	2	2	2	2	2	2	3	2
C3d	3	3	3	3	3	3	3	3
C3t	3	2	4	3	3	2	4	4
C3w	3	3	3	3	3	3	4	3
C3e	3	3	3	3	3	3	4	3
S1	1	1	1	1	1	1	1	1
S2d	2	1	1	2	2	2	2	2
S2t	2	2	1	3	2	3	1	1
S2w	2	2	2	2	3	2	2	1
S2e	2	2	3	2	2	2	2	2
S3d	3	3	3	3	4	3	3	3
S3t	3	2	2	3	3	3	2	2
S3w	3	3	2	3	3	3	3	2
S3e	3	3	3	3	3	3	3	3
S4t	4	3	3	4	4	4	3	3

RATINGS:

1 - Well suited.
2 - Moderately well suited.
3 - Poorly suited.
4 - Not suited.

AUGERHOLE OBSERVATION SHEET FOR SOIL SURVEYS.

Survey area	Traverse No.	Date
Surveyor(s)	Bearing	Flight
UTM of traverse start	Map No.	Photo No.

Classification (field): Series FAO USDA	Map unit	Obs. No.
	Grid survey - distance along traverse Free survey - site map reference	

Depth	Horiz	Colour	Texture	Consist	Mottles	Other features

Position	Drainage
Slope type & %	Parent material
Micro relief	Surface features
Vegetation	Land use

Classification (field): Series FAO USDA	Map unit	Obs. No.
	Grid survey - distance along traverse Free survey - site map reference	

Depth	Horiz	Colour	Texture	Consist	Mottles	Other features

Position	Drainage
Slope type & %	Parent material
Micro relief	Surface features
Vegetation	Land use

REMARKS:

FIELD SHEET FOR LAND CAPABILITY SURVEYS.

Survey area		Traverse No.		Date
Surveyor(s)		Bearing		Flight
UTM of traverse start		Map No.		Photo No.

Observation No					
Distance (m)					
Texture 0-20cm	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.
20-40cm	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.
40-60cm	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.
60-90cm	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.	A, X, B, L, C, D, E, F, G, I, K, S, J.
Colour at 50cm					
Mottles colour					
depth					
Wetness class	O, W1, W2, W3	O, W1, W2, W3	O, W1, W2, W3	O, W1, W2, W3	O, W1, W2, W3
Auger depth cm					
Limiting mat.	H, L, R, Gh, Gs	H, L, R, Gh, Gs	H, L, R, Gh, Gs	H, L, R, Gh, Gs	H, L, R, Gh, Gs
Effect. depth	1, 2, 3, 4, 5.	1, 2, 3, 4, 5.	1, 2, 3, 4, 5.	1, 2, 3, 4, 5.	1, 2, 3, 4, 5.
Geomorphic position	C, US, MS, LS, DH, DF, DB, H. FP, RT, PM	C, US, MS, LS, DH, DF, DB, H, FP, RT, PM	C, US, MS, LS, DH, DF, DB, H, FP, RT, PM	C, US, MS, LS, DH, DF, DB, H, FP, RT, PM	C, US, MS, LS, DH, DF, DB, H, FP, RT, PM
Slope Reading					
Class	O, A, B, C, D, E	O, A, B, C, D, E	O, A, B, C, D, E	O, A, B, C, D, E	O, A, B, C, D, E
Erosion class	O, E1, E2, E3	O, E1, E2, E3	O, E1, E2, E3	O, E1, E2, E3	O, E1, E2, E3
Hindrance to cultivation	O, g, m, r 1, 2, 3	O, g, m, r 1, 2, 3	O, g, m, r 1, 2, 3	O, g, m, r 1, 2, 3	O, g, m, r 1, 2, 3
Land capability code					
Land cap. class					

REMARKS

KEY TO THE FIELD SHEET FOR LAND CAPABILITY SURVEYS.

TEXTURE

A - sand	C - sandy clay loam	G - cracking clay	J - silty clay loam
X - loamy sand	D - clay loam	I - silty clay	
B - sandy loam	E - sandy clay	K - silt loam	
L - loam	F - clay	S - silt	

COLOUR

Munsell code

MOTTLES

Only common or many, medium or coarse, distinct or prominent mottles.

WETNESS CLASS

0 - well or better drained	W1 - moderately well drained
W2 - imperfectly drained	W3 - poorly or very poorly drained

AUGER DEPTH

Depth at which the auger strikes a limiting material.

LIMITING MATERIAL

H - hardpan	L - laterite	R - rock or weathered rock
Gh - hard gravel	(a gravel layer that the auger cannot enter easily)	
Gs - soft gravel	(a gravel layer that the auger enters easily)	

EFFECTIVE DEPTH

1 - > 90cm	3 - 30cm to 60cm	5 - rock or laterite at the surface
2 - 60cm to 90cm	4 - 0cm to 30cm	

GEOMORPHIC POSITION

C - crest	US - upper slope	MS - middle slope	H - hill
LS - lower slope	DH - dambo head	DF - dambo fringe	FP - flood plain
DB - dambo bottom	PM - piedmont	RT - river terrace	

SLOPE

Class	Percent	Degrees
0	< 1 %	< 30'
A	1 - 3 %	30' - 1°40'
B	3 - 5 %	1°40' - 2°50'
C	5 - 8 %	2°50' - 4°30'
D	8 - 12 %	4°30' - 6°50'
E	> 12 %	> 6°50'

EROSION

0 - no observed erosion	E1 - slight (sheet) erosion
E2 - moderate sheet erosion or rills	E3 - severe erosion

HINDRANCE TO CULTIVATION

\- : hindrances to cultivation cover less than 1% of the area.
g : gravel patches are a hindrance to cultivation.
m : termite mounds are a hindrance to cultivation.
r : rock or laterite outcrops are a hindrance to cultivation.

1 : the hindrance to cultivation covers 1 - 5% of the area.
2 : the hindrance to cultivation covers 5 - 10% of the area.
3 : the hindrance to cultivation covers > 10% of the area.

FORMS FOR SOIL ANALYSES.

1. FORM FOR CHEMICAL ANALYSIS

This form should be used when submitting soil samples from profiles to the laboratories for chemical analyses. A tick is entered in the relevant small box for each analysis required.

CHEMICAL ANALYSIS

PROFILE No : PROVINCE : DATE:

Soil Chemist		Soil Correlator	EXTRACTABLE CATIONS (cmol (p+)/Kg)												CEC cmol (NH4+) /Kg NH4OAc at pH7	
			NH4OAc EXTRACT				KCl EXTRACT		PYROPHOSPHATE EXTR.			CIT. DITHION.		Total Exch. Acidity		
Lab No	Hor	Depth cm	Ca	Mg	K	Na	Al	Mn	Fe	Al	C	Fe	Al			

			SOLUBLE CATIONS mmol(p+)/L				SOLUBLE ANIONS mmol(e-)/L					CaCO3 %		CaSO4 %	
Lab No	Hor	Depth cm	Ca	Mg	K	Na	CO3	HCO3	Cl	SO4	NO3	<2mm	<20mm	<2mm	<20mm

			Org. C %	Total N %	pH				Total S %	Organic soil tests					
Lab No	Hor	Depth cm			H2O	CaCl2	KCl	CaCl2 (OH)		Fibre Vol.	Mineral %	Pyroph colour	EC ds/m		

FORMS FOR SOIL ANALYSES.

2. FORM FOR PHYSICAL ANALYSIS

This form should be used when submitting soil samples from profiles to the laboratories for physical analyses. A tick is entered in the relevant small box for each analysis required.

PHYSICAL ANALYSIS

PROFILE No : PROVINCE : DATE:

Soil Physicist		Soil Correlator	PARTICLE SIZE DISTRIBUTION																			
					SAND								GRAVEL									
Lab No	Hor	Depth cm	CLAY <,002	SILT ,002 -,05	VERY FINE ,05-,1		FINE ,1-,25		MEDIUM ,25-,5		COARSE ,5-1		VERY COARSE 1-2		FINE 2-5		MEDIUM 5-20		COARSE 20-75		H2O DISP. CLAY <,002		FINE CLAY <,0002		FINE SILT ,002 -,02	

			WATER RETENTION			BULK DENS.	COLE	PLASTICITY		
Lab No	Hor	Depth cm	10 KPA	33,3 KPA	1500 KPA	Mg/M3	cm/cm	Plast. limit	Liquid limit	

			MINERALOGICAL ANALYSES		
Lab No	Hor	Depth cm	WEATHERABLE MINERALS ,02 - ,2 mm	HEAVY MINERALS ,05 - ,5 mm	CLAY MINERALS <,002 mm

FORMS FOR SOIL ANALYSES.

3. FORM FOR FERTILITY SAMPLES

This form should be used when submitting composite soil samples to the laboratories for fertility advice.

CHEMICAL ANALYSIS

MAPPING UNIT :

DATE:

TOPSOIL 0 - 20 cm						EXTRACTABLE CATIONS (cmol (p+)/kg)							
Lab. No.	Sample No.	Grid Reference	Field Texture	Org. C %	pH KCl	Ca	Mg	K	Na	Al	Effective cation Exchange capacity	Al saturation %	

SUBSOIL 20 - 50 cm					EXTRACTABLE CATIONS (cmol (p+)/Kg)							
Lab. No.	Sample No.	Grid Reference	Field Texture	pH KCl	Ca	Mg	K	Na	Al	Effective cation Exchange capacity	Al saturation %	

SURVEY NAME :	Checked	Soil Chemist	Soil Correlator
SURVEYOR'S NAME :			

PRIVATE FARM REQUEST FOR SOIL AND/OR LAND CAPABILITY ADVICE.

NOTES:

a) Please answer ALL the questions in block letters.

b) This form must be received by the soil surveyor before any survey work may be undertaken.

c) The completion of this form does NOT guarantee immediate commencement of soil survey work on the farm.

d) Please provide a location sketch map of the farm indicating access routes (see section 16).

e) All survey work and soil analyses will charged for.

1. FARM NAME(S) and NUMBER(S) TOTAL AREA (hectares)
2. APPLICANT'S FULL NAME AND ADDRESS (postal and residential)
3. NAME AND ADDRESS OF REGISTERED OWNER OF THE LAND
4. TYPE OF RIGHTS HELD TO THE LAND (Rental/leasehold/traditional)
5. DATE ON WHICH WORK COULD COMMENCE
6. IF APPLICANT IS NOT RESIDENT ON THE LAND, STATE NAME OF PERSON FOR THE SURVEY TEAM TO CONTACT. A LETTER OF INTRODUCTION WOULD BE DESIRABLE.
7. IS THERE A WATER SOURCE FOR USE BY THE SURVEY TEAM? PLEASE SPECIFY: WELL/RIVER/BOREHOLE/ETC.
8. CAN YOU PROVIDE A CAMPSITE FOR THE SURVEY TEAM ON THE FARM? IF NOT, SUGGEST ALTERNATIVES

9. WHAT IS THE REASON FOR THE INVESTIGATION? PLEASE TICK:

GENERAL FARM PLANNING	( )
LAND CLEARING	( )
IRRIGATION LAYOUT	( )
LOAN APPLICATION	( )
FERTILIZER/LIME RECOMMENDATIONS	( )
CROP DIVERSIFICATION	( )
SITE SUITABILITY ASSESSMENT	( )
OTHER (specify)	

10. TYPES OF CROPS GROWN AND/OR ANIMALS KEPT ON THE FARM AT PRESENT.

11. LAND USE FOR WHICH THE SURVEY IS REQUIRED.
PLEASE SPECIFY CROPS, LIVESTOCK, ETC.

12. HAVE THE BOUNDARIES OF THE FARM BEEN OFFICIALLY DEMARCATED? GIVE DETAILS.

13. CAN YOU SUPPLY LOCAL LABOUR FOR THE SURVEY PERIOD?

14. DO YOU KNOW OF ANY PREVIOUS SOIL SURVEYS DONE IN YOUR AREA OR ON YOUR FARM? IF SO, GIVE DETAILS (INCLUDE MAPS, FARM BOUNDARY PLANS ETC.)

15. SIGNATURE DATE

....

16. FARM LOCATION SKETCH MAP

When completed, this form should be returned to the Soil Surveyor, Dept. of Agriculture, P.O. Box 12345, ANYTOWN. If possible, you should call in person so that details of the work required may be discussed.

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METRIC / IMPERIAL CONVERSIONS.

LENGTH

in	x	2.54	= cm	cm	x	0.3937	= in
ft	x	30.48	= cm	cm	x	0.03281	= ft
yd	x	0.9144	= m	m	x	1.0936	= yd
mi	x	1.60934	= km	km	x	0.62137	= mi

MASS

oz	x	28.349	= g	g	x	0.035275	= oz
lb	x	0.45359	= kg	kg	x	2.2046	= lb
ton	x	1016	= kg	kg	x	0.000984	= ton
ton	x	1.016	= tonne	tonne	x	0.98425	= ton

AREA

in^2	x	6.4516	= cm^2	cm^2	x	0.155	= in^2
ft^2	x	929.03	= cm^2	m^2	x	0.001074	= ft^2
yd^2	x	0.83613	= m^2	m^2	x	1.196	= yd^2
ac	x	0.40469	= ha	ha	x	2.471	= ac
mi^2	x	2.59	= km^2	km^2	x	0.3861	= mi^2
mi^2	x	259	= ha	ha	x	0.003861	= mi^2

VOLUME

in^3	x	16.387	= cm^3	cm^3	x	0.061024	= in^3
ft^3	x	28.317	= l	l	x	0.035315	= ft^3
yd^3	x	0.76455	= m^3	m^3	x	1.3079	= yd^3
pint	x	568.26	= cm^3	cm^3	x	0.0017598	= pint
gal	x	4.5461	= l	l	x	0.21997	= gal

MISCELLANEOUS

lb/ac	x	1.121	= kg/ha	kg/ha	x	0.89206	= lb/ac
ton/ac	x	2.551	= tonne/ha	tonne/ha	x	0.392	= ton/ac
ac-in	x	0.01028	= ha-m	ha-m	x	97.286	= ac-in
cusec	x	0.02832	= cumec	cumec	x	35.315	= cusec

NB To convert elevations given in feet on old 1:50,000 sheets to metres, multiply by 0.3 and round the result to the nearest 20m.

eg 4250 ft x 0.3 = 1275 m = 1280 m