REPUBLIC OF ZAMBIA

TECHNICAL GUIDE No. 10

LAND CAPABILITY SURVEYING
A TRAINING MANUAL FOR PLANNING STAFF

COMPILED BY
PETER WOODE

SOIL SURVEY UNIT
LAND USE BRANCH
DEPARTMENT OF AGRICULTURE
1980

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MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

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P A R T   O N E

SOIL AND LAND

CONTENTS

INTRODUCTION

This Training Manual has grown from a series of training courses run for planning staff. The first courses were on general planning for the staff of the Central Province, and were held in 1976 and 1977.

In early 1978 I was requested to travel to other Provinces to hold courses in land capability techniques. It was realised that a complete course had to cover not only the actual soil and land appreciation, but also map reading, air photo work, field techniques, and all the other related techniques that a surveyor must be familiar with. This manual is an edited version of the lecture notes used in the courses.

The subjects covered are aimed at training planning staff to plan semidetailed land capability surveys, carry out the field work and plot their findings accurately onto air photos. Air photo interpretation and soil mapping are not covered in this manual, other than a simple description of air photo interpretation necessary for traverse planning and field navigation. No mention of the recording of parent material in the LUS code is made, as this is something requiring training beyond the level of this manual.

It is hoped that the manual will be a useful reference work for both planning and soil survey staff of all levels.

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MARCH, 1980

ACKNOWLEDGEMENTS

The number of people responsible for the preparation of some of the original notes is large, and some of the writers are unknown. The author edited and re-wrote many of the original notes for the purpose of the planning courses.

For this training manual a lot of new material was added, some of it written by the author, and much plagarised from many of the sources given in the bibliography. Acknowledgement for original notes must be made to Z.B. Simutenda (S.T.O.), A.R. Fraser (S.T.O.), R. Bond (Planning Officer), J.Woods (Planning Officer) and R. Sorensen (Soil Surveyor). The draft of this manual was circulated amongst the soil survey staff for criticisms and suggestions and thanks for their constructive help are due to Dr.P. Heilman, O. Wennerby, J. Sloerdal, K. Offergelt, J.Storro and Mr. and Mrs. J. Cheatle. Much of the material was taken from the various works cited in the bibliography at the end of the manual. Special reference is made to "Fundamentals of Soil Science" by H.D.Foth and L.M. Turk (Edward Arnold Ltd)., from which most of Chapter I was taken. The manual was typed on stencils by Mrs.G.Ramani. Finally thanks are specially due to A. Commissaris, Senior Soil Surveyor, for his constant help and encouragement with the preparation of this manual.

CHAPTER 1

WHAT IS SOIL?

Soil consists of a mixture of mineral matter, organic matter, water, and air. In an arable soil the volume occupied by each of these will be approximately 49% mineral matter, 1% organic matter, 25% water, and 25% air. It is interesting to note that about half the volume is pore space filled with either air on water.

Each soil occupies space. It covers a certain area of land and has a certain depth. Each soil is a natural body which is surrounded by other soils with different properties. The area of an individual soil may vary from less than a hectare to more than a hundred hectares.

The soils on the earths surface are undergoing continual change. Weathering of rock produces unconsolidated debris that serves as the parent material of the soil. The effects of climate, relief and living matter, acting over a period of time upon the parent material produce the soil. Present day soils are continuously evolving into soils which will have completely different properties. Only a very few soils appear to have reached an end point in their development.

Thus we can see that there are five factors in soil formation. These are climate, relief, parent material, living matter, and time. The influence on soil behaviour of any of these factors, or the influence of a variation in any one of these factors, depends upon the others in combination.

From this we can give a definition of the word "SOIL":-
Soil is the collection of natural bodies occupying portions of the earth's surface that support plants and have properties due to the intergrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time.

SOIL AS A MEDIUM FOR PLANT GROWTH

Soil is important to man in many ways. It is used as the foundation for buildings. It is used as the foundation for tar roads, and both the foundation and the surface for gravel roads. It is used for brick making. Sandy soils are used for cement and concrete, and even in glass making. But the most important use of soil is in agriculture as a medium for plant growth.

The growth of plants depends on the soil for certain factors. These are support, a supply of nutrients, a supply of water and a satisfactory environment for the roots.

Support

This is the most obvious function of the soil. Roots anchored in the soil enable growing plants to remain upright.

Nutrients

About 16 different elements are considered necessary for plant growth. Carbon, Hydrogen and Oxygen are obtained from air and water. These comprise 90% of the dry matter weight of plants. The remaining 10% of the weight of a plant is made up of 13 elements which are obtained from the soil.

Nitrogen, Phosphorous, Potassium, Calcium, Magnesium and Sulphur are required in rather large quantities and are referred to as the major elements. Nutrients required in small quantities are called trace elements and include Manganese, Iron, Boron, Zinc, Copper, Molybdenum and Chlorine.

Most of the nutrients exist in mineral and organic matter in forms that are insoluble in water and are therefore unavailable to plants. Nutrients become available through mineral weathering and organic matter decomposition.

Water

It requires about 500kg. of water (500 litres or 2½ drums) to produce 1 kg. of dry plant material. Only about 1% of this water becomes part of the plant. The rest passes through the plant and is lost through the leaves.

Since the growth of virtually all plants will be affected when a shortage of water occurs, even though it may be temporary and the plants are not in danger of dying, the ability of the soil to hold water against the force of gravity becomes very important unless rainfall or irrigation is frequent.

Root Environment

Roots have holes through which they breath oxygen. Some plants (e.g. rice) grow in standing water because they have structures that allow oxygen to move down to the roots inside the plant. However, most plants must have a supply of oxygen available to the roots from the soil.

Many micro-organisms, bacteria and fungi live in the soil. These require oxygen to survive. They are important because they break down organic matter and release plant nutrients into the soil in a form available to plants.

A soil should provide an environment free of inhibiting factors such as extreme acidity or alkalinity, disease organisms, toxic substances, excess salts, or impenetrable layers.

Physical Properties of the soil

The physical properties of a soil have much to do with its suitability for the many uses to which man puts it. The supporting power, drainage moisture-storage capacity, plasticity, ease of penetration by roots, aeration and retention of plant nutrients are all connected with the physical condition of the soil.

SOIL TEXTURE

The relative size of soil particles is expressed by the term texture, which refers to the fineness or coarseness of the soil. More specifically, texture is determined by the relative proportions of silt and clay. The rate and extent of many important physical and chemical reactions in soil are governed by texture because it determined the amount of surface on which the reactions can occur.

The soil particles are divided into groups entirely on the basis of size without regard to their chemical composition, colour, weight or other properties. The basic groups are sand, silt and clay, although the sand fraction is subdivided into coarse, medium and fine sand. The particle sizes are given below.

Coarse sand	-	2.0 - 0.5mm diameter
Medium sand	-	0.5 - 0.25mm "
Fine sand	-	0.25- 0.05mm "
Silt	-	0.05- 0.002mm "
Clay	-	less than 0.002mm diameter

Most soils consist of mixtures of different proportions of these particle sizes. These mixtures are given names indicating the relative ammounts of the basic groups. These are discussed more fully in chapter 16.

Sand particles are of relatively large size and hence expose little surface compared to that exposed by an equal weight of silt or clay particles. Because of the small surface of the sand particles, the part they play in the chemical and physical activities of a soil is almost negligible. The chief function of sand is to serve as a frame work around which the more active part of the soil is associated. Unless present in too small proportion, the sands increase the size of spaces between particles, thus helping the movement of air and drainage water.

Sand and silt consist mainly of particles resulting from the breakdown of rocks and minerals. In a given soil they differ only in size. The clay fraction in most soils, however, is composed of minerals that differ greatly in composition and properties from sand and silt.

This is because chemical weathering on the surface of rocks, sand and silt particles results in the solution of chemicals that regroup or recombine to form particles of new minerals of clay size. Since a large part of the water in the soil is held as a film on the surface of the clay particles, the amount of clay in the soil has a great influence on its water holding capacity. In addition, certain available nutrients are held on the surface of clay particles. Therefore clay acts as a storage resovoir for both water and nutrients.

Soil structure

Structure refers to the aggregation (sticking together) of sand, silt or clay particles into compound particles (lumps or peds), which are separated from the adjoining peds by surfaces of weakness.

Structure modifies the influence of texture in regard to moisture and air relationships, availability of plant nutrients, action of micro organisms, and root growth.

Pore space

Pore space is important because soil pores are largely filled with water and air. Water and air also move through pore spaces. Thus, the supply of water and oxygen for plant growth and the rate of water movement through the soil are related to the amount and size of soil pores.

CHAPTER 2

SOIL FORMATION

There are five main factors in soil formation: climate, relief, parent material, organisms and time. The action of these factors cause several physical and chemical processes to take place. These will now be discussed in turn.

The influence of Climate on Soil Formation

Climate is considered by many to be the most important factor in determining the properties of soils. Moisture (rainfall) and temperature are the two aspects of climate most important in controlling soil properties. Moisture is important because water is involved in most of the physical, chemical and bio-chemical processes that go on in a soil. Temperature influences the rate of chemical and biochemical processes (and therefore the rate and degree of weathering).

Although in tropical latitudes, the temperatures in Zambia are tempered by altitude. There is one long dry season and one short rainy season. This is called a modified Sudan type climate.

The temperatures in Zambia are high enough to cause the rapid oxidation of soil organic matter, so that the soils typically are low in organic matter.

There is a general decrease in rainfall from north to South. Northern Zambia averages about 1,000-1,500mm (40-60"), and southern Zambia averages 600-1,000mm (25-40").

Evaporation is high in Zambia, averaging around 2,150mm (over 6 feet) in Central Province. The alternate wet and dry seasons, coupled with the high rate of evaporation, causes alternate wetting and drying regimes in the soil. This is responsible for the precipitation of iron in the soil and the development of red iron-rich profiles.

The lack of organic matter mentioned earlier coupled with a heavy seasonal rainfall, is responsible for much soil erosion with the frequent removal of the topsoil or even the subsoil and their deposition further downslope. Bush fires also reduce the soil organic matter and remove the protective bush cover, thus further increasing the risk of soil erosion.

The decisive climatic factor in soil horizon development in Zambia is rainfall. This affects the degree of soil weathering and leaching. (see page 10). In southern Zambia, where annual rainfall is under 1,000mm per annum, these processes are slower than in the rainier north. The effects of increasing rainfall on the extent of leaching are modified by parent material, which influences soil texture, colour, structure, etc.

Discounting the valley and rocky escarpment soils along the south eastern side of the country (both of which are expressions of topography), the most widespread soils in Zambia are the sandveldt soils. These are light textured plateau soils (typically loamy sand or sandy loam over sandy clay loam) developed over acid and intermediate rocks. The typical vegetation is Miombo woodland. Pockets of red clays formed over sedimentary and metamorphic rocks occur within the areas of sandveldt, as determined by parent material.

A line approximately following the 1,000mm isohyet marks a significant boundary in Zambia. South of this line, the effects of parent material are dominant; the red clays being only moderately leached and incompletely weathered, providing good agricultural soils. The sandveldt soils have lower mineral reserves and are more heavily leached, but are still reasonable agricultural soils.

North of the 1,000mm isohyet, the influence of geology becomes less important. Both the red clays and the sandveldt soils are strongly weathered and deeply leached. They have very low mineral reserves and are strongly acid. In general these are poor agricultural soils because of their low capacity to retain nutrients and their acidity.

The influence of Relief on Soil Formation

The effects of elevation (altitude) have already been mentioned. At a local level the most important effects in the field are exhibited by the Catena. Any group of soils of the same age, derived from similar parent materials, under the same climatic conditions will show progressive variations as one moves from valley or dambo bottom, up the slope, over the ridge, and back to the next valley. The complete group of soils found in such a sequence is called a Catena. In practice a Catena is taken on soils over a related group of parent materials. This sequence is very well exhibited in Zambia.

The usual changes in soil characteristics related to a catenary sequence are changes in drainage, texture and depth. The drainage characteristics are reflected in the soil colour and occurence of mottling. Changes in texture and depth across a Catena are usually due to illuviation and erosion downslope.

Changes in soil type often occur where there is a change in slope or physiography.

Steep slopes tend to be more heavily eroded than gentle slopes, and dambos tend to accumulate eroded material from the higher ground. Sandy textured soils on a given slope are more prone to erosion than finer textured soils on the same slope.

The Influence of Parent material on Soil Formation

The properties of parent materials which are most important in soil development are texture and mineralogical composition. Different rocks weather and erode at different rates. Thus soils are developed more rapidly from permeable or readily decomposed rocks than from those that are relatively impermeable or resistant to decay. The texture of the parent material can have direct influence on the texture of the resulting soils. Thus granites, which are coarse textured, tend to weather to sandy soils with a low clay content.

Although clay is defined by its particle size, it is made of minerals that are different from the parent material. They are formed by chemical processes during the weathering process. Chemical weathering of the parent material produces iron in solution. These re-combine to form the new minerals called clay minerals. It is from these clay minerals that the clay in the soil is formed.

Granites, gneisses and sandstones consist mainly of quartz. This mineral does not weather under normal soil forming conditions, so soils from such rocks are usually sandy; some are gravelly or stoney as well. However, most of these rocks do contain some weatherable minerals which break down to produce some clay and iron. Soils over granites, gneisses and sandstones range from pale coloured sands to red sandy clays, according to the amount of weatherable minerals in the parent rock.

Limestones and other basic rocks (e.g. basalt, gabbro, calc-silicate schist) weather to produce large amounts of clay and iron. Under well drained conditions these rocks provide dark red clays. Weathering is sometimes irregular and some such soils have frequent rock outcrops. River and dambo alluvium derived from basic rocks may be dark-coloured cracking clays.

The Influence of living matter on Soil Formation

Biological agents modify the material produced by rock weathering in several ways. The addition of organic matter by decay of plant remains is an obvious exampls. Most soils are darker and have more organic matter in the topsoil, since there are more roots in this layer and it is nearest the ground surface on which leaves fall and decay.

Soil animals ranging in size from ant-bears to microscopic creatures are important in mixing the soil material so that the original rock structure disappears. Most important in this respect are termites, both those which produce mounds and those which merely make covered channels on the ground surface and on tree trunks.

Termites bring material from deep layers to the ground surface. Over a period of many years, this material is gradually washed over the ground surface. Since termites can only carry material of up to about 2mm in diameter, their activity leads to a sorting of soil material. In most upland soils, this is the reason for the separation of an upper soil layer containing only fine earth (sand, silt, and clay) from a lower layer containing gravel and stones over rocks which produce gravel and stones when weathered.

In the relations between vegetation and soil, there is more two-way interaction than with the other soil-forming factors. Soil type has a strong influence on the vegetation type, while at the same time the vegetation type has a strong influence on the soil type.

The major influence of vegetation on soils is caused by the rate of supply of dead plant material. This includes dead leaves and wood which fall onto the soil surface, and dead roots within the soil.

Under Zambian conditions the amount of plant material ranges from 30-100 tonnes/hectare. Most of this is actual living matter(trees, grass, etc.) but it is constantly circulating through the soil as the dead material enters the soil, rots, becomes plant nutrients and is again taken up by the plants. However, it is not the total amount of plant material that is significant in soil formation, but the rate of growth and decay. An important part of the influence of vegetation is it's effect on soil moisture. A light tree cover gives a greater exposure to wind and sun than a heavy tree cover. Also, a light tree cover leads to less leaf-fall and therefore a lower mulching effect than a heavy tree cover. Thus a soil with a light tree cover dries out more readily, and to a greater depth, whilst a heavy tree cover tends to conserve moisture. Since most chemical soil forming processes (see later) depend on the soil water, this will affect the soil formation.

The Influence of Time on Soil Formation

Soils are constantly undergoing change. The changes take place slowly, and many people think that none occur. Parent material may be transformed into an immature or young soil in a relatively short period of time if conditions are favourable. This stage is characterised by organic - matter accumulation in the surface soil and by little weathering or leaching. Only the A and C horizons are present. The mature stage is reached with the development of a B horizon. An old soil has very great differences between the A and B horizons.

Not all soils have been developing for the same length of time. Some horizons develop before others, especially those at the surface which may take less than 100 years to develop. Horizons formed from rock weathering may take more than a million years to develop.

Physical Processes in Soil Formation

The most important physical processes in soil formation are mechanical weathering, eluviation, erosion, and the effects of biological agents such as roots, termites, etc., as already discussed.

Physical weathering occurs when rocks from deep in the earth are exposed due to the removal of overlying layers. The release in pressure results in expansion and cracking of the rock. Strains from temperature changes, freezing of water, and the errosive action of water and wind slowly break up the hard rock.

Eluviation is the process of leaching, especially in high rainfall areas. It results in the downward movement of fine soil fractions and of ions (mainly iron and calcium), carried by the percolating rainwater. It often results in illuviation (the formation of a zone of deposition of leached material), or the complete removal of the matter in the drainage water. Strongly leached soils tend to be acidic and of a low fertility due to low cation exchange capacity and low base satturation.

Erosion is a surface process. It is very important in the tropics. On a micro scale it is partly responsible for the formation of colluvial deposits such as piedmonts of hills, which have markedly different profiles to surrounding land, due to the transfer of material from above. On a large scale it is the first stage in the transport of soil materials to form alluvial deposits.

Chemical Processes in Soil Formation

Chemical weathering occurs because rocks and minerals are seldom in equilibrium with near-surface temperatures, pressures, water, and atmosphere. The rocks and minerals therefore change into products that are more stable under the near-surface conditions. If, as time goes on, the soil enviornment changes, so too will the products of weathering.

Hydrolysis

Hydrolysis is the most important process in the chemical weathering of the soil. Water, in which a great variety of ions can be present, reacts with minerals. The usual reaction is that of water and acid (H_2CO_3 from atmospheric CO_2) on the minerals. Other acids such as those occuring from the decay of organic matter, also occur. Cations can remain in the soil either in the soil solution as part of the structure of clay minerals, or as exchangeable ions on the surfaces of soil particles. Some ions are cycled through plants from the soil and back again. Some are leached out.

Chelation

It is the formation of complexes between organic matter and metallic ions. It is responsible for a considerable amount of weathering. Chelating agents are formed by biological processes in soil. Once in solution the chelate may be stable at pH conditions under which the ion would ordinarily precipitate out.

Oxidation

It is the process by which an element loses an electron. Iron is the èlement most commonly oxidised in a soil, and the oxidation products give the soil the characteristic yellowish brown to red colours. In soils the most common oxidising agent is oxygen dissolved in the soil water.

Hydration and Dehydration

Are processes by which water is added to or removed from a mineral. The result may be the formation of a new mineral.

Ion exchange

Ion exchange from within the crystals of clay minerals (as opposed to ion exchange from the surface of clay or organic particles) can cause the alteration of one clay mineral to another.

THE DEVELOPMENT OF SOIL PROFILES

The formation of soil profiles is the combined effect of the factors and processes discussed above. It can be summarised as the combined effect of additions to the surface (minerals from wind and rain water, biological material and alluvial material), transformations within the soil (physical, chemical and biochemical), vertical transfers within the soil (eluviation, leaching, evaporation, and biological transport) and removals from the soil (biological, leaching, and erosion). For any one soil the relative importance of these processes varies.

A soil usually consists of layers (horizons) of mineral and/or organic material, which differ from the parent material in their physical, chemical, mineralogical and biological properties. A soil profile consists of the vertical arrangement of all the soil horizons down to the parent material.

There are seven different horizons defined, each of which is identified by a letter. They are H,O,A,E,B,C and R. The most usual horizons found are the A,B,C and R horizons.

The A horizon is a predominantly mineral horizon formed at or near the surface that usually shows an accumulation of humified organic matter mixed with the mineral fraction. It is in a dynamic equilibrium with continuing gains and losses of organic matter. Under conditions of rapid oxidation of organic matter, the A horizon may be very slight. Where surface erosion is constantly occuring, the A horizon may never have chance to form properly, as it will be removed as fast as it forms. This is often the situation in Zambia.

The B horizon is a mineral horizon primarly characterised by an illuvial concentration of clay, iron aluminium or humus and the formation of structure.

The C horizon is a mineral horizon from which the soil has formed but which does not show properties of the other horizons. This includes gravel layers.

The R horizon is continuous rock.

Poor water drainage and the accompanying low oxygen content in a soil leads to reducing conditions. The result is that iron and manganese are in a reduced state, and the compounds formed give the characteristic grey and bluish colours. If conditions are part oxidising and part reducing due to fluctuating water content or water table, some of the iron will be oxidised, and compounds with brown and red colour will be formed. Quite commonly, under such conditions, part of the matrix is reduced and part oxidised, and the characteristic colours are mixed. This is called mottling, and is a very important diagnostic feature in Zambia. It is how seasonal waterlogging of a particular horizon can be recognised when surveying in the dry season.

It must be remembered that each soil type covers a particular type of landscape. It is defined by both it's land form and it's profile characteristics. An individual soil profile occupies a very small area, essentialy a point. Thus, a given type may contain many different profiles. However, all the profiles within a given soil type have certain differentiating characteristics in common.

In other words, the soil is not only a vertical body, as observed in a profile, but also a horizontal body as part of the landscape. Just as there is a range in characteristics from the surface down to the parent material, so there is a lateral range in characteristics from place to place. A soil type within any classification system is defined by human logic. But soil is a natural body, and may vary widely within the limits we arbitarily set to define it. Each soil must therefore, be examined at several points before any conclusions may be drawn.

CHAPTER 3

LAND CAPABILITY SURVEYS

"Land" consists of all the aspects of the physical environment, of which soil is only one. A "land unit" comprises the soil, the climate, the geology, the hydrology (drainage), the vegetation, the existing land use, and other factors mentioned below.

"Land capability" is the capability of a unit to be used for a given purpose. A land capability survey is thus not quite the same thing as a soil survey. In a soil survey we look only at the soil, and classify it (give it a name), so that any soil scientist reading the map or report should be able to recognise it and understand it's features.

A land capability survey, however, looks at the soil at the same time as all the other features of the area, and says what that soil is capable of under those conditions. A single land capability unit may therefore include more than one soil type. A land capability survey is the first stage in the planning of the future land use of any area.

The function of land use planning is to guide decisions on land use in such a way that the resources available are put to the best use, whilst at the same time conserving those resources for the future. Successful land use planning can only take place when it is known what uses or crops the land is capable of supporting. The best way of using a soil depends on many economic, social, political, and sometimes even religious considerations, in addition to the soil characterisitics. A complete plan must also take account of the size of tracts of land, their relation to water, other land, transport facilities, and markets. Preference of the owner or land user, and his resources in capital and skill, also play a big part in the selection of land uses, cropping systems, or soil management practises.

Natural soils differ greatly from place to place. Yields of crops almost everywhere can be improved through better soil management, but the practices needed depend on the kind of soil. Land capability surveying is concerned with the examination of the soil and the surrounding land to determine what the land is physically capable of supporting. Only when that has been decided is it possible to consider the other factors.

A soil or land capability map has little value unless the information from it is used in farming or in some other soil managing activity. A good survey must be both practical in it's purpose, and scientific in it's construction. Unless the map serves a practical purpose there is no use in wasting time and money on it's production. Unless the mapping units are scientifically conceived, the map is almost sure to lose it's usefullness as techniques advance and change.

Soils are three-dimensional individual pieces of landscapes. A soil has depth and area, and it occupies a slope or pattern of slopes. Each soil has many characteristics, and in one way or another it's characteristics reflect it's entire history. Each soil evolved in and with it's environment, and it interacts in many ways with its present environment. The job of the surveyor is to predict how the soils of a given kind will respond when used for a given purpose.

Survey results should be arranged for easy reference and use by the planning staff. The soil map shows the location and extent of each kind of soil. The units of classification should tell the planner the main characteristics and responses of the soils that are important for his work. The soil user generally wants to apply the most profitable management on each kind of soil and good land capability interpretations should help him do that.

The physical factors that determine the capability of a soil for a given agricultural use are:-

1. Effective depth: this is the thickness of soil available for satisfactory root development.

2. Texture: the different proportion of different sized groups of soil grains. This affects ease of cultivation, drainage, drought risk, erosion risk, amount of fertilizer needed, suitability for different crops and many other factors.

3. Hindrance to Cultivation: Gravel, stones, rocks or anthills that occur in sufficient quantities to hinder the farmer in his cultivations.

4. Limiting Material: If there is a limitation in the effective depth, the nature of the limiting material can be important because roots may penetrate one type of material (e.g. gravel) and not others e.g. rocks.

5. Slope: A land with a steep slope is more liable to have soil erosion when cleared than a land with a gentle slope.

6. Erosion: Evidence of existing erosion can indicate if the land is suitable for clearing, or if soil conservation measures are needed. Slope, topsoil texture, rainfall, and vegetation coverage are also important considerations in assessing the erosion hazard under a proposed system of land use.

7. Wetness: This refers to the degree of wetness within the rooting range during the wet season (the growing season). A poorly drained soil will remain fully or partially water logged in the root region for long periods. This restricts the amount of air around the roots, and results in poor growth. Since most surveying is done in the dry season, the height of water table cannot be observed directly. Thus the degree of wetness is determined by the subsoil colour, degree and depth of mottling, occurence of rusty root channels, vegetation, topographic position, subsoil texture, and limiting layers.

When all of the above factors have been recorded, we have carried out a simple basic soil survey. From those factors we can now determine the characteristics of the soil, and then from the results interpret the land capability classification.

The basic soil survey is what you have carried out when you have been in the field and recorded all the observed features. These results can then be interpreted in many ways. You may want to produce a map of the suitability of the soils for road foundations, or for forestry. A planner might want a map of the erodibility of the land so that he can plan major conservation works. You may want a map showing the suitability of the land for irrigation, or citrus production, or many other uses. You may also want a map showing the different types of soil based on one of the many classification systems. In Zambia the soil survey unit produces both soils maps, which do not directly tell you about the potential use of the soil, and maps showing an interpretation of the capability of the soil to produce certain crops. These are call land capability maps.

Kind of Survey

To make a survey, the surveyor examines and classifies the soils in the field, locates the soil boundaries and plots these on a map, describes the soils shown on the map, and finally interprets the mapping units to serve the purpose for which the survey was made.

Soil surveys can be made at several levels of intensitys, depending on the nature of the area and its stage of development, the time, money and personell available, and the uses that are to be made of the information. The level of survey determines the intensity of field work. The choice of the map scale depends upon the level of the survey.

This choice of scale is important. A map published at a large scale will be assumed to be accurate for measurements made on it with a normal ruler etc.

Map users tend to (wrongly) assume that soil or land types change from one to another within the thickness of the line drawn to indicate the soil or land boundary. On large scale map the lines cover a narrower ground width than on a small scale maps.

Most map users will realise that an area demarcated on a small scale map must contain variation within it, because of the large ground area represented. However, on a large scale map there is a feeling that as topographic and other physical features are shown in great detail (or at least could be), then so must be the soil or land features. The scale of the map therefore, acts as an unwritten indication to map the user of the accuracy of the map. A large scale implies great accuracy, whilst a small scale implies less accuracy.

The map user can assume that the surveyor has mapped at a scale commensurate with the survey intensity and methods. It is always possible in the office to reduce a large scale to a smaller scale. Generalisations can be brought into the legend to match the smaller scale and more general way the information is presented. However, it is not permissable to go from a small scale to a larger scale without further field checking.

The most important levels of survey are listed below, with a brief description of their uses and map scale. The map scale refers to the final publication scale. It is usual to use air photos of a larger scale as field maps and for interpretation and mapping purposes. The final map is then reduced in scale for publication. This automatically reduces the errors on the published map.

Exploratory Surveys: These are not surveys in the strict sense in that they do not attempt full coverage of the area. They are rapid road traverses made to provide a minimum of information about otherwise unknown regions. Map scales vary from 1:2,000,000 to 1:250,000. They are used for feasibility studies in order to determine areas for further studies.

Reconnaissance Surveys: These are the smallest scale of survey to achieve coverage of the whole survey area. The usual map scales are from 1:250,000 to 1:100,000, but maps from 1:500,000 (rapid reconnaissance) to 1:50,000 (detailed reconnaissance) are included. They are used for National and Provincial development planning.

Semi-Detailed Surveys: These cover the whole area by air photograph interpretation combined with a substantial amount of field survey. Map scales range from 1:60,000 to 1:20,000. They are used for farm plans and catchment conservation plans.

Detailed Surveys: These are produced mainly by field survey. Soil boundaries are "followed" and plotted on the ground. Map scales range from 1:30,000 to 1:20,000. They are used for irrigation schemes and other high cost projects.

Intensive Surveys: These are produced in the same manner as detailed surveys, and are mapped at scales larger than 1:10,000. They are used for irrigation schemes and research plots.

The land capability system is designed to indicate the relative suitability of land for rainfed, medium and large scale commercial farming. For arable land maize, tobacco, soya-beans, sunflower and groundnuts are the main crops considered. Use of ox or tractor cultivations, adequate use of fertilizers, pesticides and weed control measures are assumed, together with a high level of management or technical supervision. For non-arable land, it is assumed that grazing will be the major use.

It will be noted that chemical analysis has not been mentioned. Usually we consider only those factors that the farmer has no control over. A poor nutrient supply or high acidity can be corrected by the use of fertilizer or lime. They do not therefore, enter our land capability classification. However, some soils are unable to store plant nutrients even when added as fertilizers. This results in a low fertility that the farmer cannot correct, and in this case it should be recorded in the land capability classification. However, at the time of writing the recording of this factor is under review, and it will not therefore be considered further in this manual.

P A R T T W O

MAP READING

CHAPTER 4

MAP PROJECTIONS, MAGNETIC, GRID & TRUE NORTH

MAP PROJECTIONS

The earth is a sphere; a ball. The surface of the earth is therefore continuously curving in all directions. The problem facing a map maker is to accurately draw a representation of the spherical surface of the earth onto a flat piece of paper.

In you consider a cone, it can be cut and unrolled to form a flat surface. Similarly, a cylinder may be cut and rolled flat. In both these cases, no distortion would be caused to the features on the surfaces of these shapes when they were converted from a solid body to a plane. However, there is no way that a sphere may be cut and converted to a flat surface. In order to represent the surface of a sphere on a flat surface the features on the surface of the sphere must be distorted on the flat surface. Some parts must be stretched and others compressed. Whatever you do, it is impossible to accurately represent distances, directions (bearings), shape and area on the flat surface.

If a map is produced with the direction of all points from all others accurately represented, it will be found that the shapes of features seen on the surface of the earth (a sphere) are distorted on the map (a flat surface). If the shapes and areas are correct, distances and direction will become inaccurate. All maps are therefore a compromise.

Over a small area of land, the inaccuracies on a map are so small as to be insignificant, because the earth is so very large that the curvature is slight over small areas. Thus with the maps in common use in Zambia at scales of 1:250,000 and 1:50,000 the distances, bearings, shapes and areas are accurate enough for normal useage. In fact, the errors on a single map are smaller than can be measured.

However, over a large area, the inaccuracies between two distantly spaced maps can be large. Thus a type of "projection" is used over a limited area of the earths surface, so that within that area, the errors from map to map are minimal.

The type of projection used in Zambia for the production of 1:250,000 and 1:50,000 topographical maps is called the Universal Transverse Mercator projection.

A small area of the earths surface is taken, and drawn in such a way that a line on the ground following a constant bearing from one point to another, will appear as a straight line on the map. In fact, a line of constant bearing on the ground follows a curved, not a straight line, but over small distances the curve is so slight that it cannot be noticed. Since a line of constant bearing is a straight line on the map, the map may be covered by a regular grid of lines crossing at right angles, and the angles between any grid line and any line of a given bearing will be the same.

However, when an area is mapped in this way, we come back to the problem of the earth being spherical and the map being flat. By taking only a small area of the earths surface, the problems within the area mapped are minimised, but difficulties arise where we try to relate a point within our mapped area to some point outside that area. This is important to us when we want to calculate the bearing of one point from another.

In order to define any point in the world, geographers have imagined a system of lines which form a grid over the surface of the earth. One set of lines cross at two points called the north pole and south pole respectively. These are called meridians or lines of longitude. The other lines go round the earth parallel to each other. These are called line of latitude. The lines of latitude and the meridians cross each other at right angles, and would be seen as straight lines along the spherical surface of the earth.

Thus, any line that is parallel with a line of longitude is running from the south pole to the north pole. It is said to have a bearing of true north.

But such a straight line along the spherical surface of the earth appears as a curved line on our flat map. We have thus got the situation where our map shows the correct distances, directions, shapes and areas and is covered by a grid with a constant relationship to bearings, but the direction of true north from any point follows a curved path across the map. Thus the difference in angle between the vertical grid lines (called "grid north") and the direction of true north varies from place to place within the mapped area.

Bearings and Magnetic Declination

A bearing is the direction of one point from another, indicated as an angle measured clockwise from the direction of north.

However, before we can start measuring the angle clockwise from north, we must first know what is meant by north. In fact, "north" can mean three different things. There is true north - the direction of the ~~vertical grid lines at~~ North pole from any point. There are also two other norths which we use for convenience.

On topographic maps we have the system of grid lines covering the area. The vertical grid lines run approximately north-south, so that they can be used to show "grid north". Grid north is the direction of the vertical grid lines at any point. This is very convenient as any point on the map is close to one of the grid lines for easy reference. As explained above, the direction of the vertical grid lines varies from true north from place to place. The difference between true north and grid north is usually printed on the map.

However, when we are in the field, we have no way of measuring either true north or grid north. In the field, therefore, we use what is called "magnetic north". Magnetic north is the direction in which a compass needle points at any place. This is not usually the direction of true or grid north.

The whole earth acts like a magnet whose magnetically north pole is somewhere in northern Canada, and not at the north pole. The reason that geographers did not simply choose the magnetic north pole to also be the true north pole (and thus make everything very simple) is that the exact position of the magnetic north changes from year to year. As it moves its position, the direction of magnetic north throughout the world moves with it.

Therefore, the difference in angle between true north and magnetic north changes from place to place, and also from time to time. This difference is called the "magnetic variation" or the "magnetic declination". (see Fig.4-1). The amount of magnetic declination for a given year is usually printed on the map, with the amount and direction that the magnetic declination will change each year from that figure (see Fig.4-2).

Therefore, from the map we can find out

(1) what was the magnetic variation at the time the map was drawn;
(2) The length of time from when the map was drawn to the present;
(3) The annual change in the declination.

We can therefore calculate the present variation as the original variation plus the number of years since the map was produced, times the annual change.

$$\text{Present variation} = \text{Original variation} \mp \left(\text{Years since map drawn} \times \text{Annual change}\right)$$

In Zambia at the time of writing, however, the magnetic declination given on many of the maps has been found to be inaccurate. It is better, therefore, to measure the magnetic declination yourself. For practical purposes we measure the magnetic-to-grid and not the magnetic-to-true declination. This is so we can then use the grid lines for all measurements on the map. The method is described later in the section on "traverse planning".

FIG 4-1

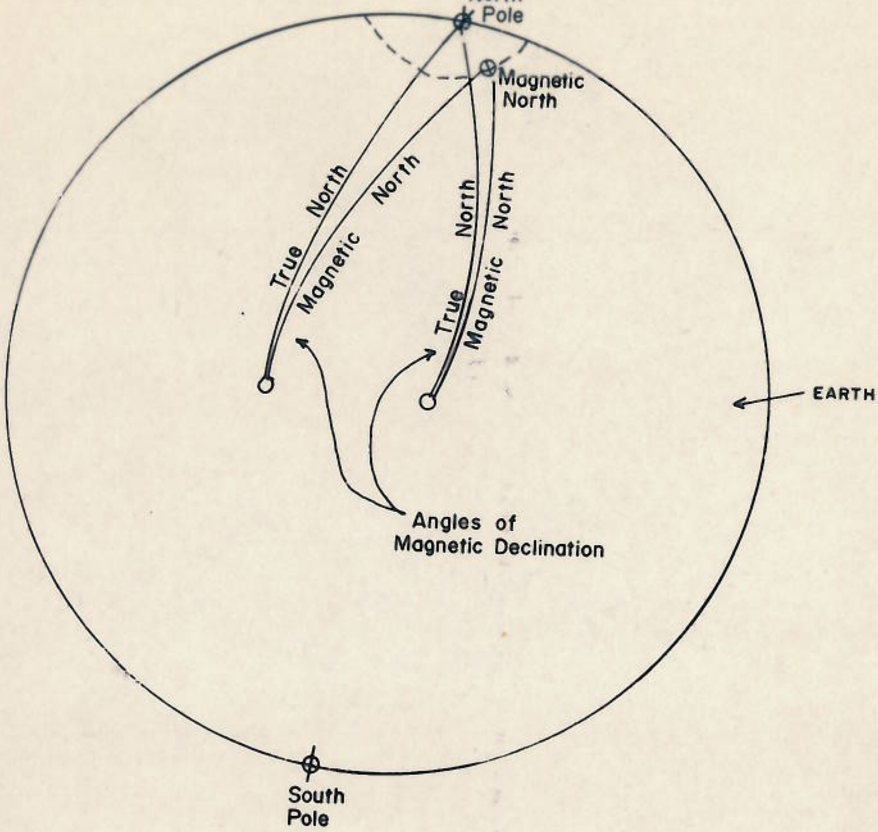
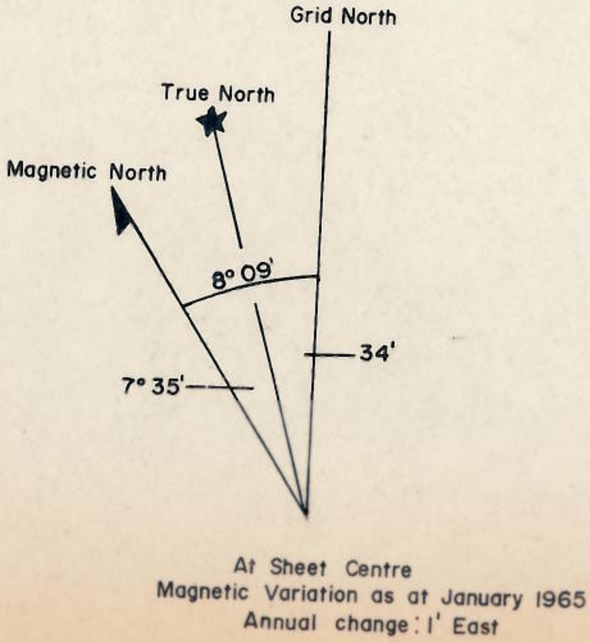

North
Pole
Magnetic
North
True North
Magnetic North
True North
Magnetic North
EARTH
Angles of
Magnetic Declination
South
Pole

FIG 4-2


Grid North
True North
Magnetic North
8° 09'
34'
7° 35'
At Sheet Centre
Magnetic Variation as at January 1965
Annual change: 1' East

CHAPTER 5

MAP SCALES.

The scale of a map is probably its most important feature. By choosing a suitable scale we can determine the space available on the map for the representation of detail. The scale is the ratio of the distance between two points shown on the map and the distance between the same two points on the ground. Thus the scale enables us to calculate distances on the ground from the map and conversely to plot distances measured on the ground onto the map.

The scale of a map is therefore a way of expressing the amount by which distance on the ground has been reduced when drawing the map. If a map has been drawn so that distance on the ground has been reduced 1,000 times then the scale of the map is 1:1,000. If the reduction is 100,000 times, then the scale is 1:100,000. These figures may also be shown as a fraction:

e.g. $\frac{1}{1,000}$

In Zambia the two most common scales are 1:50,000 and 1:250,000.

Let us look at a map with a scale of 1:50,000. This scale tells us that one unit on the map is equivalent to 50,000 units on the ground. The most important thing to note here is that units used on each side of the equation must be the same. We can therefore, say that:

1cm on the map is equivalent to 50,000cm on the ground.

or that

1 metre on the map is equivalent to 50,000 metres on the ground

or that

1 inch on the map is equivalent to 50,000 inches on the ground

or that

1 of any unit on the map is equivalent to 50,000 of the same units on the ground.

The map scale is neither metric nor imperial. You choose whatever units you want to measure in. The scale merely tells us the relationship between those units on the map and the same units in the field.

In Zambia we use the metric system. This has the advantage that it is very easy to convert one unit to another. Each unit is ten, a hundred or a thousand times bigger or smaller than the next unit in the metric system. To multiply by ten, we simply add an extra nought onto our number, or move the decimal point one place to the right. To divide by ten we remove a nought, or move the decimal point one place to the left.

The metric units of distance are as follows:-

1 millimetre (mm) = $\frac{1}{10}$ centimetre (cm)

1 centimetre (cm)	=	$\frac{1}{100}$	metre (m)
1 metre (m)	=	$\frac{1}{1,000}$	kilometre (km)

<u>or</u>

10 millimetres (mm)	=	1 centimetre (cm)
100 centimetres (cm)	=	1 metre (m)
1,000 metres (m)	=	1 kilometre (km)

<u>or</u>

1mm x 10 = 1cm; 1cm x 100 = 1m; 1m x 1,000 = 1km;

Therefore, on our 1:50,000 map, we can say that one unit on the map is equivalent to 50,000 units on the ground. Using centimetres as units we can say that one centimetre on the map is equivalent to 50,000 centimetres on the ground. To convert this to metres we divide by 100, or move the decimal point two places to the left. Thus we can say that one centimetre on the map is equivalent to 500 metres on the ground.

Notice that the 1:50,000 map is marked off in 2 centimetres squares. Check this with your ruler. Therefore, each side of a square is 2 centimetres on the map. This is equivalent to 100,000 centimetres on the ground or to make it easier 1,000 metres on the ground (remembering to mark off 2 places from the right) or even easier, 2 centimetres on the map is equivalent to 1 kilometre on the ground.

This is the basic rule about any map that you use. The scale is the relationship between a unit of measure on the map and that same unit of measure on the ground.

CHAPTER 6

CONTOURS, SLOPES AND GRADIENTS

CONTOURS

Contours are the most common method of representing relief. A contour is a line drawn on a map passing through points of equal elevation or height above sea level. Contours never cross one another but on very steep land they will be quite close. On the 1:50,000 map used most frequently, the contour interval is either 50 feet or 20 metres. The most recently issued maps have a 20 metre contour interval. The contour lines are usually brown in colour.

The difference in height between contours is called the contour interval. Sometimes, to make the contours easier to read, every fifth, tenth, or even twenty-fifth contour is made thicker than the others. This is called the index contour.

Note that on all maps contours give the following information about relief.

1. The distribution of high and low ground and the aerial outline of hills, which is their extent when viewed directly from above.

2. An indication of the steepness of slope clearly defining rather flat or gently rolling areas from very steep scarps and hills.

3. The contours help to tell what direction a river is flowing in and they show the boundary between one catchment and another.

SLOPES AND GRADIENTS

There are three different ways of expressing slopes. They are all different ways of saying the same thing.

A slope may be expressed as:-

1. A ratio slope (gradient)
2. A percentage slope
3. Degrees of slope (angle from the horizontal)

1. Ratio slopes (gradients)

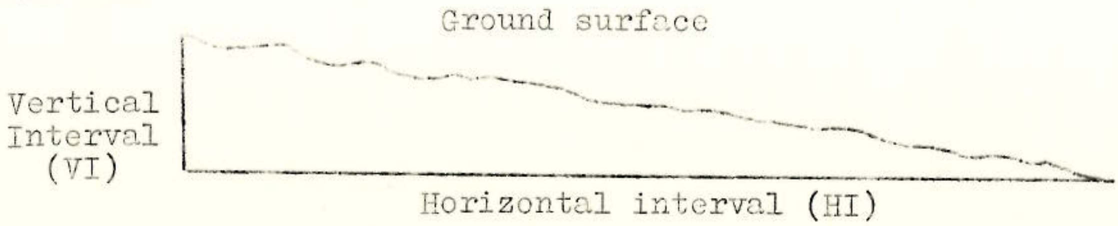
"Gradient" means the amount of slope. This is the normal way of expressing a slope in leveling surveys. To calculate the gradient between two points, two things must be known:-

1. The vertical interval (VI)
2. The horizontal interval (HI)

The vertical interval is the vertical difference in height between two points.

The horizontal interval is the horizontal (level) distance between the two points.

Fig. 6-1



The gradient is the ratio of the vertical interval to the horizontal interval. This is expressed as a fraction with a numerator of one.

$$\text{Gradient} = \frac{VI}{HI}$$

A gradient of $\frac{1}{100}$ (also written 1:100) means the ground rises 1 metre for every 100 metres travelled horizontaly. In fact, it does not matter what units are used, so long as both the vertical interval and the horizontal interval are expressed in the same units.

e.g. If the vertical interval is 3 metres and the horizontal interval is 150 metres:-

$$\text{Gradient} = \frac{VI}{HI} = \frac{3}{150} = \frac{3/3}{3/150} = \frac{1}{50} \text{ (or 1:50).}$$

2. Percentage slopes

These are really ratio slopes written the other round. With a gradient we answer the question, "How many metres must I go along, to rise up one metre?"

"Percent" means "for every 100". With a percentage slope we answer the question, "How many metres up will I rise if I go along 100 metres?".

$$\text{Percentage slope} = \frac{VI}{HI} \times 100$$

Again, the units must be the same for both the horizontal and vertical intervals.

e.g. If the vertical interval is 3 metres, and the horizontal interval 150 metres:-

$$\% \text{ slope} = \frac{VI}{HI} \times 100 = \frac{3}{150} \times 100 = \frac{300}{150} = 2\%$$

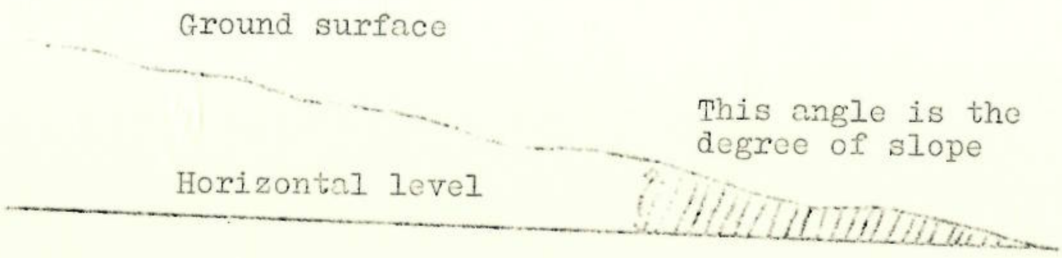
To convert a gradient to a percentage slope, multiply by 100 and solve the equation.

To convert a percentage slope to a gradient, divide by 100 and express it is a fraction with a numerator of 1.

3. Degrees of slope

The steepness of a slope may also be expressed in degrees. This refers to the angle between the slope and the horizontal:

Fig.6-2.



This is what is measured by an abney level.

One degree of slope corresponds approximately to a gradient of 1:60.

To convert degrees of slope to a gradient, divide by 60.

To convert a gradient to degrees of slope, multiply by 60.

(NB This simple rule only holds good for slopes of 20° or less)

e.g.i.Convert a gradient of 1:50 to degrees of slope:-

$$\frac{1}{50} \times 60 = 1.2^{\circ}$$

(NB There are 60 minutes in degree.
Therefore 0.2 degrees = 0.2 x 60 minutes = 12'
The final answer is therefore $1^{\circ}12'$).

e.g.ii.Convert a slope of 6° to a gradient:-

$$6 \div 60 = \frac{6}{60} = \frac{6/6}{6/60} = \frac{1}{10} \quad \text{(or 1:10)}$$

Calculating Gradients from Contours

We can calculate gradients from the contours on the 1:50,000 maps. The vertical interval (VI) between two contours on the map is the same as the contour interval, mentioned above. It is always given in the map key. The horizontal interval is found by measuring the distance between the two contour lines, and using the map scale to find the ground distance. Once we have the horizontal and vertical intervals, the gradient, percentage slope or degrees of slope can be calculated as described above.

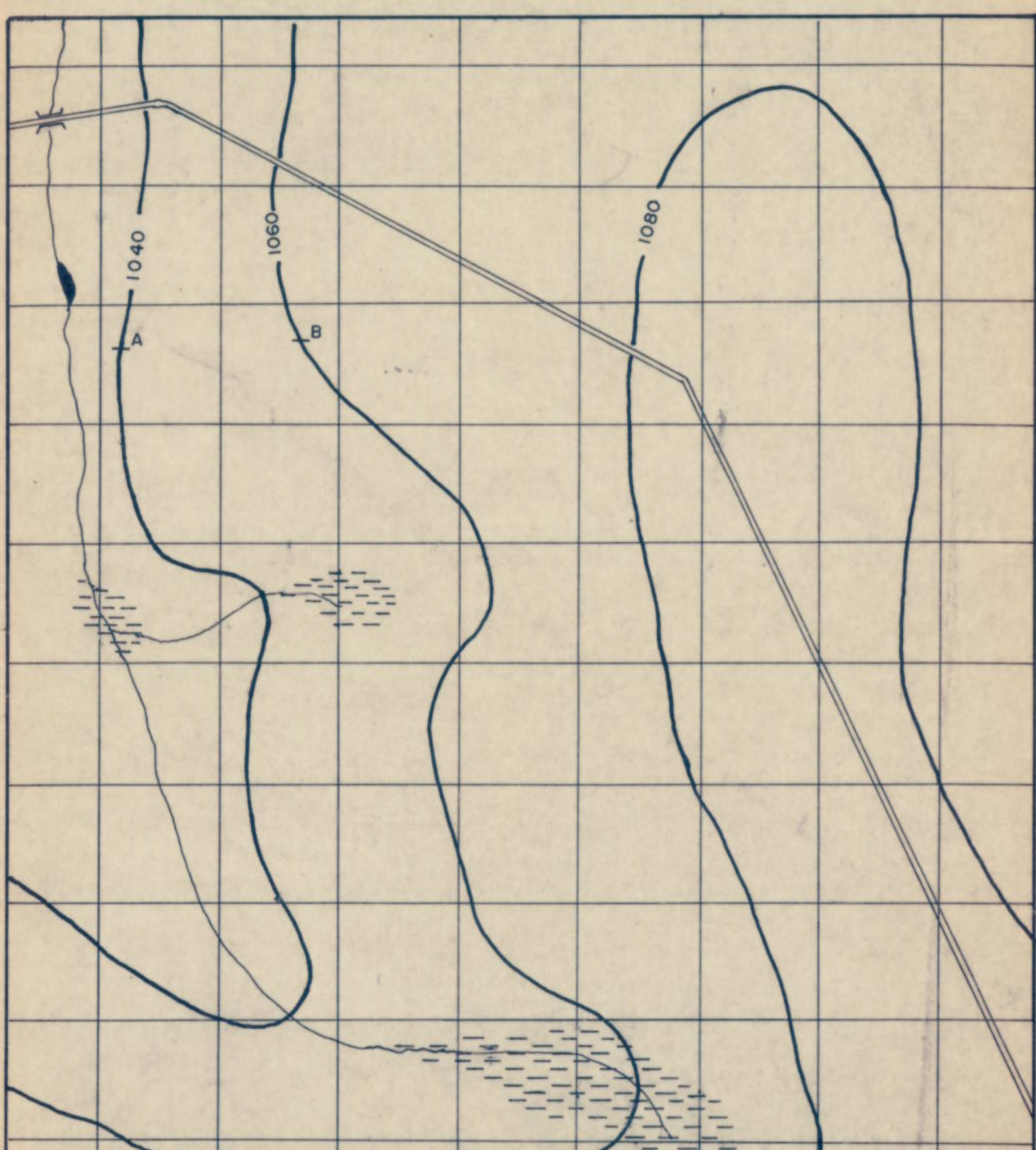
For example Fig.6-3 is a section of a 1:50,000 map, on which we want to measure the gradient from point A to point B.

Distance A to B	=	3cm
Map scale	=	1:50,000
Therefore distance A to B on ground (HI)	=	1,500 metres
Vertical interval A to B (VI)	=	1,060m - 1,040m
	=	20 metres.

$$\text{Gradient} = \frac{VI}{HI} = \frac{20}{1,500}$$

$$= \frac{1}{75} \quad \text{or } 1:75$$

FIG 6–3



Most maps also have other indicators of height above sea level. They are used for bench marks in accurate surveys. Those found on the maps in Zambia are as follows:-

Trigonometrical stations

(usually referred to as Trig Stations or Trig points) are normally marked on the ground by a 1.3 metre concrete pillar surmounted by a moveable vane, or often in towns, a ground mark consisting of a cartridge case embedded in cement. The position and height of a trig point is accurately determined and may be used as a base point whenever it is conveniently situated near the area to be surveyed.

Bench marks

are usually marked only on large scale maps but are to be found on some 1:50,000 maps. In rural areas they may be identified by means of a brass plug embedded in concrete. The height of the Bench mark refers to the height of the brass plug and not the ground surface.

Spot Heights:

There is no visible evidence of a spot height although occasionally one may find temporary marks on roads. On the map they appear as black dots with the height written alongside.

SCALES AND SLOPES WORKED EXAMPLES

Below are five worked example which cover most cases met with in calculating scales and slopes.

Case 1

Scale	1:30,000
Length measured on map	= 13mm
Problem:-	13mm : ?
Length on ground	= ?
Calculation:-	1mm : 30,000mm
	1 x 13mm : 30,000 x 13mm
	13mm : 390,000mm
	= 39,000cm.
	= 390m.

Case 2

Scale	1:30,000
Length measured on ground	= 620m.
Length on map	= ?
Problem:-	? : 620m.
Calculation:-	1m : 30,000m.
$\frac{1}{30,000m}$	: $\frac{30,000}{30,000m.}$
$\frac{1}{30,000m}$	: 1m
$\frac{620 \times 1}{30,000m}$	: 1 x 620m

$\frac{620}{30,000m}$	: 620m.
$\underline{0.02m}$	: 620m.
Therefore length on map	= 0.02m.
or	= 2cm.

Case 3

Slope 1 in 800	
Height difference	= 5cms.
Horizontal distance	= ?
Problem	5cm : ?
Calculation	1cm : 800cm.
	1 x 5cm : 800 x 5 cm.
	5cm : 4,000cm.

Therefore Horizontal distance = 4,000cms.
or = 40m.

Case 4

Slope	1 in 500
Height difference	= ?
Horizontal difference	= 30m
Problem	? : 30m
Calculation	1m : 500m
$\frac{1}{500m}$	: $\frac{500}{500m}$
$\frac{1}{500m}$	: 1m.
$\frac{1 \times 30}{500}$ m	: 1 x 30m
0.006m	= 30m.

Therefore Height difference= 0.06m
or= 6cm.

Case 5

Scale	= 1:50,000
Area measure on map	= 3 sq.cm.
Area on ground	= ?
Problem	3 sq.cm. : ?
Calculation	1cm : 50,000cm.
	1cm x 1cm : 50,000cm x 50,000cm.
	1sq.cm. : 2,500,000,000sq.cm.
	3 x 1 sq.cm:3 x 2,500,000,000 sq.cm.
	3sq.cm. : 7,500,000,000sq.cm.
Therefore area on ground	= 7,500,000,000sq.cm.
or	= 750,000sq.m.
or	= 75 ha.

CHAPTER 7

GRIDS AND GRID REFERENCES

Before we can begin to work closely with maps and solve various problems we all must learn to speak the same language. If we learn how to locate ourselves by grid references we will have a basic key to the language of maps.

When we are dealing with fairly large scale maps such as the 1:50,000 series the method of locating ourselves by latitude and longitude becomes cumbersome. Map makers have divised a quicker and easier method known as grid reference.

The basic principle of a grid reference is very simple. If we were to consider a point somewhere on this page, we could define its position by giving the distance horizontaly from the left hand edge of the page to the point, and the distance verticaly from the bottom edge of the page to the point. This is how grid references on a map work. To make the measurements of distance from the edges of the map easier, lines are ruled at regular intervals on the map. One set of lines are horizontal and the other set vertical, forming a grid. The spacing of the grid lines depends upon the scale of the map.

In Zambia we use the Universal Transverse Mercator (UTM) Grid which divides the country into squares with sides of 100km, 10km and 1km. Thicker lines define the 100km and 10km squares.

To give the Full Grid reference of a point on a Map - (see Fig.7-1)

1. Write the grid zone designation, given at the bottom of the map. e.g. 36L.

2. Write the 100km square identification, using the key at the bottom of the map. e.g. TA, so that we now have 36LTA.

3. Pay no attention to the smaller co-ordinate figures given in the margin. They refer to an obsolete system. Pay attention only to the large marginal figures.

4. Take the west (left hand) edge of the square in which the point lies, and read the figures printed opposite this line on the north (top) or south (bottom) margin. e.g. 18, so that we now have 36LTA18.

5. Estimate tenths eastwards (to the right) from the edge of the square to the point. e.g. 2, so that we now have 36LTA182.

6. Take the south (bottom) edge of the square in which the point lies, and read the figures printed opposite this line on the west (left hand) or east (right hand) margin. e.g. 91, so that we now have 36LTA18291.

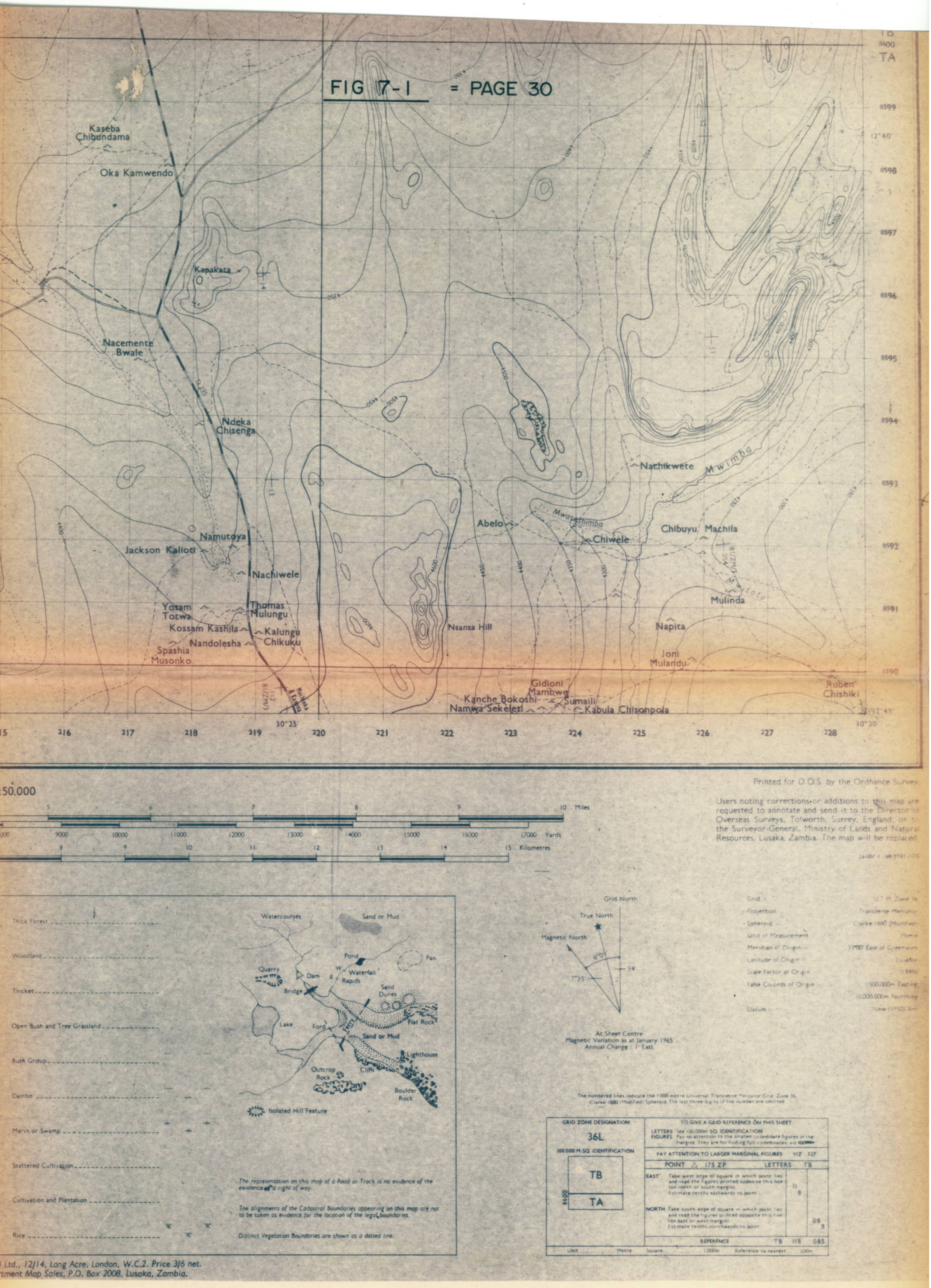


FIG 7-1 = PAGE 30
Kaseba Chibundama
Oka Kamwendo
Kapakata
Nacemente Bwale
Ndeka Chisenga
Namutoya
Jackson Kalioti
Nachiwele
Yotam Totwa
Thomas Mulungu
Kossam Kashila
Kalungu Chikuku
Nandolesha
Spashia Musonko
Nsansa Hill
Abelo
Mwaseshimba
Chiwele
Chibuyu Machila
Nachikwete
Mwimba
Mulinda
Napita
Joni Mulandu
Gidioni Mambwe
Kanche Bokoshi
Sumaili
Namwa Sekeleti
Kabula Chisonpola
Ruben Chishiki
TB
TA
8600
8599
8598
8597
8596
8595
8594
8593
8592
8591
8590
12°40'
12°45'
30°25'
30°30'
215 216 217 218 219 220 221 222 223 224 225 226 227 228
:50,000
Miles
Yards
Kilometres
Printed for D.O.S. by the Ordnance Survey
Users noting corrections or additions to this map are requested to annotate and send it to the Director of Overseas Surveys, Tolworth, Surrey, England, or to the Surveyor-General, Ministry of Lands and Natural Resources, Lusaka, Zambia. The map will be replaced.
Thick Forest
Woodland
Thicket
Open Bush and Tree Grassland
Bush Group
Dambo
Marsh or Swamp
Scattered Cultivation
Cultivation and Plantation
Rice
Watercourses
Sand or Mud
Pond
Pan
Quarry
Dam
Waterfall
Rapids
Bridge
Sand Dunes
Lake
Ford
Flat Rock
Sand or Mud
Lighthouse
Outcrop Rock
Cliffs
Boulder Rock
Isolated Hill Feature
The representation on this map of a Road or Track is no evidence of the existence of a right of way.
The alignments of the Cadastral Boundaries appearing on this map are not to be taken as evidence for the location of the legal boundaries.
Distinct Vegetation Boundaries are shown as a dotted line.
Grid North
True North
Magnetic North
8°09'
7°35'
34
At Sheet Centre
Magnetic Variation as at January 1965
Annual Change : 1° East
GRID ZONE DESIGNATION
36L
100,000 M SQ IDENTIFICATION
TO GIVE A GRID REFERENCE ON THIS SHEET
REFERENCE TB 118 085
Ltd., 12/14, Long Acre, London, W.C.2. Price 3/6 net.
rtment Map Sales, P.O. Box 2008, Lusaka, Zambia.

7. Estimate tenths northwards (up) from the edge of the square to the point. e.g. 8, so that we now have 36LTA182918. This is the full map reference.

8. Providing all references are on the same sheet, it is only necessary to carry out steps 4-7, giving a six figure reference e.g. 182918.

9. In order to refer to a 1km square, a four figure map reference is given. In this case carry out only steps 4 and 6 e.g. 1891.

There are two simple rules to help you remember how to give a grid reference.

When you enter a house or office that has two floors, you first enter the ground floor, and secondly go upstairs. Thus, with map references you first read along the bottom of the map, and secondly read up the side of the map.

The second rule is about how you write a capital letter L. You first write the vertical line I, and secondly write the horizontal line - . Thus, with map references you first take the vertical grid line and read its number, and secondly take the horizontal line and read its number.

Identifying a position from a Grid Reference.

1. If the reference is a full one, identify the 100km square by its letters or numbers. This may need reference to an index map of the grid for the whole country, but usually a reference to the 1:250,000 sheets is sufficient (because you will usually know the approximate area). Then obtain the appropriate 1:50,000 sheets.

2. Divide the remaining six figures into two halves, and ignore the last figure in each half. The remaining figures are found printed against first a vertical and then a horizontal grid line, and these are identified.

3. When these are found, use the last figure in each half to estimate tenths eastwards and northwards.

PART THREE

AERIAL PHOTOGRAPHS.

CHAPTER 8

AERIAL PHOTOGRAPHS AND STEREOSCOPIC TECHNIQUES

An aerial photograph is one of to-day's most complete and informative yet most economical, representation of the earth's surface. Aerial photography reveals hills and valleys, soil and water patterns and vegetation types. Air photos are used in soil surveys, farm planning, conservation layouts, and dam surveying, as well as having many other applications.

Most of the aerial photography used in Zambia has been taken when there is little or no cloud cover. At this time of year during August or September the land is free from vegetation cover. This means that more details show up on the photo. Most Zambian aerial photography has been taken with black and white film.

The air photos used in Zambia are usually at scales of 1:30,000, 1:20,000 and 1:12,000. To take these photos the aircraft flies at a height of between 9,000 feet (3km) for 1:12,000 photos, and 18,000 feet (5.4km) for 1:30,000 photos.

In order to take the air photos, the aircraft flies at a constant speed and height above sea level in a straight line, from one edge of the area to the other, and as it goes, a camera mounted in the floor of the aircraft automatically takes photographs at regular intervals. It is arranged that each photo overlaps the previous photo by 60%. When the aircraft reaches the end of a run, it turns and flies back across the area on a new run, paralled to the previous run. Each of the photos in the new run overlaps those of the previous run by 20-30%. (see Fig.8-1).

The Camera

In order to understand some of the following descriptions and drawings, it is first necessary to learn a little bit about how a camera works.

When a photograph is taken with a camera, the shutter opens for a short time (usually around 1/1,000 of a second), allowing light from the subject to pass through the lens onto the film. When the light touches the film a chemical reaction occurs in the film, forming the picture.

Light travels in straight lines. Because of this as the rays of light pass through the camera lens, they cross over, so that the picture formed on the film is upside down. (see Fig.8-2).

The distance from the camera lens to the film is called the focal length of the lens. This is used when calculating the scale of the photos.

The Scale of the Photographs

Refering to Fig.8-3, the scale of the photograph is the ratio r : R, or $\frac{r}{R}$.

FIG 8-1

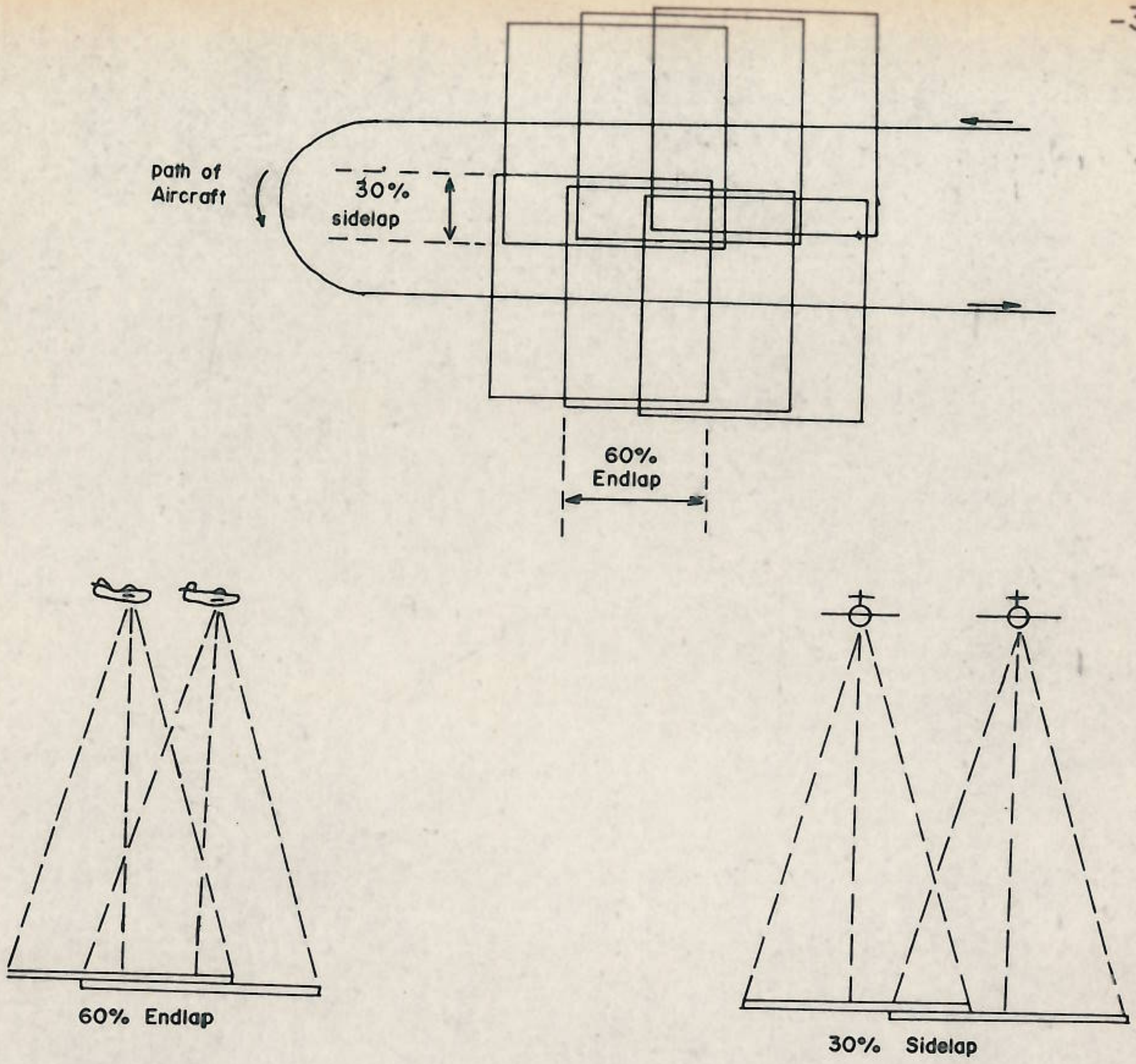

path of
Aircraft
30%
sidelap
60%
Endlap
60% Endlap
30% Sidelap

FIG 8-2

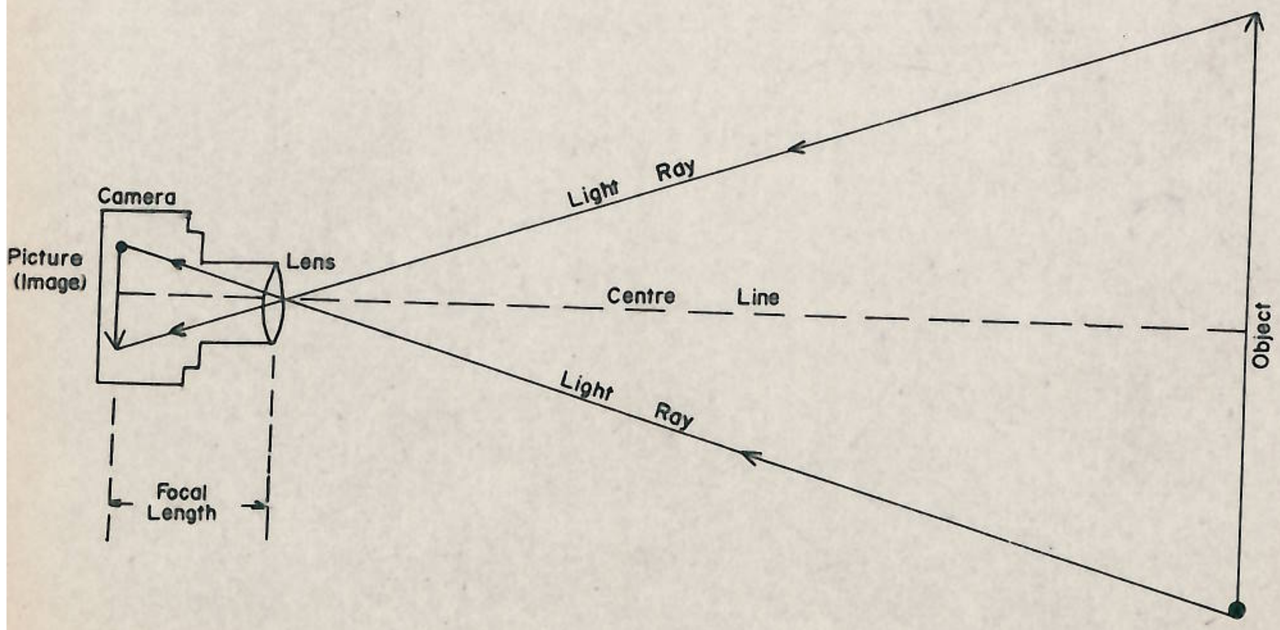

Camera
Picture
(Image)
Lens
Light Ray
Centre Line
Light Ray
Object
Focal
Length

FIG 8–3

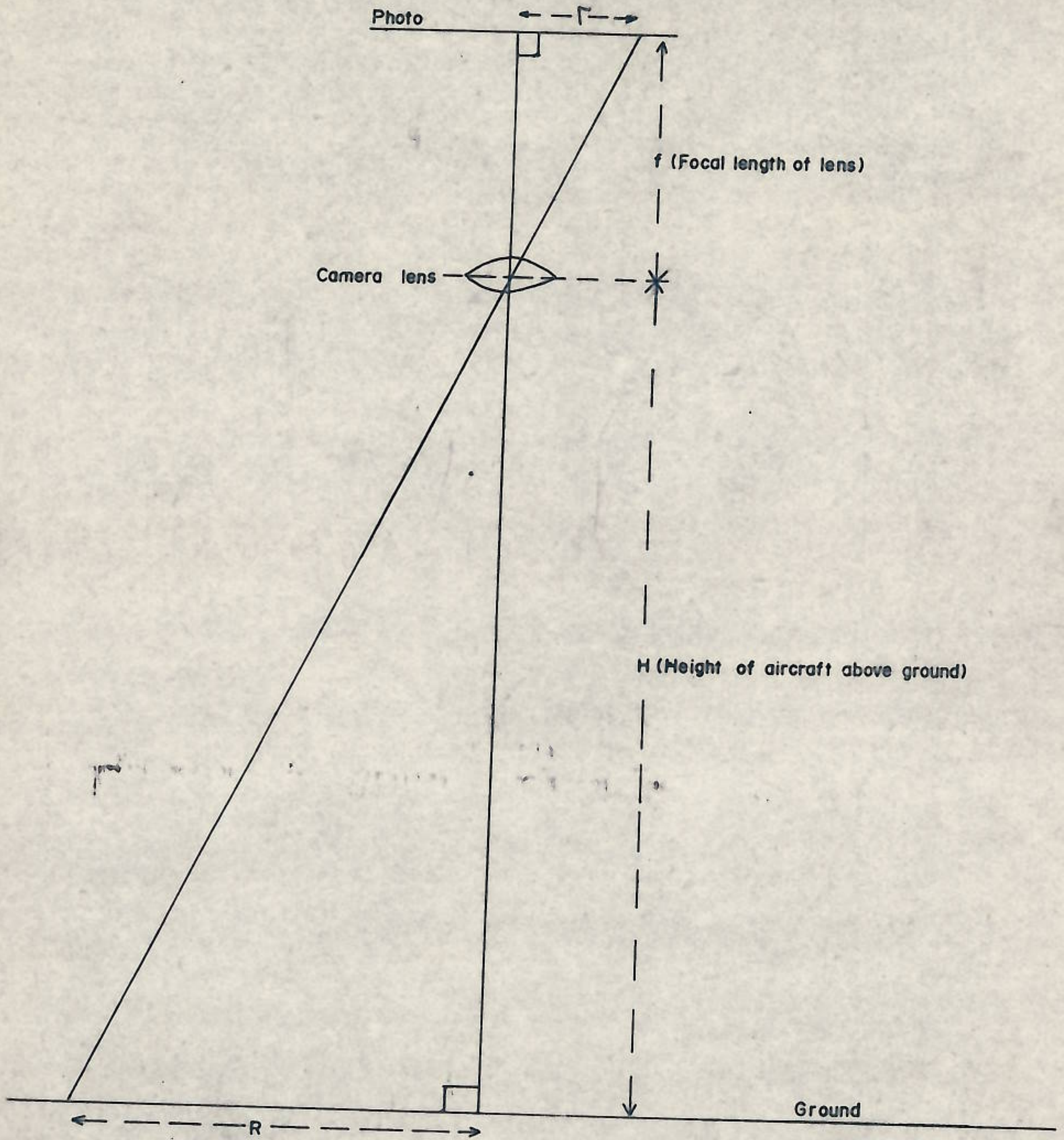


Photo
r
f (Focal length of lens)
Camera lens
H (Height of aircraft above ground)
Ground
R

We know from geometery that as the two triangles each have a right angle, they are similar triangles. This means that:

$$\frac{r}{R} = \frac{f}{H}$$

Therefore the scale is $\frac{f}{H}$

Both of these values can be readily determined. The focal length of the camera (F) is usually printed on the photo. The height of the aircraft ABOVE SEA LEVEL is also usually printed on the photo (often as a photograph of the altimeter of the aircraft at the instant the air photo was taken). In order to work out the height of the aircraft above the ground, the elevation of the ground above sea level must be subtracted from the height of the aircraft above sea level.

Example

Photo number 522 of the Serenje 1965 flight.1:50,000 sheet 1,230 C4. (NB This is a real example which you can check if you look at the maps and photos referred to).

Referring to the map, the principal point (centre) of the photo lies on the 4,850 ft. above sea level contour. This converts to 1,455 metres above sea level.

The aircraft altimeter on the photo is registering a height of 4.395km above sea level. This is 4,395 metres above sea level.

The height of the aircraft above the ground is therefore 4,395 - 1,455 = 2,940 metres.

The focal length of the lens is printed on the photo as FL153.54mm.

The scale of the photo is the ratio of the focal length (f) to the height of the aircraft above the ground (H).

Scale = f : H
Scale = 153.54mm : 2,940 metres

The same units must be used on each side of the equation.

Scale = 153.54mm : 2,940,000 mm
Scale = 1 : 19,148.

It is interesting to note the scale quoted on the photo is 1:20,000.

Usually the scale quoted is only an average scale for the whole set of photos. It can be seen that the nearer the aircraft is to the ground the larger the photo scale will be.

"Built - In" Errors in Air Photos.

1. The scale over an air photo is rarely constant. This is because the top of a hill is nearer to the camera than the bottom of a valley. Therefore, the scale of the hill top will be larger than the scale of the valley.

2. The photo is flat. The ground is usually undulating (not flat). Because of this, when the undulating ground surface is portrayed on the flat photograph, equal distances on the ground do not always come out as equal on the photo.

   Fig.8-4 is a diagram of a piece of ground where beacons have been established at 1km intervals as chained along the ground surface. However, on the flat surface of the photo it can be seen that the distance AB and BC are not equal.

3. If the aircraft does not maintain a steady height above the ground in flight, the scale of adjacent photos will differ.

4. If the aircraft tilts from side to side, the scale will vary from one side of a photo to the other. (see Fig.8-5).

5. The same effect is obtained if the aircraft pitches in flight. (see Fig.8-6).

6. If a wind is blowing from one side, the pilot has to turn the aircraft into the wind in order to keep flying along the correct flight line. If he does not turn the aircraft into the wind, it will drift sideways, as shown in Fig.8-7. The photos will then no longer follow the correct flight line.

   If the aircraft is turned into the wind to correct for drift, the camera must be rotated to compensate for the attitude of the aircraft. Fig.8-8 shows how the photos will be "crabbed" if this is not done.

Features of the Air Photo

The main features of the air photo are shown in Fig.8-9 The principal point is the centre point of the air photo. If the aeroplane carrying the camera is flying level, as it should, then the principal point marks the point on the ground which was vertically below the camera. (see Fig.8-10). This is an important point to know. When we plot it on a map it shows us where the photograph was taken.

We locate the principal point by joining the fiducial marks with a ruler and marking where they cross at the centre of the photograph. Either the corner fiducial marks or the side ones can be used. (see Fig.8-11).

As the aeroplane flies along in a straight line photographs are taken about every 30 seconds. The ground covered by each photograph overlaps the next by about 60%. This means that the principal point of the photographs from either side will appear at the edges of the middle photograph. (see Fig.8-12).

By joining the three principal points that appear on a photo, we can plot the path taken by the aircraft. This is called the flight line. It is used for setting up the photos for stereoscopic viewing, which is covered in the next section.

FIG 8-4

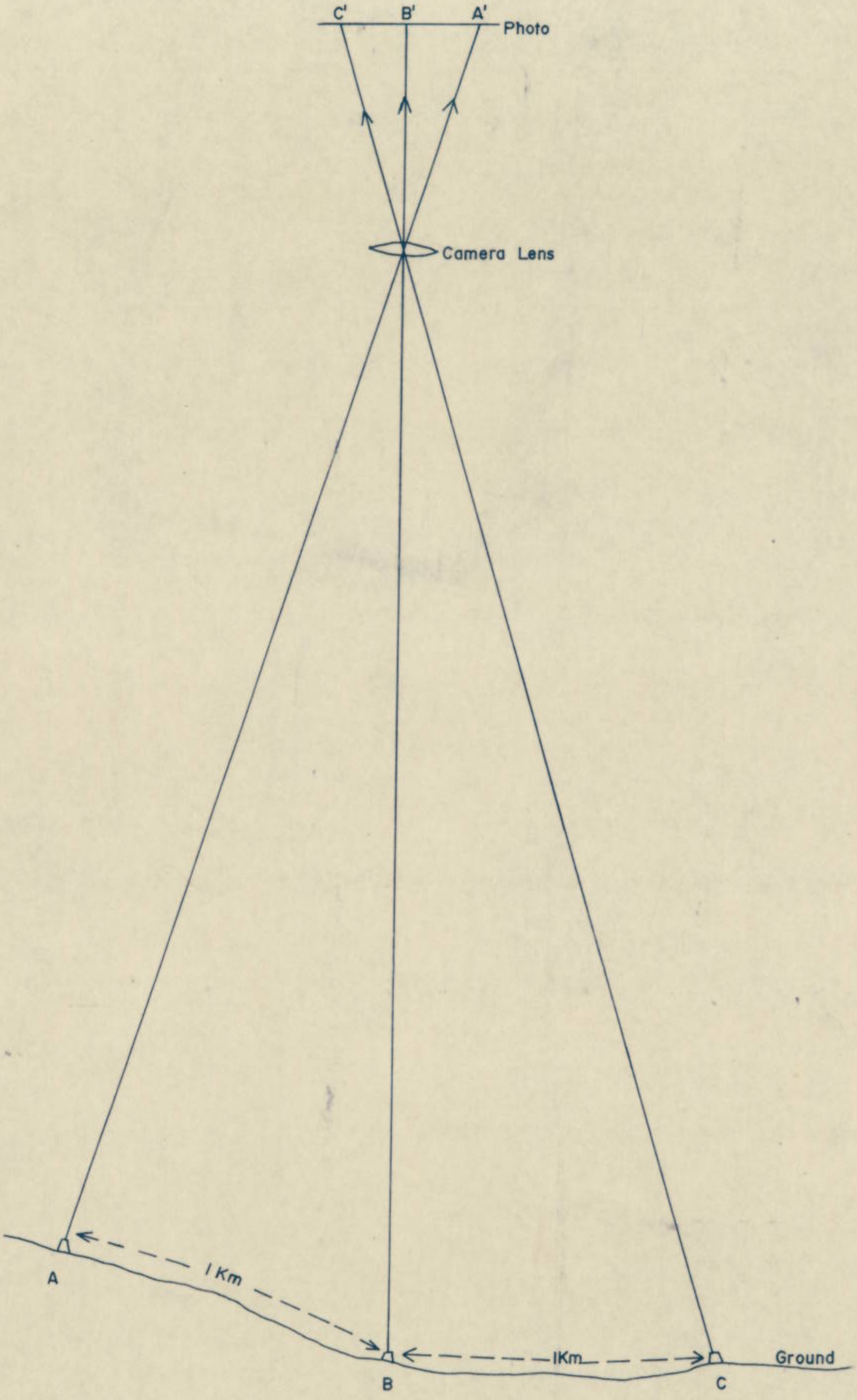
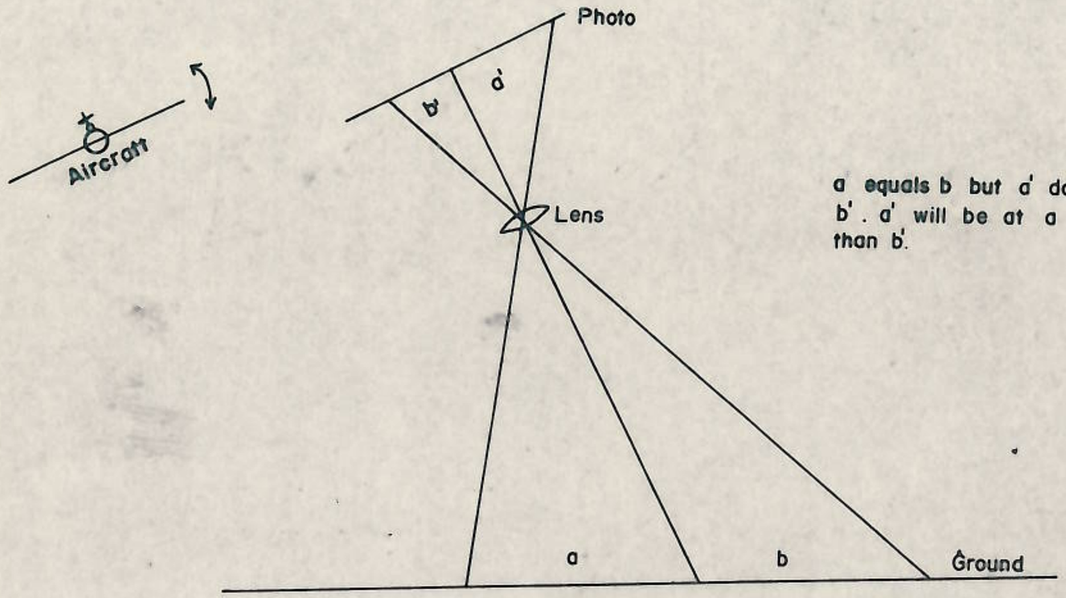
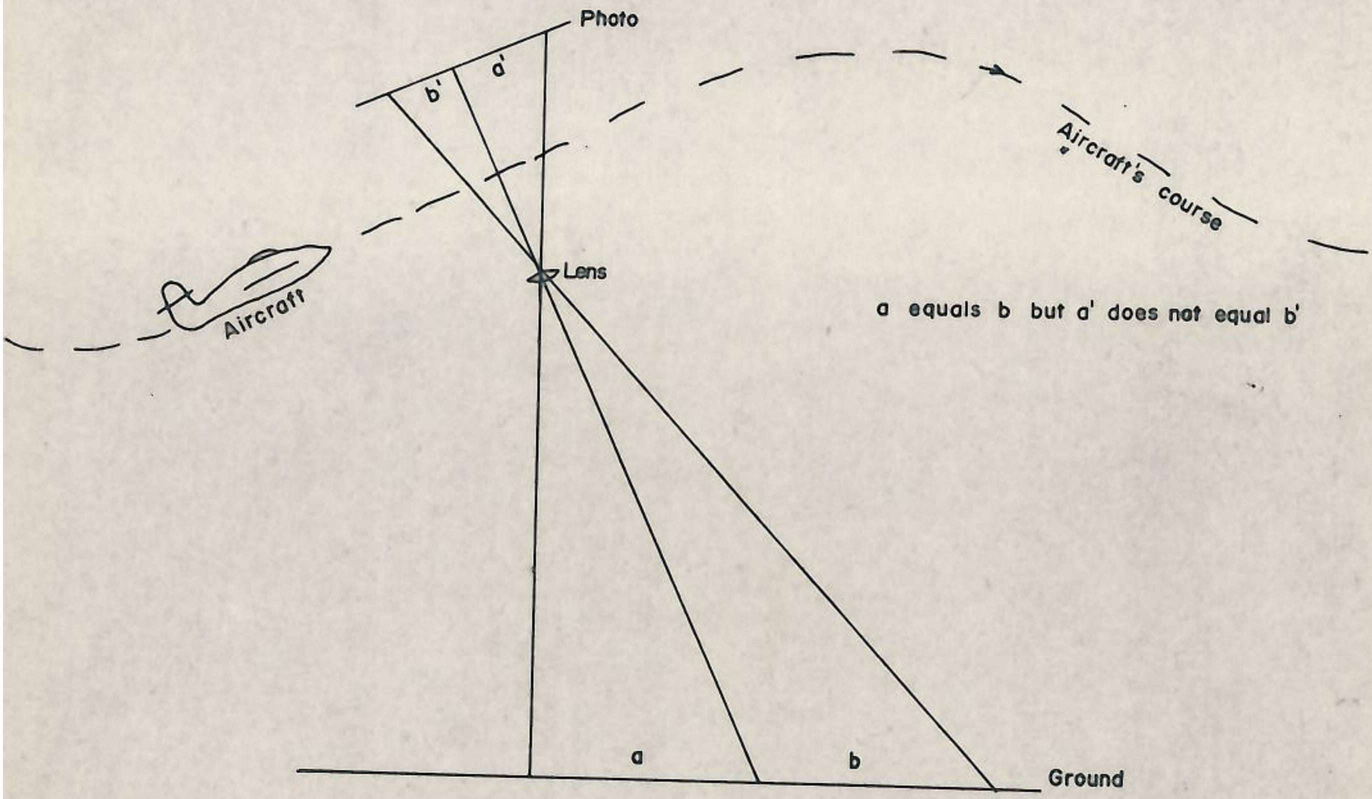


FIG 8-5



a equals b but a' does not equal b'. a' will be at a larger scale than b'.

FIG 8-6



a equals b but a' does not equal b'

FIG 8-7

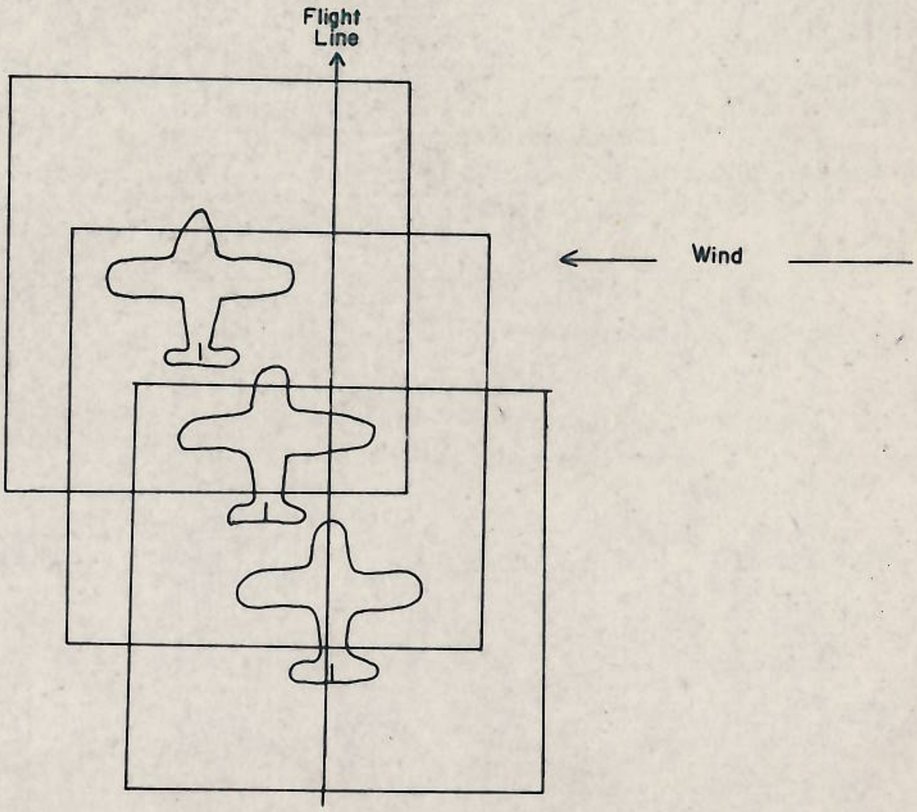


FIG 8-8

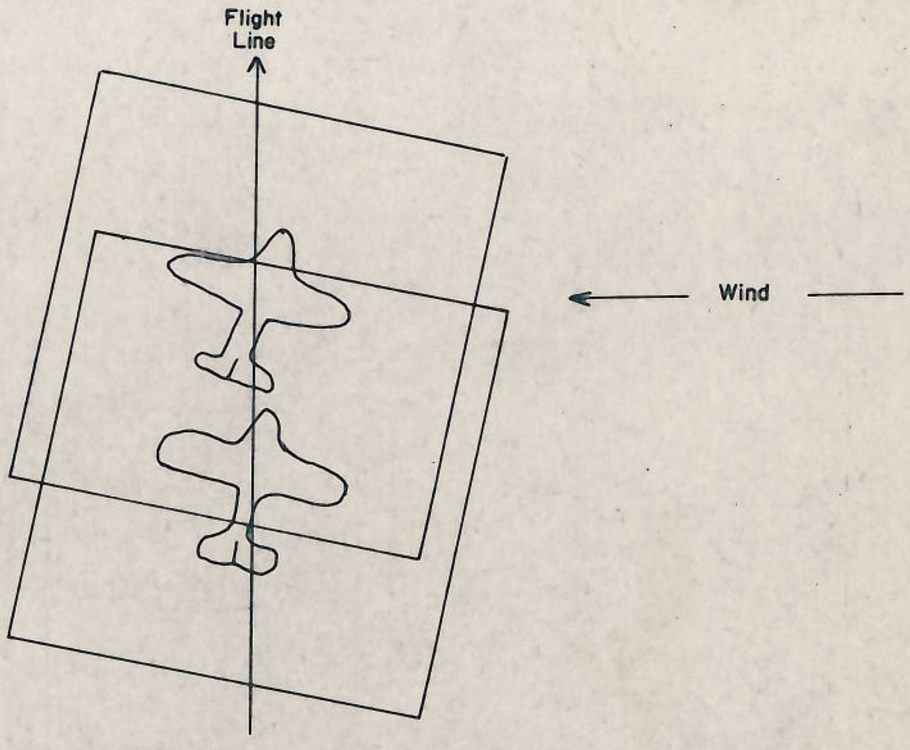


FIG 8-9

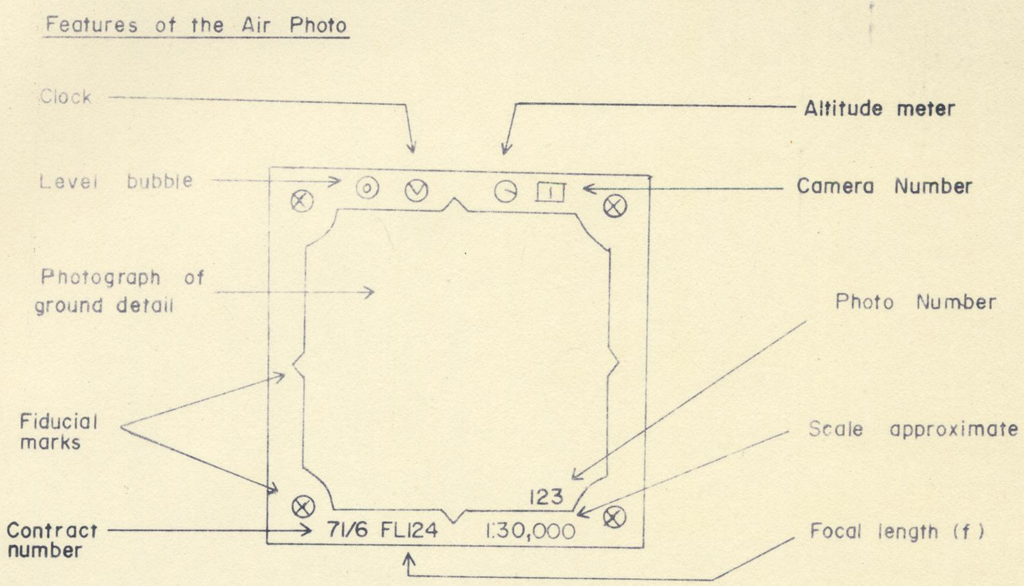


FIG 8-10

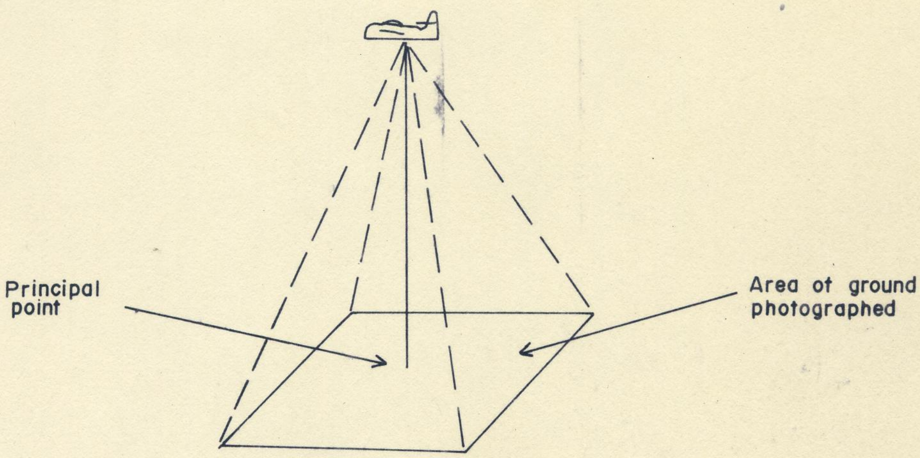


FIG 8-11

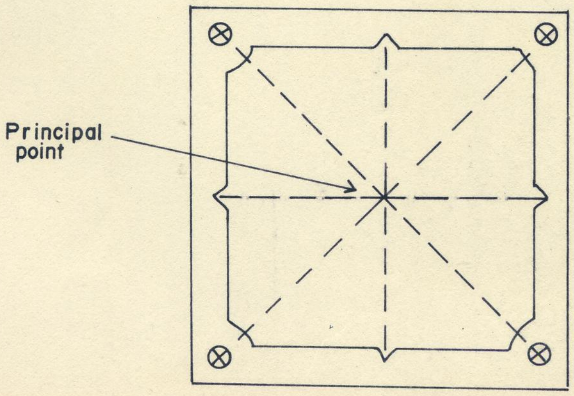


FIG 8-12

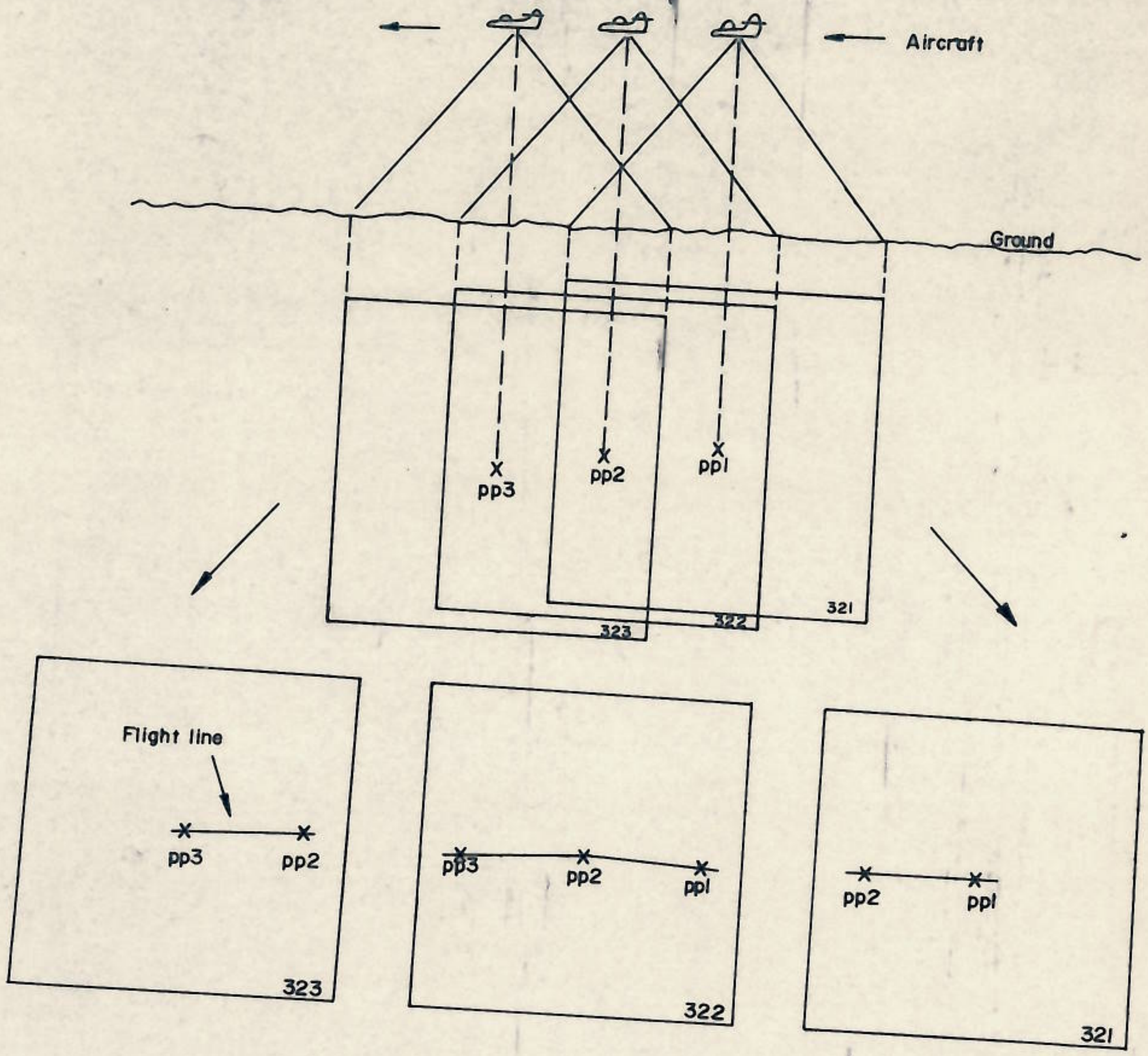
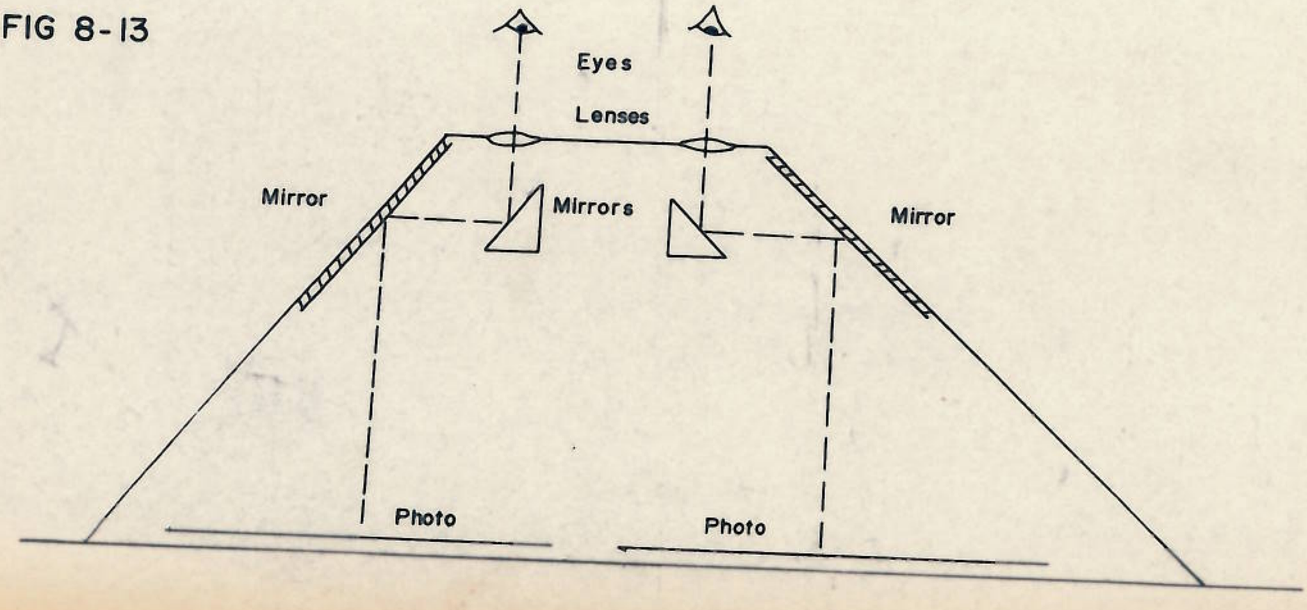


FIG 8-13



STEREOSCOPIC VISION

Stereoscopy is the production of a three - dimensional effect from two dimensional pictures. It means that hills and valleys can be clearly seen on what is usually seen only as a flat picture.

When you look at an object, each of your eyes focuses on that object from a slightly different position, and transmits a slightly different image to the brain. The brain thus receives two different pictures of the same object. But you "see" only one picture. This is because your brain has combined the two pictures together, to give you a single three dimensional image of the original object.

If you close one eye, you see only a two-dimensional image, with no impression of depth. If you doubt this, try to thread some cotton through a needle, keeping one of your eyes closed all the time. You will find it extremely difficult.

Thus when you look at an object, both of your eyes focus on to it and in so doing, each eye gets a slightly different view of the object, and your brain converts the two different images into the single three dimensional picture.

By the same line of reasoning, if we take two pictures of the same area taken from slightly different view points, for example two adjacent air photos with considerable overlap, let the left eye see one of these, and the right eye the other the brain will react as it normally does, and, from the slight difference between them, will produce a three dimensional image of the area. Note that the two images must be different; two copies of the same photo will not do.

In order to view photos stereoscopically, therefore, you must be able to focus one eye onto one photo and the other eye onto the other photo simultaneously. Very few people, however, are able to use their eyes independently in this way without instrumental aids.

A stereoscope is simply an instrument that separates the line of sight of your eyes, thereby allowing each eye to look at different photo simultaneously as shown in Fig.8-13.

A pair of overlapping photographs is put under the stereoscope. Thus each eye is looking at a photograph of the same area of land, but each photo was taken from a different position. As far as the brain is concerned, therefore, there is no difference to normal vision, when each eye views the same object from a slightly different position. Your brain therefore combines the two images into a single three-dimensional (stereoscopic) picture of the area.

When examining photographs under a stereoscope it will usually be apparent that the vertical part of the image, and hence all heights and slopes, are greatly exaggerated. This is easily explained. Two eyes 6.2cm apart looking down at a hill from 3km high would obtain impressions differing by such very small amounts that the brain would be unable to produce from them any impression of depth. However, when we look down the stereoscope, two camera "eyes" have been substituted for our own eyes, and these were 2 or 3 kilometres apart in the sky. From the much greater differences that these reveal the brain is able to build up a greatly exaggerated impression of depth. Fortunately this exaggeration is quite regular so that although slopes are distorted, relative heights are not.

Kinds of Stereoscope

There are two kinds of stereoscope used by the Land Use Branch. The big ones that we use in the office are called mirror stereoscopes. With these a large area of each photograph can be viewed at any one time. They are easy to use, but are heavy, expensive, and rather fragile.

The other kind is a pocket, or lens, stereoscope. These are cheap and robust, and easy to carry about in the field. However, they are not as easy to use, and only a small area of any photograph may be covered at any time. The mirror stereoscope gives a 1:1 image, whereas the pocket stereoscope gives an image magnified by two times.

Setting up the photographs

Before viewing photographs under a stereoscope we must get the right photographs the right way round.

1. Make sure the two photographs have consecutive numbers e.g. 422 and 423.

2. Locate the same piece of detail on each photograph e.g. a field or a dambo.

3. Place the detail on one photograph directly above the same detail on the other THE SAME WAY ROUND. (i.e. when you look underneath the top photo you see exactly the same picture on the bottom photo). see Fig.8-14.)

4. The photo edges on two sides should be together. If not check that the detail is the same way round.

5. Turn the photographs together so they are like the "CORRECT WAY ROUND" diagram above.

6. Separate the two photographs to left and right.

Using the Stereoscope

Always handle the stereoscope with care. It is a very expensive piece of equipment. Never touch the mirrors or lenses with your fingers. If you do, dirt or grease will be left on the reflecting surfaces and will reduce the quality of the image you see.

Always put the instrument away in its box overnight or whenever, you have finished with it.

FIG 8-14

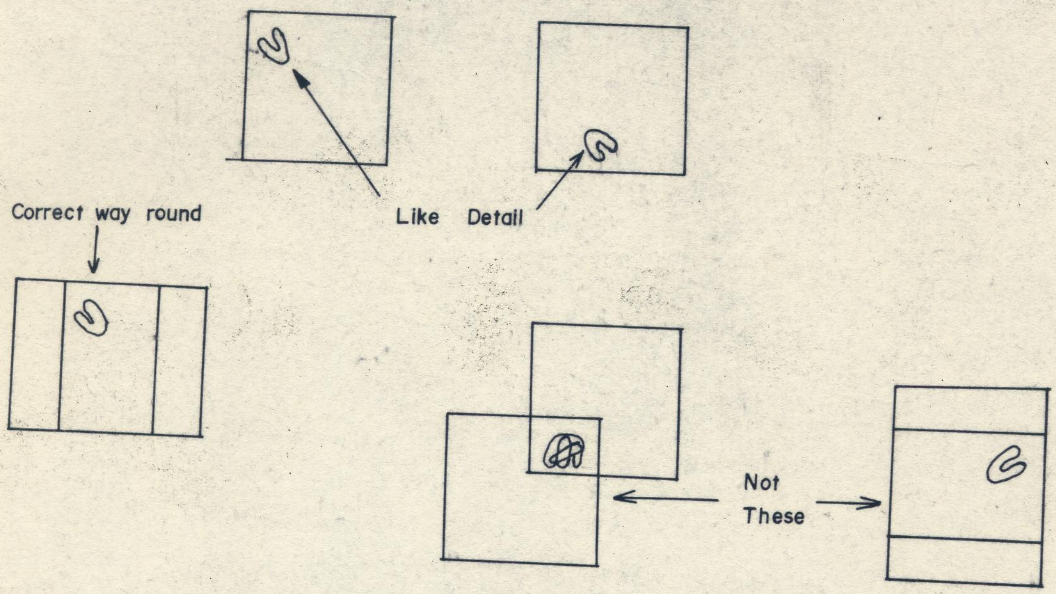
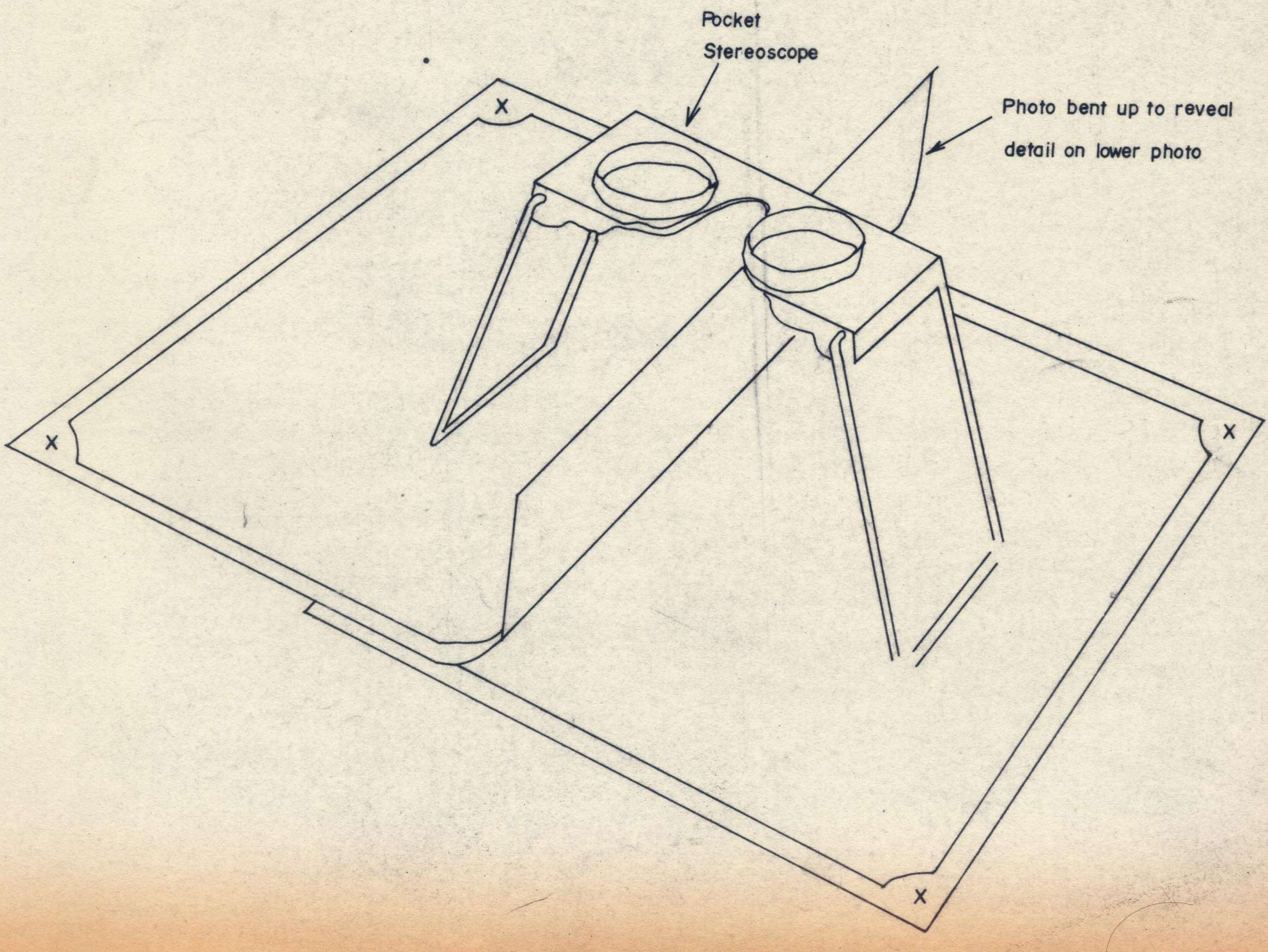


FIG 8-15



Never draw on air photos with ink, ballpen, felt-tip pen or pencil. Always use a chinagraph (wax) pencil. For rubbing out marks a soft rubber or cotton wool may be used, but preferably the photo should be washed with carbon tetrachloride.

Never use selotape on air-photos. It strips off the emulsion when it is removed. Always use masking tape.

Using the Stereoscope for Rapid or Occasional Use.

1. The two photos should be parallel to one another.

2. Place the 2 photographs under the stereoscope with the overlap area on the right photo under the right hand mirror/lens and the left overlap area under the left hand mirror/lens. With a mirror stereoscope the photos should be about 3cm apart, although this depends upon the distance between your eyes (called your "eye-base").

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

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

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

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

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

8. With a pocket stereoscope the same technique is used, but 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 lower photo. (see Fig.8-15).

Using the Mirror Stereoscope for Prolonged Use.

The method given above is quick and easy, but if the photographs are not positioned exactly eye strain through prolonged viewing may result. Where very many photos are to be interpreted, therefore, the following method should be used. Once you are familiar with the method you will find that the initial trouble in preparation is well worth while.

1. Preparing the Stereoscope

This is a personal preparation that varies from person to person according to their eye base. It only has to be done once, and is then permanent.

1. Ask someone to measure the distance apart of your eyes. Then set the lenses of the stereoscope that distance apart, using the sliding scale on the stereoscope body. see Fig.8-16.

2. Mark a straight line on the desk, the width of the stereoscope. This may be scribed directly onto the desk, drawn on a strip of masking tape, or onto a piece of wood, paper, card or metal.

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. (see Fig.8-17).

6. Mark the positions of the four legs of the instrument. The instrument 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.

9. Measure the half-way point between these two marks, and mark it strongly 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 centre of the left-hand field of view. Mark that point strongly.

11. The instrument is now set-up according to your eyesight. The line, marks along the line, and marks for the instrument legs can be made permanent, so that you will not have to repeat the above procedure in future. They may even be scribed into the top of your desk.

2. Preparing the Photographs

1. Mark the principal point on each photo. This is done by finding where lines joining the fiducial marks cross (see Fig.8-18)

2. Transfer the principal point from one photo to the adjacent photos on each side. This is done by comparing points of details found on both photos at or near the principal point (see Fig.8-19).

3. Draw a line from the centre of the photo (i.e. its principal point) through the transferred principal point of the adjacent photo, to the edge of the photo. This is called the '**flight**' **line**. On the opposite edge of the photo make a small mark where the line would cross the edge if extended (see Fig.8-20).

FIG 8-16

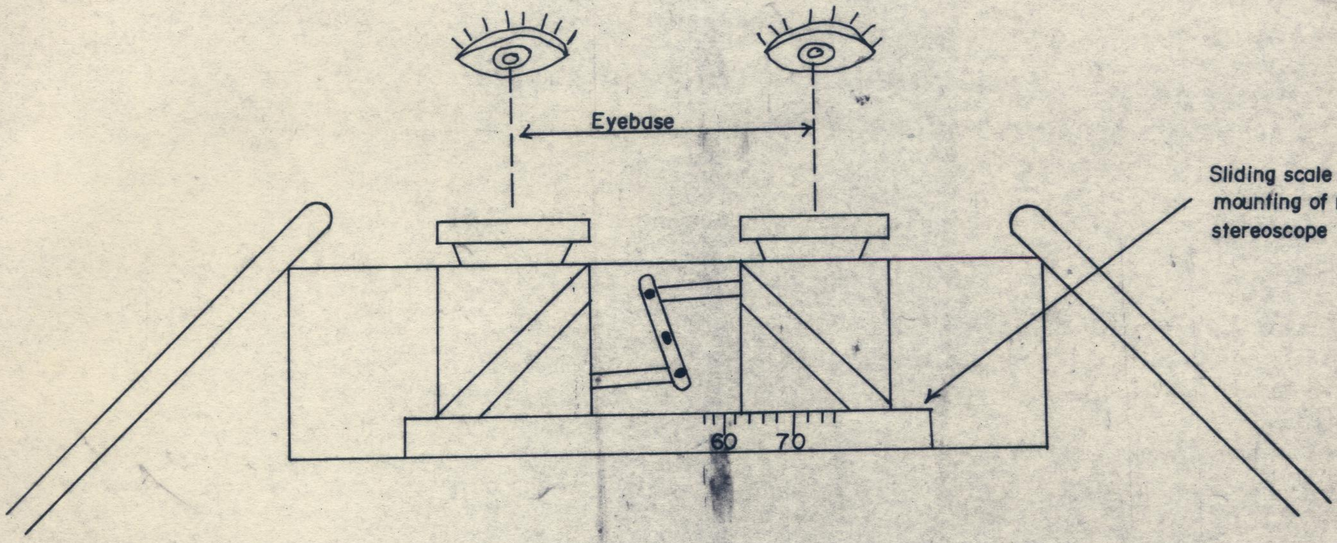
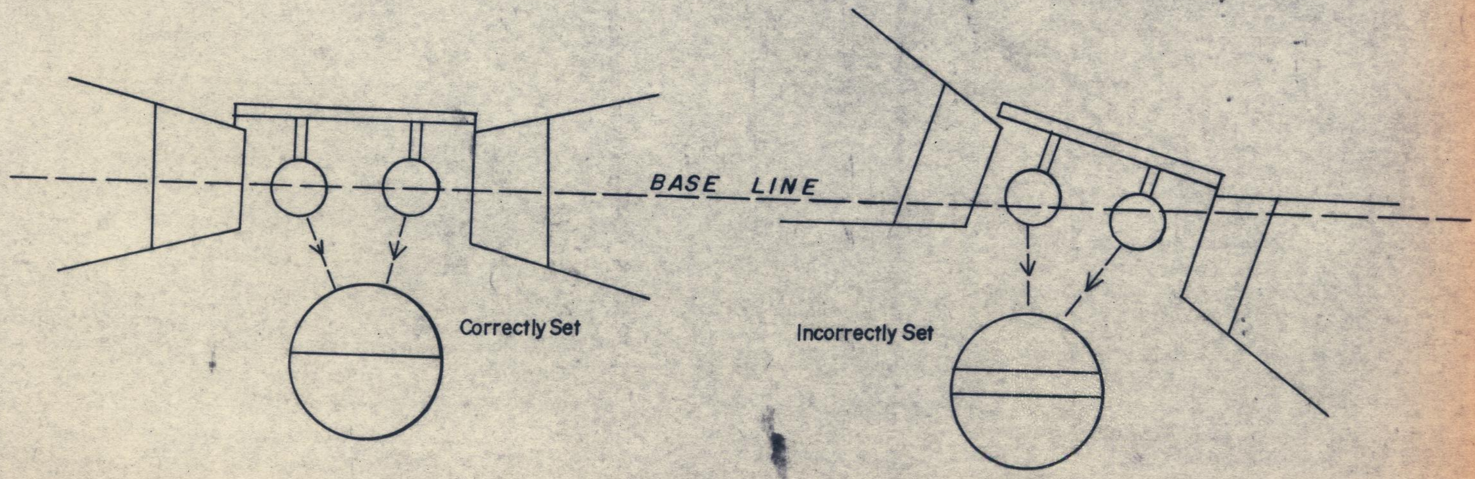
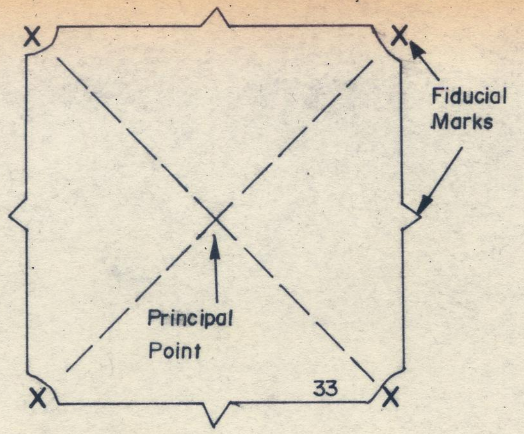


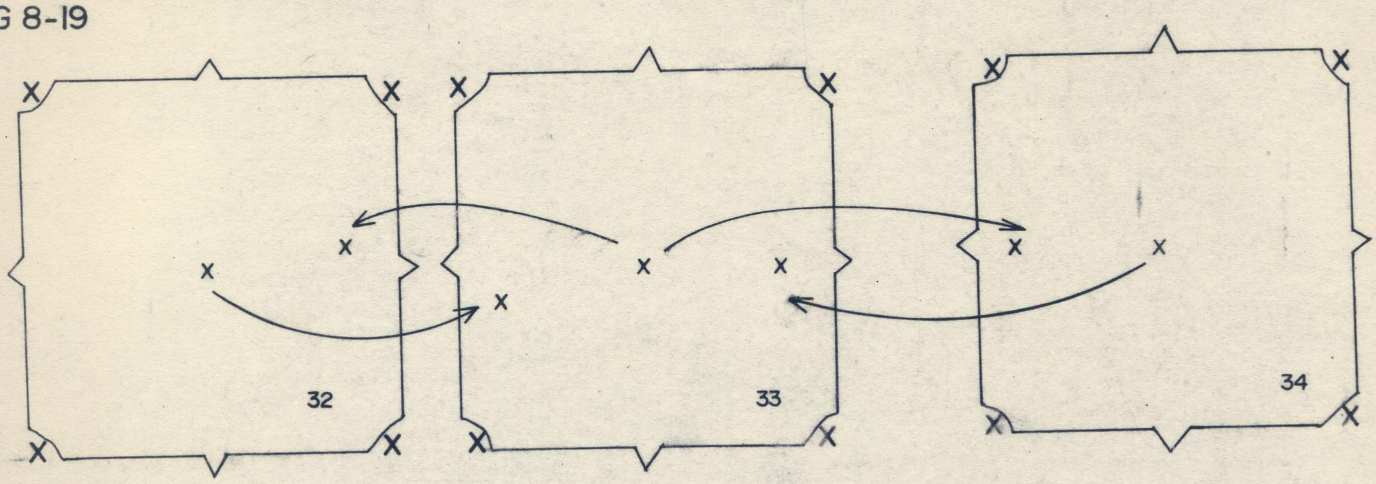
FIG 8-17



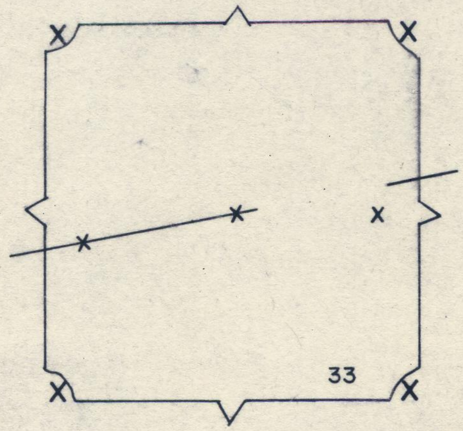
IG. 8-18



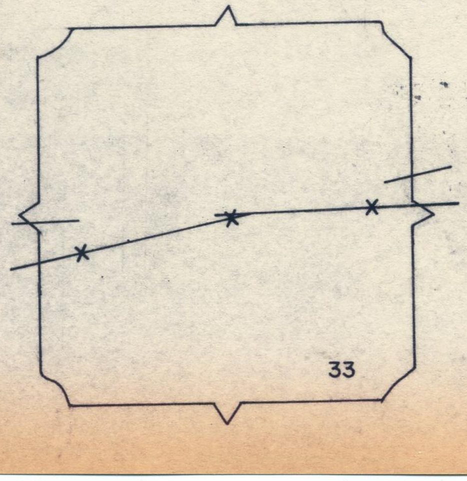
IG 8-19



IG 8-20



IG 8-21



4. Do the same for the other transferred principal point on the other side of the photo. You may or may not have a straight line across the photo. (see Fig.8-21).

5. The photos are now ready for stereo viewing.

VIEWING THE PHOTOGRAPHS

What we have done so far is to locate a straight line exactly along the centre of the field of view of the stereoscope, and to mark on that line the central point in the left hand field of view.

On the photos we have marked the centre of each photo (the principal point) and the flight line, which is the exact path the aircraft took between taking one photo (from above the principal point of that photo) to taking the next photo (from above the principal point of the next photo).

It will be seen that the area on the right hand side of one photo, is exactly the same as the area on the left hand side of the next photo. On the two photos we therefore have the same area viewed from two different points. This is what is necessary for stereoscopic viewing.

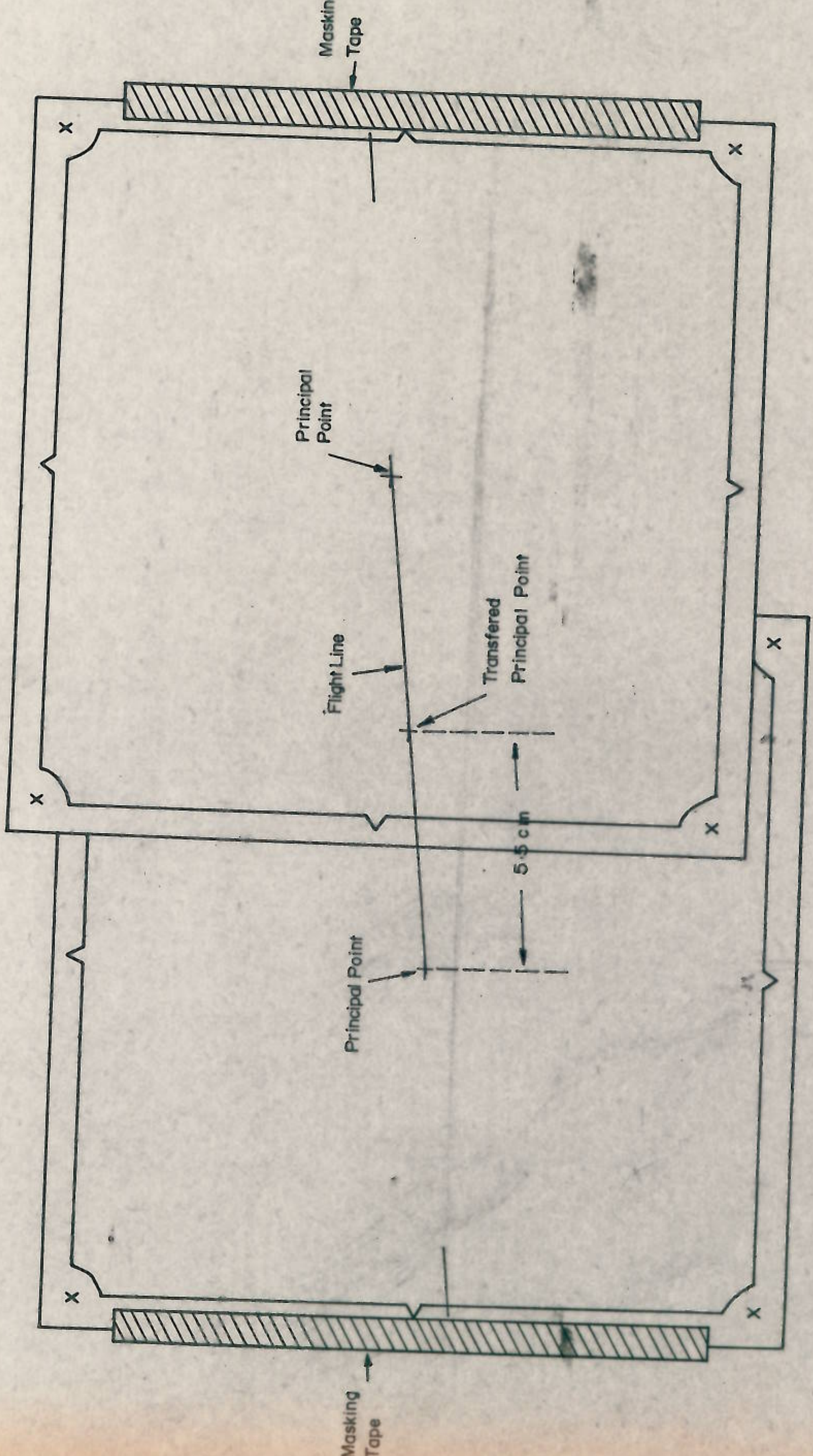
To view the photographs stereoscopically the principal point of the left hand photo must now be positioned over the centre of the left hand field of view marked on your desk. The transferred left hand principal point on the right hand photo is located over the point where the centre of the left hand field of view is seen under the right hand side of the stereoscope i.e. the right hand mark along the line. The photographs must now be turned until the 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 over the corners. The photos should now be set for effortless stereo viewing. You will find that on looking down the stereoscope, a perfect stereo image is instantly seen, and prolonged viewing can be carried out with no eye strain.

Using the pocket Stereoscope for Prolonged Use.

1. Base-line the photos as described above.
2. Fasten the left hand photo to your desk using masking tape along the left hand edge only.

3. 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 to align the photos) and the homogeneous points (Principal point and transferred principal point) are approximately 5.5cm apart.

4. Fasten the right hand photo along its right hand edge with masking tape. Each print can now be liften and placed on top of the other in order to completely examine the entire stereoscopic overlap (see Fig.8-22).



Masking Tape
Principal Point
Flight Line
Transfered Principal Point
5.5 cm
Principal Point
Masking Tape

FIG 8-22

PUTTING COMPLETE MATCH LINES ON AIR PHOTOS

The preparation of the air photos already described is all that is necessary for stereoscopic viewing. If a lot of photos are in use, the mapping of soil or land capability boundaries can be eased by putting complete match lines on the photos. This is merely an extension of the technique already described, but the area of stereoscopic cover on each stereopair is enclosed by lines. These lines match with the lines on adjacent photos and are therefore called "match lines".

The procedure is as follows:

1. Mark horizontal match lines 2.5cm from the top and bottom of each photo. (see Fig.8-23).
2. Mark the central vertical match line through the fiducial marks in the centre of the top and bottom of each photo. (see Fig.8-24).
3. Mark the principal point along the vertical match line of each photo. This is done by laying a ruler between the fiducial marks on the edge of each photo, and marking where it crosses the central vertical match line.
4. Transfer the central vertical match line to each adjacent photo. This is done by locating ground features at the top and bottom of the line, and finding the same features on the adjacent photos. There are then joined by a straight line.
5. Transfer the principal point to each adjacent photo, either stereoscopically or using ground features. (see Fig.8-26).
6. Draw a line from the edge of the photo, through the two principal points. On the opposite edge of the photo make a small mark where the line extended intersects the edge.
7. Do the same on the other side of the photo. You may or may not have a continuous line across the photo. (see Fig.8-27).
8. The photos are now ready for stereo viewing. They are set under the stereoscope as before. The match lines give you boundaries for your interpretation. Anything outside the box will be covered on adjacent photos.

FIG 8-23

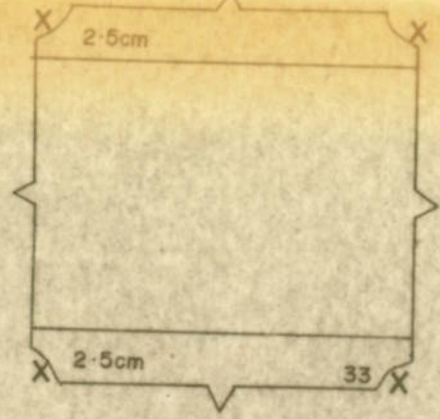


FIG 8-24

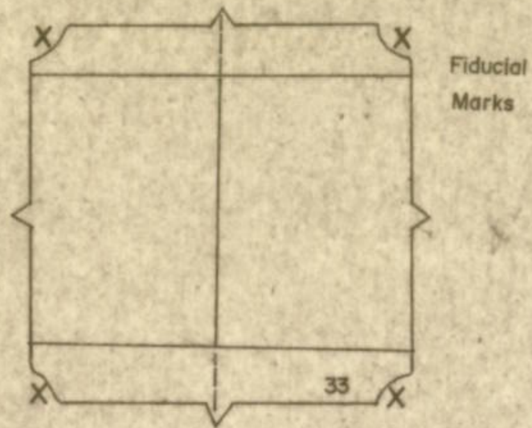
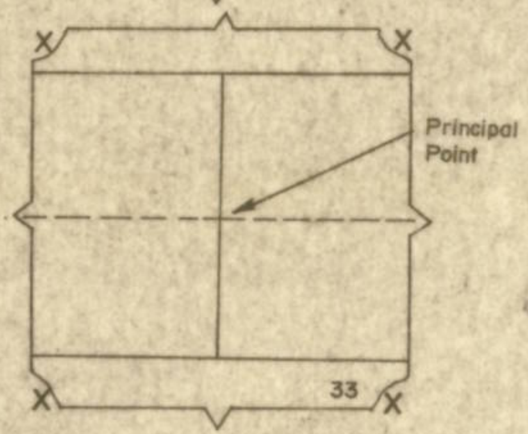
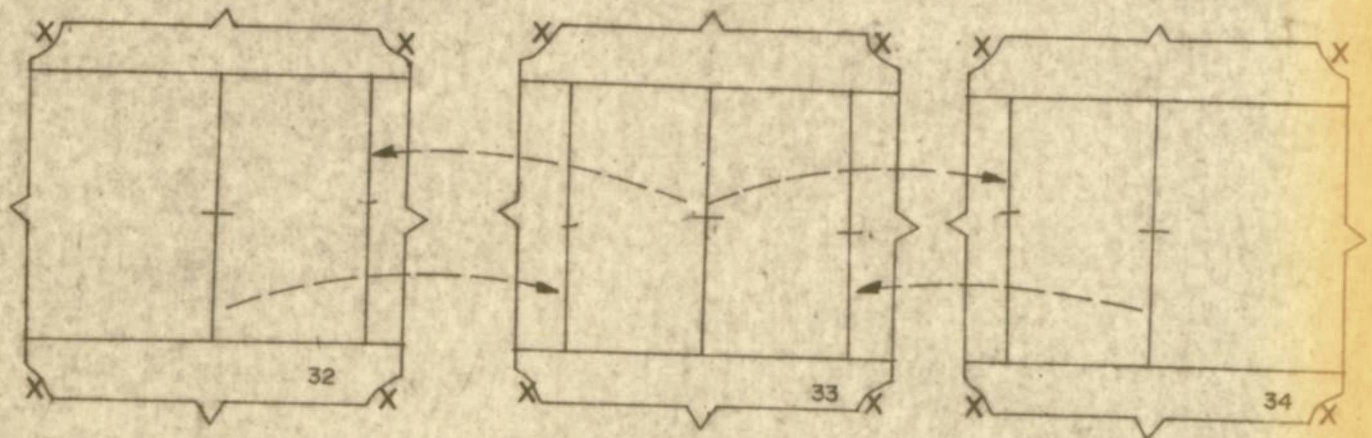


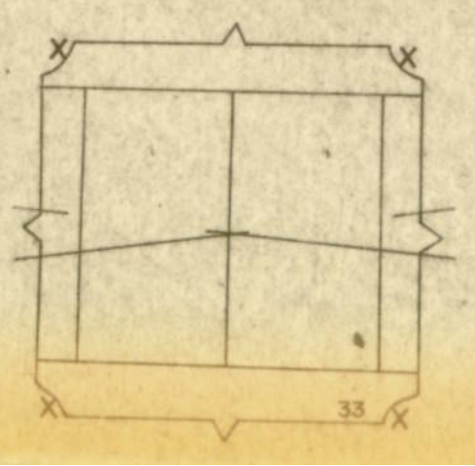
FIG 8-25



8-26



8-27



P A R T   F O U R

PRACTICAL NAVIGATION.

CHAPTER 9

INTERPRETATION FROM AERIAL PHOTOGRAPHS

There is much more detail on an air photo than on a map of the same area. But the appearance of the detail can, in fact, be confusing. On a map symbols are used to represent different features and their meanings given in a key, whereas on the photo there are no clearly defined symbols, but only difficult-to-recognise images.

On a map it is possible to show tiny items of detail by a large symbol with a greatly exaggerated scale, but everything on a photo corresponds to its actual size on the ground, so that small features can be difficult to see.

All features which are visible from the air will appear on the photo. The fact that a photo has so much detail can infact lead to confusion, especially in areas where there is a lot of detail giving a cluttered appearance to the photo. Thus, although a photo has more detail than a map, the information on the photo may be less easily understandable than the information shown on a map.

Normally, when looking at an object, we recognise it by its size and shape, its colour, and other objects or features associated with it. We have to use the same processes when looking at objects on air photos. However, objects which we readily recognise on the ground may look very different on an air photo, so we have to learn anew to recognise familiar features on the photo.

Relief is shown on a map by contour lines and these are absent from the air photo. However, it is possible to view air photos stereoscopically. This means that we can actually see the hills rising up out of the picture, and the valleys as depressions in the picture. Thus it may be easier to get a realistic impression of the relief of an area from air photos than from a map.

Certain features that are usually shown on maps are missing from air photos. These include the exact direction of north, and the grid lines. A scale is given on all air photos. It is only approximate, but is accurate enough for field navigation purposes.

We have therefore to become familiar with the recognition of features on an air photo, and to gain an appreciation of the scale of the photo and the relationship between the features at the scale. Once we can do this, the air photo becomes similar to an immensly detailed map, and it can be used in the same way for navigation.

THE USE OF AERIAL PHOTOGRAPHY FOR SOILS WORK

Aerial photographs are widely used as a base on which to plot data about soils and to draw boundaries between kinds of soils with or without the aid of a stereoscope.

Air photos are available in Zambia at scales ranging from 1:80,000 to 1:6,000. Small scale photos give a good overall impression of a large area, so that broad trends can be seen. Few photos are needed to cover a given area. Large scale photos show the area in greater detail. However, for a large area, very many photos have to be handled. Suitable scales for different survey intensities are as follows:

1:80,000 - 1:40,000 - Exploratory and rapid reconnaissance.
1:40,000 - 1:20,000 - Reconnaissance and semi-detailed.
1:25,000 - 1:12,000 - Detailed.

Stereoscopic interpretation of aerial photographs gives a soil scientist additional clues about the kinds of soil he is likely to find and especially about where the soil boundaries lie. There are, of course, limitations. No one can "see" a soil on an aerial photograph. A soil is a three-dimensional unit of the landscape. It has depth. From the picture the soil scientist can at most see only the surface-and that imperfectly. He can see the third dimension only by digging a pit or augering.

Yet the study of aerial photographs gives important clues about the shape of surfaces, the vegetation, and the soil colour. Often the pattern of features is repeated over large areas. By studying examples of landscapes that make up patterns with a field survey the soil scientist can learn the local relationships between specific kinds of soil and patterns in the photographs. This helps him in plotting soil boundaries accurately and rapidly. It helps him with reconnaissance soil surveys that are made before detailed soil surveys of a selected part of a large area are carried out.

To be reliable, the kinds of soil and the soil mapping units must be identified from ground observations. The principle here is not one of "either-or". Even though we cannot make a reliable soil map from examining aerial photographs alone, the photographs should not be ignored; soil maps can be made more accurately and more rapidly with good photo interpretation than without it.

Exploratory or reconnaissance soil surveys play an important part in areas having little soil suitable for cropping or in areas where the proportion of soils suitable for cropping is unknown. If sizeable areas of soils suitable for intensive use are discovered by these surveys, they can then be covered by more detailed soil surveys for planning such use. Approximate identification of the kinds of soil can be made by interpretation of aerial photographs, and a suitable soil map can be made provided that adequate examples of soil have been studied on the ground.

There are many differences between features seen on the air photo, and the same features seen on the ground. The shape on the photo is usually the plan (top view), instead of the more familiar elevation (side view). Not only do we not easily recognise that view, there is also the fact that many objects which vary greatly in side view may have similar top views on the air photo. In this case the size of the object may help to identify it as well as its relation to other nearby features. It is not usually necessary to accurately measure the size of an object, but one should always have an over-all appreciation, or "feeling" for the scale of the photos, and this is only gained by experience. It is useful to remember what 1cm represents at various scales (e.g. 1cm = 300 metres at 1:30,000;500 metres at 1:50,000 etc). The finger nail of your little finger is about 1cm wide. You are therefore never without a rough ruler in the field!

IMAGE CHARACTERISTICS WHICH AID PHOTO INTERPRETATION

Most air photos are in black and white. Colour film is expensive and in fact colour may not make the photos any easier to interpret. On black and white film all colours are shown as black, white, or shades of grey. We therefore talk about the "tone" instead of the colour of an object on an air photo. The tone of an object on an air photo may confuse us when we think of the colour of the same object. This is because black and white film reacts differently to different colours to the way our eyes react. Thus, if we look at a bright red object and a dark blue object, the red one looks brighter to our eyes. However, on the photograph it is often the dark blue object that has the lighter tone.

But it is not only colour that affects the tone of an object on air photos. Smooth surfaces such as roads reflect a lot of light and so produce light tones on the photo whatever their colour. Rough objects, on the other hand, will appear darker because they do not reflect as much light. Different crops growing in fields reflect different amounts of light due to their different leaf characteristics. Similarly different types of vegetation in the bush reflect different amounts of light. Thus mushitu shows as black, whilst secondary miombo forest shows as pale grey.

Some things absorb a lot of light, and thus reflect little light; the most common case is water. Such things have a dark tone on the photo.

Often in day to day life we recognise an object by its association with other things. Somebody may wave to us as they flash past in a car, and we do not get a chance to see their face. However, as there is only one person we know personally who owns that type of car, we are able to deduce who it was. This kind of deduction is extremely important in air photo interpretation. For example, many schools are a large collection of buildings with a distinctive playing field attached. Mines may be identified by their slag heaps and slime dams.

Windrows show clearly as dark, regular lines across a field before burning. Chitemene cultivation has distinctive dot or line patterns. Tiny villages can be first recognised by many footpaths converging towards them. River courses may be seen from the dense Mushitu vegetation along the water course, or by the sharply defined edge of a fire zone.

It is difficult to make generalisations about air photo interpretation, because each area has its own specific characteristics in terms of vegetation, micro relief, drainage pattern, parent material, altitude etc. However, a few general statements can be made.

Bare rock, laterite, or bare soil have a white or very light grey colour. So do sandy dambo fringes.

Areas of shallow soils often have light grey colours, with a low tree density (Musuku bush), or can have scattered very large trees.

Ant hills (termite mounds) appear as round dots on air photos. Usually they are very dark or black because they support dense bushes or trees which absorb light. Concentrations of large termite mounds are usually found near dambos, or on dambo edges - more frequently on clayey soils than on sandy soils.

An irregular surface accompanied by depressions without outlets (sink holes) indicates limestone bedrock underneath the soil, and in most cases heavy textured soils.

Thicket occurs as black or very dark grey patches on the photos. This vegetation is often found on heavy soils, or bordering water courses.

Man-made changes in the landscape are usually easy to identify e.g. Chitemene fields, villages, gardens etc.

Some changes in tone on the photo may have nothing to do with soil variation. For example, bush fires may give peculiar patterns of grey or black, depending on the length of time between the date of the fire and the date of the photography.

Sheet erosion registers as a tonal difference appearing as light patches. Seriously eroded areas not covered by vegetation photograph light. Light tones, however, are not always indications of sheet erosion. It should be taken into account that steeply sloping soils are more likely to erode than those gently sloping, that in areas of subdued relief erosion is likely to occur at the crests of low ridges, and that eroded areas may be covered by crops or native vegetation and therefore will not show up on the photos.

Gullies appear as long scars with definite irregular borders; they contrast with sheet-eroded areas, which have more diffuse and smoother outlines. Gullies are common in natural drainage and at the boundaries of fields.

Slope - breaks can usually be seen under the stereoscope, except where the relief is very gentle. Soil boundaries often occur at slope breaks and sometimes this is the only indication of the position of the boundary.

THE USE OF AERIAL PHOTOGRAPHY FOR LAND USE SURVEY

Before any member of the Land Use Branch goes into the field for any reason at all, he should have already studied the air photos of that area. This is very important. It means that when the field worker arrives, he is already somewhat familiar with the area. He knows approximately how wide the ridges and dambos are. He knows of any prominent hills. He knows whether the slopes are steep or gentle, how much land has been cleared, how dense the vegetation is, and whether there are many or few anthills. In other words, he is not going into an area unprepared.

The Land Use Branch Provincial Offices have all the air photos of the Province. The drawing office staff will quickly locate any photos you may require. All photos must be signed out.

When you have obtained the photos of the area you are to visit, they should be examined under the stereoscope. Various features are then marked onto the photo using a chinagraph pencil. Features marked will depend upon the type of survey you are to carry out. The following colours should be used to identify different features:-

RED/BROWN - 1/ Boundaries, including farm boundaries, soil or Land Capability boundaries, cleared land boundaries.

2/ Soil or Land Capability code notations.

3/ Red Hatching-Mountains and rocky outcros.

BLUE - 1/ Dambo fringes and Water courses.

2/ Traverse lines and traverse data (bearings, distances etc).

GREEN - 1/ Internal Fences

2/ Grassed Waterways

3/ Slope breaks

4/ Vegetation changes

5/ Match lines

BLACK - 1/ Crests (Watersheds)

2/ Roads

ORANGE - Graded contour ridges and storm drains

WHITE - Direction of slope.

Before a soil or land capability survey is carried out, the air photos of the area should be match-lined, and examined under the stereoscope. This has two purposes. Firstly the surveyor can get a "feel" of the area, as mentioned above. Secondly, the route of the traverses can be decided upon, the augering points determined, and any obstacles noted and avoided (e.g. if a Land Rover is to be used, wide dambos, deeply incised rivers or rocky areas can be noted to be avoided). The length of each traverse can be calculated from the photo scale, and adjusted to form a reasonable days work.

When each days work is ended, the main air photo interpretation starts, always under the stereoscope. The days traverses are marked accurately onto alternate photos, with the classification recorded against each pit. Other features recorded in the field notebook are marked as appropriate. A magnifying glass is useful for the study of details. Then, with the aid of your field notebook and general knowledge of stereo techniques, the soil boundaries can be identified and marked.

Each area must be "learned" individually by careful observation and comparison of changes on the photo, and changes in the soil, and changes on the land. This applies to even the most experienced surveyor.

With practice, the air photo ceases to be a meaningless jumble of grey tones, and is recognised to be one of the most useful tools the field worker posesses. But a word of warning. Air photo interpretation is a very useful tool, but it cannot replace field work. A map and report based on one day of field work and ten days of office work is not worth much more than the one day of field work alone. If there should be any doubt between what is observed in the field and what is thought to be seen on the photo, the field observation is always the one to rely on.

CHAPTER 10

TRAVERSE PLANNING

TRAVERSE DIRECTION

Any group of soils of the same age, derived from similar parent materials under the same climatic conditions, will show progressive variation as one moves from the valley or dambo bottom, up the slope, over the ridge, and back down to the next valley. The complete group of soils found in such a sequence is called a catena.

This is a very important concept, because it means that within a survey area, any soils over the same parent material, occupying the same physiographic position, are likely to have similar characteristics. It is for this reason that it is possible to infere with reasonable accuracy what soils occur between traverses. If soils occured purely at random, an extremely intensive survey would be necessary for even a very small survey area. However, by recognising the catenas in a given area, the soils between the traverses can be recognised from air photo interpretation.

Thus, wherever possible, each traverse should be planned to cover a catena. This means that the traverses should run across the ridges and dambos, i.e. at right angles to the topographical strike.

Before going into the field, the air photos should be examined under the stereoscope. The ridge and valley pattern can then be determined, and the traverses planned to cross the ridges. Any prominent slope breaks, changes in vegetation, or changes in landform or tone should be noted, and the traverses planned to cross these features. It can then be determined in the field whether these features are related to changes in soil type, or not.

On large scale survey the 1:50,000 maps can be used in conjunction with the air photos for traverse planning. These maps are usually contoured, so that the ridges and valleys are clearly seen, and traverses can be planned to cross them. Also, the degree of slope can be calculated from the map by measuring the distance between the contours. Thus steeper or more shallow slopes than usual can be identified for further investigation in the field.

Traverse Bearings

In the field, a magnetic compass is used to indicate the direction in which to walk along each traverse. Unless it is intereferred with by nearby objects made of iron, or electrical equipment, it always points to the magnetic north. A bearing is given as degrees of arc (360° in full circle) east of (or clockwise from) north.

Having decided upon the direction of your traverse, the traverse must then be plotted onto the 1:50,000 sheet in pencil. The line of the traverse is extended if necessary, so that a protractor can be placed on the traverse line, centred on a point where the traverse line crosses one of the vertical grid lines. The protractor is rotated until it reads the magnetic bearing of grid north for that area on the vertical grid line. The magnetic bearing of the traverse can then be read off.

Although each 1:50,000 sheet has the difference between true, grid, and magnetic north printed on it, at the time of writing, the differences given are known to be inaccurate. Thus, for each 1:50,000 sheet used in the survey you must calculate your own. To do so, proceed as follows:-

1. Find a straight length of road, or a cut line, near the centre of your survey. Locate this on your map.

2. Take the bearing of this road, checking your result from the other end by use of a back bearing.

3. Place a protractor on the map at a point where one of the vertical grid lines crosses the road. Rotate the protractor until the compass bearing of the road, read on the protractor, coincides with the road on the map.

4. Read off the magnetic bearing of the grid line, and note it down.

N.B. It will probably be necessary to extend the road line in each direction with a pencil line so that the protractor can fit over it.

For each traverse drawn onto the 1:50,000 sheet, you can now find a point where one of the vertical grid lines crosses the traverse. Put the protractor on the point, and rotate it until the magnetic bearing of the grid line (found above) is on the grid line, then read off the magnetic bearing of the traverse.

On a small scale survey covered by a very few air photos, the bearings can be determined directly from the photos. Having measured the compass bearing of your road etc; place the protractor on the road on the photo centred where the traverse crosses the road, and read off the magnetic bearing of the traverse.

Never assume that the top of the photo is north. The exact orientation of every photo will vary due to the errors inherent in all air photos.

Traverse Distance

When walking, a distance of between 8 km and 12 km through bush forms a reasonable days work. A speed of about 2km/hour can be assumed when augering every 200 or 300 metres. Over open land, or along foot-paths and roads, a greater distance can be easily covered. The exact distance is often determined by the topography. A closed box traverse starts and finishes at the same point. If a vehicle can be sent to meet the team at another point, an open traverse can be used.

When surveying from a Land Rover along or tracks, measuring distance with the speedometer, over 50 km can be covered in a day, augering at 500m - 1km. This would be on a rapid reconnaissance type of survey. These figures are very tentative as it all depends on the field conditions, intensity of the survey, and the homogeneity of the land.

Traverse and Augering Intervals

The level of the survey depends on the use to which it will be put. Most land capability surveys are used for farm project planning, and it is usual to carry out the surveys at a "semi-detailed" level. The distance between the traverses, and the distance between each augering along the traverses, will vary according to the needs of the survey, but for a semi-detailed level, a distance between traverses of 500m - 1 km, and a distance between augering along the traverses of 200 - 500m is usual. The most useful spacing is 600 metres between traverses, with augerings at every 300 metres. These distances fit nicely with the use of a 30 metre chain, and aerial photographs at a scale of 1:30,000.

Over small areas, a regular grid may be used, but on larger surveys the traverses can go in different directions, so as to best cross the topographic strike. In this case the distance between the traverses may be closer than the limits at some places, and more distant at others. The important thing is to keep the average distance to the limits set for that survey.

On a reconnaissance survey (such as the soil survey unit usually carries out) distance between traverses can be from 1.5 km to 2 km, with augerings carried out at between 300m and 800m intervals.

Usually intervals of 1.5 km x 300 m would be used. On such a survey, each augering represents 60 ha.

On a semidetailed survey with a 600 x 300 grid, each augering represents 18 ha.

Miscellaneous considerations

1. Wherever a road or cut line is running across the catena, then use it for a traverse to save time and effort.

2. Where access is very difficult, it is often best to put in a base line for Land Rover access along a ridge. You then plan box traverses from the base line across the catena. The base line is cut just sufficiently for the Land Rover to pass. Four men should complete up to 6 km in a day.

3. If necessary, it is possible to cross almost any dambo or river (except a very big river) with surprising ease. Half a kilometer of sodden dambo can be bridged by four men in a day by constructing a "corduroy" road of logs layed across. However, only spend the time and effort on this if you are really sure it is necessary. There is often a better way in elsewhere.

4. Plan traverses to start and finish at prominent features e.g. road corners, villages, bends in a river, etc. This makes the field navigation much more simple.

5. Beware of old air photos. Footpaths become disused and over grown, while new ones appear. Villages are abandoned and rebuilt a few hundred metres away. New roads are put in. It is as well to avoid the use of bush footpaths as traverses unless you are absolutely sure you are on the right one.

6. Traverse lines should be drawn on alternate photographs. This leaves the stereo-pairs clean for subsequent photo interpretation of the land capability boundaries. Draw the lines using a sharp, blue, chinagraph pencil.

CHAPTER 11

THE MEASUREMENT OF DISTANCE IN THE FIELD

There are many ways of measuring distances in the field. Those usually used in the Land Use Branch are pacing, chaining and the cycleometer.

1. Pacing

Pacing means counting how many paces, or steps, you take whilst walking. If you practice pacing along a known distance (e.g. a chain layed out along the ground), you will be able to learn to make each of your paces exactly 1 metre long. This needs concentration and practice to achieve. Once you can do this, it is possible to measure distances very accurately by pacing, providing you always concentrate on what you are doing.

Usually, when walking up a hill, we take smaller (shorter) paces than when walking down a hill. However, if you have learnt to pace exactly 1 metre per step, and if you concentrate on doing so, you can overcome this tendency to vary the length of your pace.

This is the most accurate way of measuring distance by pacing. However, it can be slow and tiring. In thick grass it may be impossible. Where high accuracy is not so important, a quicker method is to walk normally, and make an allowance for the fact that your paces are not exactly 1 metre each.

Over any given sort of terrain each and every person has a slightly different length of pace. Every field officer should therefore know how many paces he takes over a given distance. Most people's paces are less than 1 metre. Therefore the number of paces taken must be converted to the correct number of metres, and this conversion depends upon the individual doing the pacing, and the type of ground he is walking on.

In order to work out your personal conversion factor for each type of ground, you should measure, using a tape, chain or cycleometer, a known distance. Walk along this line using your normal walking pace, and count how many paces you take. Do this several times and work out the average number of paces you take. The longer the distance, the more accurate will be your result. Then divide the distance you covered by the number of paces. This gives you the average length of one of your paces. Write this number in the front of your field note book.

2. Chaining

A chain is a length of metal links with markers at fixed distances along it. Each individual link represents a given distance. The chain is used in conjuction with "arrows" and requires at least two men to take the measurement.

The chain has a handle at each end. The front man pulls the chain along the ground until the handle at the back, held by the second man, is level with the starting point. The back man holds the handle on this point, at ground level, whilst the front man, also holding the chain at ground level, pulls the chain tight, then places an arrow in the ground at this point. The front man then walks along, pulling the chain behind him. When the back man reaches the arrow in the ground he again holds the handle at ground level whilst the front man again pulls the chain tight and places an arrow in the ground. The back man then removes the arrow from the ground and carries it with him.

The distance chained is therefore either:-

1. (The No.of arrows held by the back man + 1) x length of chain.

or

2. (The No.of arrows started with - the No. of arrows remaining at the front) x length of chain.

Intermediate distances are taken by subtraction using the distance markers on the chain.

A metric chain is 30m in length with divisions measured equally from either end to the centre.

A third man may be used to carry arrows from the back man to the front man.

Always walk in a straight line, going over, not around anthills etc.

Tie brightly coloured bits of cloth onto the arrows so that they can be easily seen in tall grass.

After every ten chain lengths, when the back man returns the ten arrows to the front man, the arrows should be counted to ensure that none have been missed.

3. The Cycleometer

The cycleometer is a small wheel mounted on the end of a handle. It is connected to a revolution counter, which counts how many times the wheel goes around. If the wheel has a circumference of one metre, then it will go round once for each metre it is pushed along. The revolution counter will thus give a reading in metres.

The cycleometer is easy to use, needs only one man to operate it, gives a continuous direct reading of distance travelled, and can even be pushed along by the surveyor if he is alone. It is recommended as the best form of distance measurement for most soil surveying, although on detailed surveys a chain may be more accurate. It is most important that the operator knows what he is doing.

In the bush, the operator will tend to follow a twisting course which means the distance recorded will be slightly higher than the true distance covered.

This will vary according to terrain and the operator, so the allowance needed to record the true distance has to be found by experiment at the beginning of a survey. Errors of up to 10% can be recorded in rough or uneven country. On a road the cycleometor will give a true reading.

It is usually adequate to record distances to the nearest 10 metres for soil surveying. After all, a chinagraph line is about 1mm wide, which on a 1:30,000 aerial photo represents 30 metres. Of course, the accuracy to which you must work depends on the level of the survey and the scale of your maps and photographs.

CHAPTER 12

COMPASS WORK

The type of magnetic compass most frequently used by Land Use Staff is the "prismatic compass". It consists of a Circular metal case with a glass top, inside which is a Circular card, graduated in degrees of arc. The card is free to pivot about a central needle, and has a magnet mounted beneath it. The north - seeking pole of the magnet always points to the magnetic north. The compass is filled with alcohol or oil to slow down the movement of the card.

When the lid is opened flat a fine pointer is seen at the front of the instrument. The bearing along which the hair line on the lid is pointing can be read off beneath this pointer on the inner scale. This is quick, but not very accurate.

For more accurate work the lid is opened vertically, and the prism above the handle is flipped over onto the glass face. In order to find the bearing of an object from his position, the compass man sights through the prism, turning until the hair line on the lid is concurrent with that object. The bearing can be read directly on the scale visible inside the prism. The scale is accurate to the nearest degree, and half degrees (30 minutes) can be estimated.

To walk along a traverse of a given bearing, the compass man sights through the prims, turning until the bearing he requires is read on the scale. He then notes which tree or other feature the hair line on the lid is concurrent with, and walks to that point. He repeats the operation from point to point.

When reading the scale, note that it reads from right to left. The short divisions are the single degrees, the long divisions are at every five degrees, and the medium length divisions are the tens of degrees, coinciding with the number located immediately beneath. (see Fig.12-1).

For quick and rough traverse work, where accuracy to the nearest one or two degrees is adequate, the adjustable ring around the outside of the case is used. Each number on the ring represents 10 degrees. Thus, if the compass man wants to walk on an approximate bearing of 80° he loossens the locking screw on the outside of the compass body, and turns the ring until the figure 8 coincides with the hair line at front of the compass, and locks the ring. He then places the compass flat in the palm of his hand, with the prism folded out of the way, and the lid open flat. By keeping the north mark on the card directly beneath the north mark on the glass face, and walking in the direction the hair line on the lid is pointing, he will be following a bearing of approximately 80°.

The following hints should be observed:-

1. When using a compass STAND STILL
2. Stand well away from vehicles, metal roofs, water tanks, power lines or any other metal object. Make sure a man with a soil auger is not standing next to you. Any metal object may effect the

G 12-1

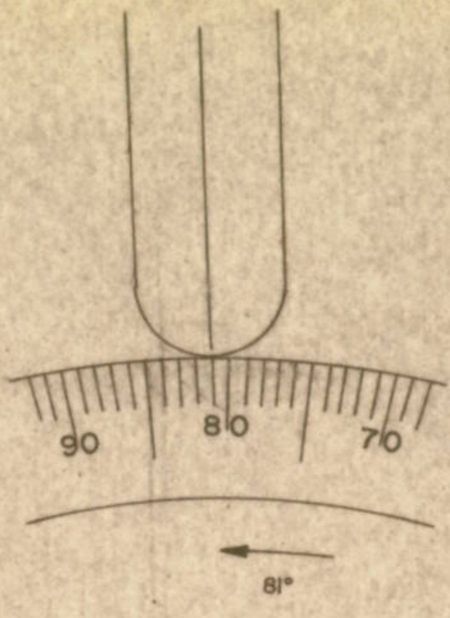
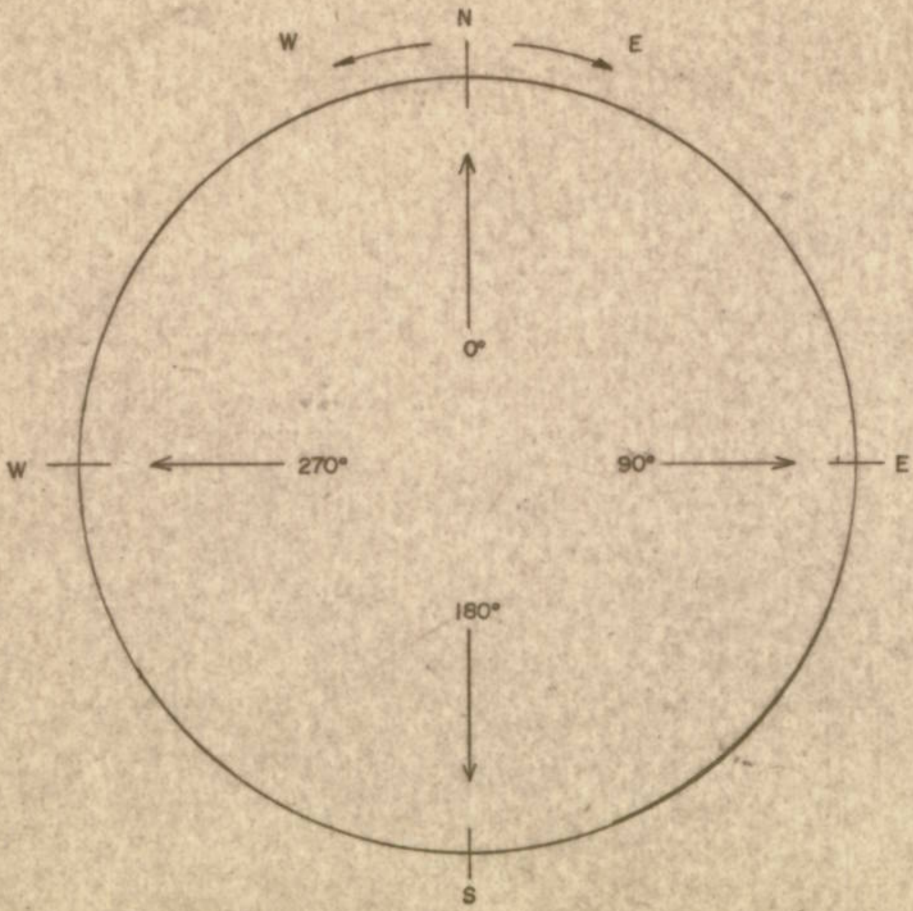


FIG 12-2



compass which will then give a false reading.
3. When not in use, keep the compass in its case.
4. Do not let the compass get hot.
5. Always check that the compass card is not sticking by swinging the compass gently from side to side and making sure the card swings freely.
6. If an air buble is seen in the compass, return it for repair immediately.
7. Read to the nearest 0.5^{o} (30')
8. Hold the compass on your second finger, with your thumb through the ring, and your first finger around the front of the case.
9. When recording a bearing always state if it is a magnetic, grid, or true bearing.

Bearings and Back Bearings

The compass card represents a full circle divided into 360^{o}. The card reads $0-360^{o}$ east of North. Thus N is 0^{o} or 360^{o}. A bearing of 185^{o} East is therefore the same as 175^{o} West.

i.e. $^{o}W = 360^{o} - {}^{o}E$

A Back Bearing is 180^{o} different to a foreward bearing. To work out a back bearing use the following rule:-

If the foreward bearing is less than 180^{o}, ADD 180^{o}.

If the foreward bearing is more than 180^{o}, SUBTRACT 180^{o}. (see Fig.12-2).

CHAPTER 13

THE ABNEY LEVEL

The Abney level is a small hand held instrument that is used for quick measurements of slope. It is light and easy to carry and is quite robust. It may be used without a staff and staff man, and is extremely useful for reconnaissance trips prior to more detailed contour surveying, for measuring percentage slopes during soil surveying and any other times when a quick check of a slope is required (e.g. to check that a suspect graded contour is in fact falling in the right direction). A field officer should carry an Abney level with him on all trips into the field.

The Abney level consists of a telescope tube with a small opening on the top of the tube at the end held distant from the eye. Above this opening is mounted a pivoted spirit-level. Inside the tube is a mirror, so that in half of the field of view an image of the spirit-level bubble may be seen. Horizontally across the field of view is a needle.

The instrument is sighted so that the needle coinsides with any distant reference point that lies at the same height above the ground as the operators eye. The reference point can be a companion of the same height, a mark previously placed on the side of a Land Rover, a pocket knife stuck into a tree or a small blaze on a tree, etc. The reflection of the bubble is then brought into line with the needle by rotating the milled knob, thereby moving the spirit-level. The spirit-level is therefore adjusted to the horizontal position, while the telescope is paralell to the slope of the ground. The angle of the slope may therefore be read from the scale with the aid of the magnifying glass.

The scale on the Abney level is of a type known as a vernier scale. The main (large) scale gives the value of tens and units of degrees. The vernier (small) scale gives the value of minutes.

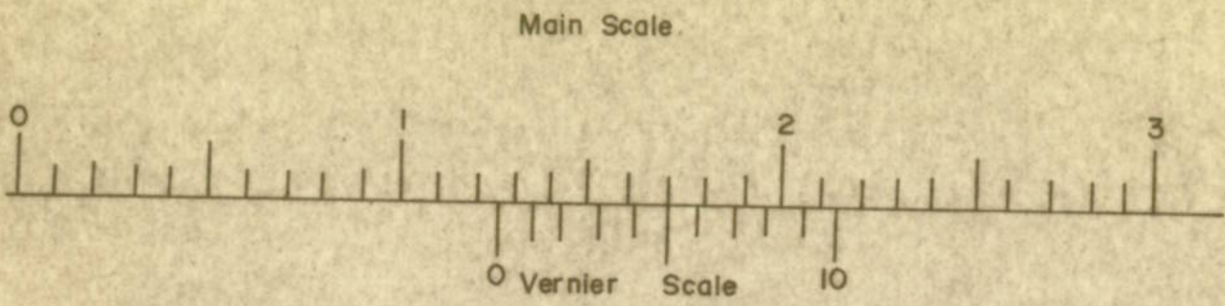
A vernier is a type of scale whereby it is possible to measure very small divisions accurately. Consider a normal centimeter ruler. The accuracy to which it can be read is limited to the nearest millimeter. Fractions of a millimeter may be estimated, but how accurately they may be estimated depends upon the individual concerned. This is true for any situation where a reading is taken at some point long a graduated scale. The vernier allows accurate readings to be taken for the fractions of the smallest division on the main scale.

The vernier has a main scale, which is the normal scale for measurement, and a vernier scale, which is used for estimating the fractions.

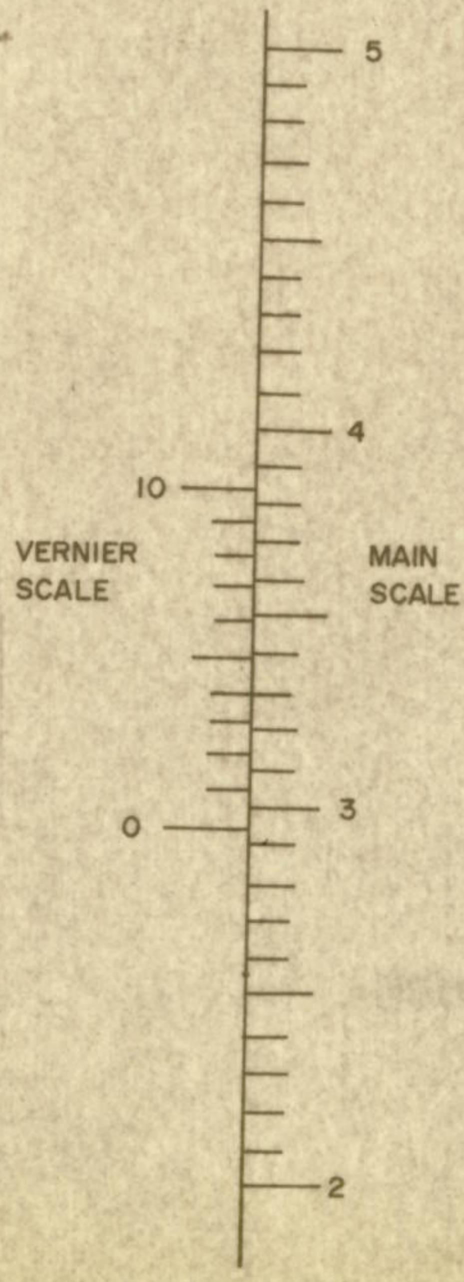
Ten divisions on the vernier scale usually cover the same distance as nine divisions on the main scale (see Fig.13-1).

FIG 13-1

VERNIER SCALES



Reading 125



Reading = 294

The vernier is read as follows:-

1. The hundreds figure on the main scale is read. This is the figure that appears beyond the 0 point on the vernier scale. Different instruments vary in layout, see the diagram.

2. The tens figure on the main scale is read in the same way.

3. The units figure is read on the vernier scale. starting with the 0 point, each subdivision is examined in turn.

It will be found that one subdivision on the vernier scale falls exactly in line with a subdivision on the main scale, so that the two form one continuous line. The number of this subdivision on the vernier scale (not the one on the main scale), counting from the zero point, represents the units figure. It is immaterial which division on the main scale the vernier division corresponds with.

The scale on the Abney level is graduated in degrees and minutes. (see Fig.13-2). The main scale gives the value of tens and units of degrees.

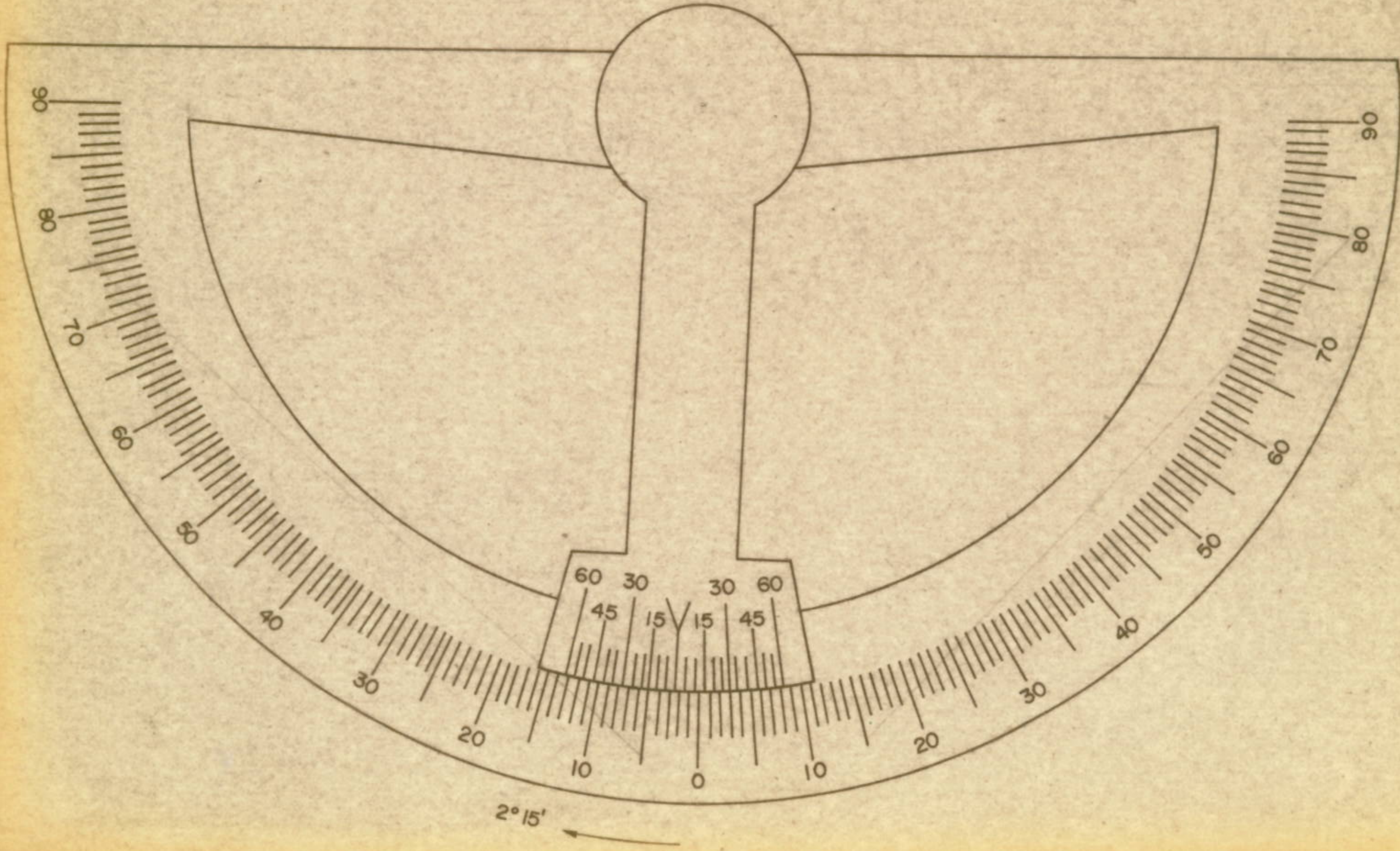
The vernier scale gives the value of minutes. There are 60 minutes in a degree. The instruments in the Land Use Branch can be read to either the nearest 5 or nearest 10 minutes.

The level can operate in both directions, i.e. up or down the slope. The scale thus reads either side of the zero graduation. The vernier scale therefore also has to read in both directions. With the instruments at present in the Land Use Branch, the vernier scale on the left is used if the main scale on the left is in use. The vernier scale on the right is used if the main scale on the right is used.

The left hand scale is read when measuring down a slope. The right hand scale is read when measuring up a slope.

FIG 13-2

ABNEY LEVEL VERNIER SCALE



CHAPTER 14

SOME COMMENTS ON FIELD TECHNIQUES

1. A field team consists of a compassman with two labourers for blazing, the surveyor with one labourer for augering, and some labour for measuring distance; the number depending on whether a chain or cyclometer is used. A driver and camp watchman are also required on a big survey.

2. Walking is almost always better than using the Land Rover in the bush. You see more, you do not spend all day breathing exhaust fumes, and the Land Rover will last much longer.

3. Always beacon the beginning and end of every traverse, or part of a traverse if you change direction. Always clearly blaze your line through the bush. This is important, you often want to return either for checking, or to show the Planning Officer the soils you have described.

4. Auger to at least 90cm. On big surveys, and at the beginning of all surveys, auger to 120cm.

5. Mark the auger handle with welded spots. The top of the can assembly is 30cm from the end. Put spots on the handle at 60cm, 90cm, and 120cm.

6. If you strike a root, never allow two men to try to turn the auger to cut the root. If one man alone cannot cut the root, a new hole must be started. Two men will break the auger.

7. Texture with the left hand. This leaves your right hand clean for recording.

8. Never touch the colour chips in the colour book. You will change their colour.

9. Never leave the colour book open in the sunlight. The colours will fade.

10. Take the colour of a freshly broken face of the soil. Never touch the soil face before taking its colour.

11. Carry air photos on a clip board, held at the edges so that they cannot curl up in the heat.

12. Carry a pocket stereoscope with you. Use it to determine your exact location in the field.

13. Mark all relevant features seen in the field onto the air photos, and record them in your field note-book. These include footpaths, roads, rivers, hills, villages, rock outcrops, gravel patches, vegetation changes, slope breaks etc. Record in your note-book the distance travelled from the last pit to these features. Record the distance to the edge and centre of each dambo you cross.

14. When in the forest it is almost impossible to know exactly where you are. Therefore, each time you cross a road, path, dambo, or you come to a village, hill and outcrop, or any easily recognisable feature, you can check your position on the air photos. If you find that you are in the wrong place, you must decide whether to go back and start again, or to correct your bearing from that point.

15. Always close your traverse either to your starting point (in the case of a box traverse), or to some prominent feature seen on the map or photo. This is most important.

16. Never auger close to, or down hill from, an anthill. Ant-hill soil is different from the surrounding soil.

17. Never let the man with the auger, or men with axes, stand close to the compass man. Your traverse will go astray.

18. Take home a piece of each different type of rock you find, so that the planning or soil survey staff can identify it. Record in your field notebook where you found it.

19. If the measured point where you are to auger is by an outcrop, move away and try a nearby place. If you strike a limiting layer, try another hole nearby to check that you had not struck an isolated bit of rock or gravel.

20. Do not just auger at the appropriate interval, and no where else. If you see change in vegetation, a change in slope, and occurence of or disappearance of gravel; a change in soil colour, or any other apparent change, then stop and auger, regardless of the distance from the last pit.

21. Soil brought up onto the surface and onto trees by termites is subsoil. Its' colour is close to the subsoil colour, and therefore you can often estimate the drainage (wetness) class of the soil by looking at the material brought up by the termites.

22. Tree roots running along the surface is an indication of shallow soils.

23. Ant bear holes are an indication of at least moderately deep soils.

24. In the rains, a large plastic bag should be carried to protect your field notebook, air photos, colour book etc. You can write inside the plastic bag in the rain.

25. Mark very clearly when your line passes important foot-paths etc. You may need these paths later for digging pits etc.

26. Finally, it is unwise to follow a honey bird early on in day. You may become so distracted that you never finish the traverse!

CHAPTER 15

SETTING UP A CAMP

1. Camp Location

a. The camp should be located in the middle of the survey area, so that daily distances travelled for traversing are kept to a minimum.

b. The access to the camp should be along a good road.

c. The camp should have a safe, clean water supply.

It is usual to select approximately where the camp should be on the basis of points a and b above. A visit is then made to the Chief, who will usually recommend one of the village headmen in that area. The village itself is then visited and the water supply checked. If it is suitable, the headman will help select the exact site in relation to his village.

2. Preliminaries

Before moving into an area, it is essential that the relavent authorities are informed. Firstly, a letter similar to the one shown below, should be typed in several copies, and signed by the provincial or district Agricultural Officer.

....

Sample letter:

Ministry of Agriculture and
Water Development,
Department of Agriculture,
P. O. Box 123,
SOMEWHERE.

29th February, 1979

To Whom it may concern

SOIL SURVEY, CHIEF SOMEBODIES AREA

The soil survey unit of the Land Use Branch of the Department of Agriculture, Somewhere, will carry out a soil survey within Chief Somebodies area, Somewhere District, from 4th July, 1979.

The team will be led by Mr. A.N. Other, soil surveyor, from the Department of Agriculture, Somewhere, and will consist of up to 6 men.

They will establish a camp site within the area, and are expected to work from that camp for about 3 months.

The team will walk and drive across the area using maps, aerial photographs and compasses for navigation. At intervals they will auger holes to examine the soils, and will also dig a few deep inspection pits. They will be using a Land Rover, registration number GRZ 123A for transport.

The Soil Survey programme is funded by the Norwegian Agency for International Development (NORAD) under its technical assistance programme to Zambia. It is a long term project aimed at producing a reconnaissance soil map of Zambia.

A sketch map of the area to be surveyed is attached. This is to certify that the team is engaged on legitimate GRZ duties, and to request that they be given all necessary assistance.

(signed)

A.N.Y. BODY
PROVINCIAL AGRICULTURAL OFFICER

The distribution of this letter will vary according to local circumstances. Among others it should be sent to the Provincial Permanent Secretary, the District Governor, the District Secretary, the District Agricultural Officer, the Officer-in-Charge of the Police in the District, the Chief and the local councillor. It is wise to also send a copy to the Regional Commander of the Zambia National Defence Force, especially if there are any known restricted areas or instilations in or near the survey area.

3. Checking the site

A week or two before the start of the survey a day should be spent checking the camp site, and talking to local officials. Usually a visit is made to the District Governor or District Secretary, the District Agricultural Officer, the Police, and the Chief in the area. The local councillor may also be included. You should carry copies of the letter of authority. It is on this visit that the Chief or councillor should direct you to a suitable village. The headman should then be found and the exact location of the camp site finalised.

4. Making the camp

If you intend to camp for more than a few days, it is well worth making the camp comfortable. Try to ensure that each member of the team has his own tent, although this is not always possible. Ensure that everybody has either a camp bed, or a matteress, or preferably both. Everybody should also have his own chair.

Pit latrines should be deep, and sited as far from the tents as possible. This will reduce the number of flys encountered. A communal meeting house can be constructed. This is a shady place to sit when it is hot, and a shelter during the rains.

All teams should have camp baths issued. However, a hot shower is much more pleasant after a day in the bush.

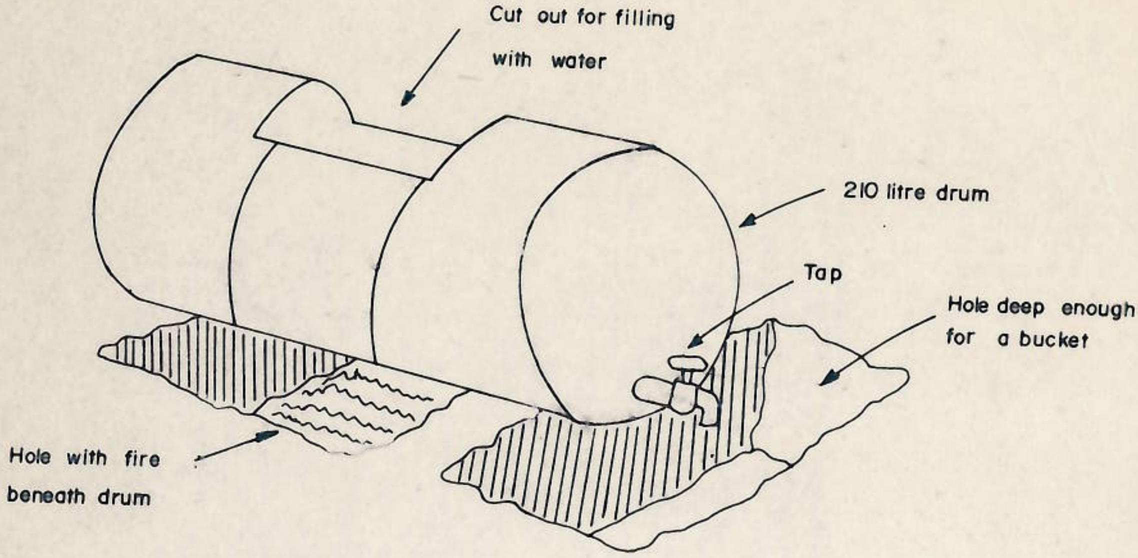
The illustrations show how to make a hot water boiler, and a shower unit in camp (see Fig.15-1).

The camp should be under trees for shade. Termites (White ants) should be avoided - they eat the tents! The camp should not be very close to a dambo. If it is, it will be cold during the winter, and there will be more mosquitoes. During the rains it is wise to dig small trenches uphill of each tent to divert flood water around the tents.

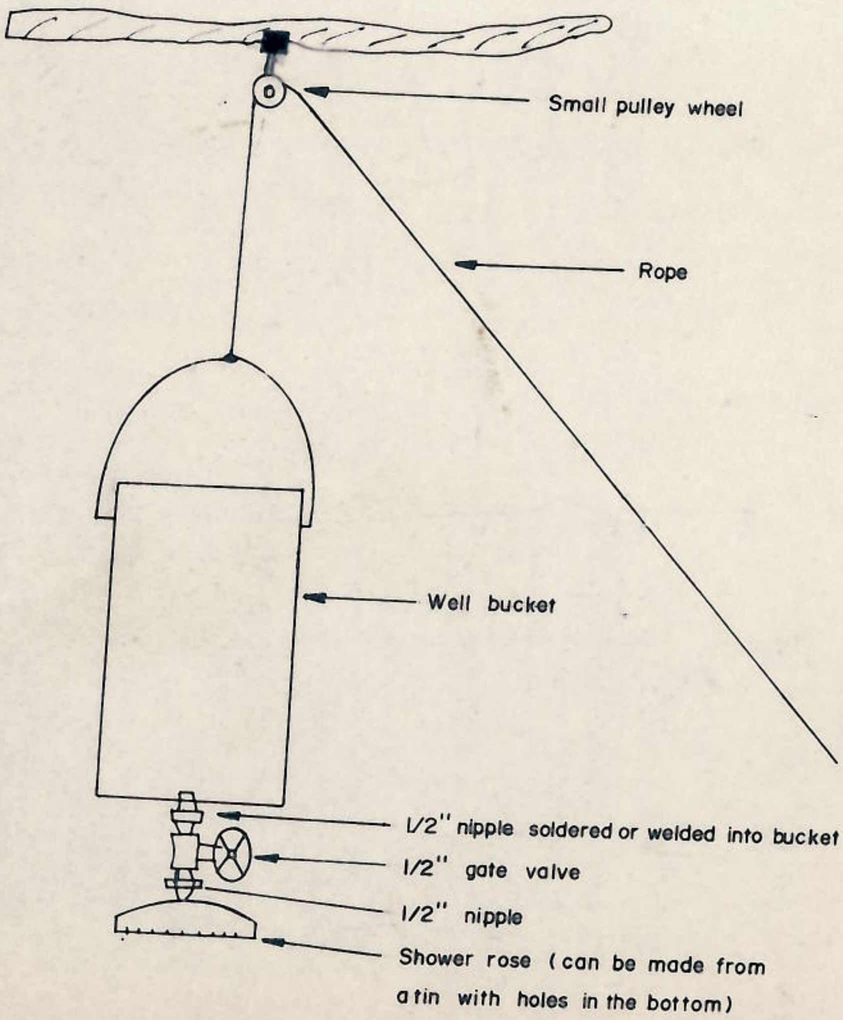
A camp watchman should be employed, preferably from your Provincial Office. It is not usually necessary for him to watch at night, but it is necessary for him to remain in camp at all times when nobody else is there (e.g. when the team is surveying). It should be made clear to him that his duties include carrying water, collecting firewood, and having hot baths or showers ready for the team on return from the bush. Other duties can be negotiated individually.

Finally, if you can get hold of an old vehicle battery, and the means to charge it, you can rig up a light near the camp fire to sit under at night (or in your tent). A 21 watt vehicle indicator (flasher) bulb gives a good bright light.

HOT WATER GEYSER



BUSH SHOWER



CHAPTER 16

THE LAND CAPABILITY CODE

Soil and land characteristics that are observed in the field, have to be recorded in your field notebook. These observations are then used to classify the land into a land capability class.

If we tried to write a description of every site, using normal English, we would waste a lot of time, become very frustrated, and rapidly fill many notebooks. A short-hand in the form of a code has thus been developed for field recording. It consists of a line, on top of which, by a series of numbers and letters, are represented four soil and land characteristics, and below which are represented another four. The arrangement is as follows:-

Effective Depth	Texture	Hindrance to cultivation	Limiting material
Slope	Erosion	Wetness	Colour

As an example, the full description of a soil may have been described thus:

"Moderately deep with an effective depth of between 60 and 90cm. The texture of the layer between the surface and 20cm is sand. The texture of the layer between 20cm and 40cm is loamy sand. The texture of the layer between 40cm and 60cm is sandy loam. The texture of the layer below 60cm is sandy clay loam. Gravel on the surface is a hindrance to cultivation and gravel in the subsoil forms a limiting layer. The slope of the land is between 1% and 3% and there is slight erosion. The soil is moderately well drained with a subsoil colour of dark yellowish brown".

That same description may be written in your field notebook thus:

2 A Y B C $_g$ Z

A E_1W_1(10YR4/4)

The symbols for each soil or land characteristic are arranged as shown above, so that they may be read off as shown below:-

2 AXB Cg1 Z

- Effective Depth
- Texture of Layer between surface and 20cm.
- Texture of layer between 20cm and 40cm.
- Texture of layer between 40cm and 60cm.
- Texture of layer between 60cm and 90cm.
- Hindrance to cultivation
- Limiting Material

A EI WI (10YR4/4

- Colour of subsoil
- Wetness
- Erosion
- Slope

Each of these characteristics will now be dealt with in turn.

EFFECTIVE DEPTH

The effective depth is the thickness of soil available for satisfactory plant root development (which is different for different crops). It is therefore the depth at which hard rock, hard laterite, a hardpan, a water table, or other soil conditions are met which impede root development. 90cm or more is regarded as sufficient for the normal choice of crops. Thus only when such a layer is met within 90cm from the ground surface is it regarded as limiting for the crops considered in the Land Use classification system.

However, for some crops or forms of Land Use (tree crop, irrigation, etc.), a deeper soil may be required. Therefore, if a limiting layer is found between 90cm and 120cm, its presence should be recorded in your field note-book.

The symbols used in the land use code to indicate the effective depth are as follows:-

Code symbol	Depth of limiting layer	Name of depth class
1.	More than 90cm.	Deep
2.	60cm - 90cm.	Moderately deep
3.	30cm - 60cm.	Moderately shallow.
4.	Less than 30cm.	Shallow.
5.	Rocks, stones or gravel at surface.	-

If gravel is encountered, however, an allowance has to be made for the fact that plant roots are able to penetrate into the gravel layer, although their movement will be restricted. In gravelly soils, therefore, the effective depth is calculated as follows:-

a. If a gravel layer is encountered closer to the surface than 30cm, and if the auger enters the gravel layer easily, the effective depth is depth class 5.

b. If a gravel layer is encountered closer to the surface than 30cm, and if the auger cannot enter the gravel layer easily, the effective depth is depth class 4.

c. If a gravel layer is encountered below 30cm, and if the soil material above the gravel layer is sand (A) or loamy sand (Y), the effective depth is taken as the augering depth to the gravel.

d. If a gravel layer is encountered below 30cm and if solid rock or laterite sheet is encountered within the gravel layer above 90cm, the effective depth is the augering depth.

e. If a gravel layer is encountered below 30cm, and if the soil material above the gravel layer is sandy loam (B) or heavier, and if the auger enters the gravel layer easily, the effective depth is the augering depth plus 30cm.

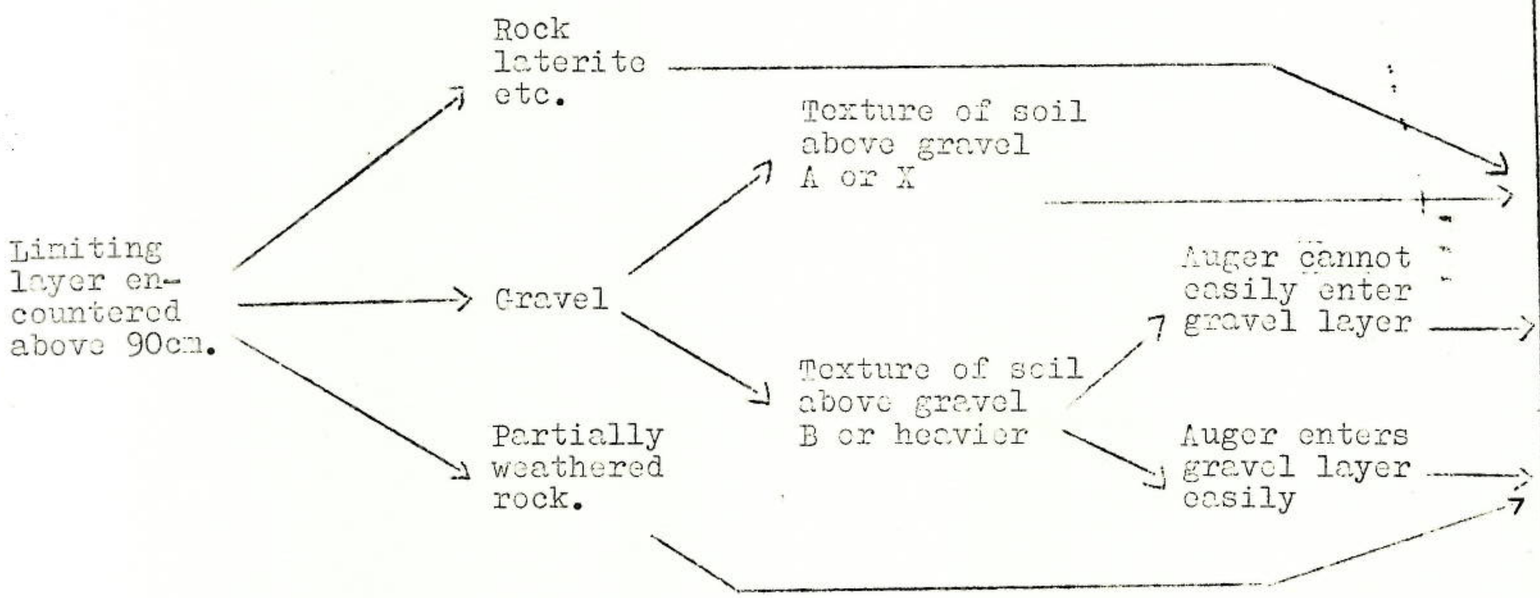
f. If a gravel layer is encountered below 30cm, and if the soil material above the gravel layer is sandy loam (B) or heavier, and if the auger cannot enter the gravel layer easily, the effective depth is the augering depth plus 10cm.

g. If partially weathered rock is encountered above 30cm, the effective depth is depth class 3.

h. If partially weathered rock is encountered below 30cm, the effective depth is the augering depth plus 30cm.

The above conditions are summarised on the flow chart.

FLOW CHART SHOWING EFFECTIVE DEPTH CLASSES



Augering depth to limiting layer (cm).		
0-30	30-60	60-90
4	3	2
4	3-2 *	2-1 *
3	2	1

* Effective depth = augering depth + 10cm.

Many beginers believe that 90cm is far too deep for most plants, and that a shallow or moderately shallow soil is quite sufficient for good plant growth. There are two reasons why this is not so. The plant roots consist of thick roots that anchor the plant, and fine hair roots that absorb water and nutrients from the soil. These hair roots are almost invisible and if you pull up a plant, they break off in the soil and are never seen. On many plants these go far deeper than the main roots. Secondly, the soil beneath the rooting depth is an important storage space for water and nutrients, that can be brought up to the rooting depth by capillary action.

Soil is a mixture of rock and mineral particles of different sizes and organic matter. These particles have been named according to their size.

Sand	2.0mm	-	0.05mm diameter
Silt	0.05mm	-	0.002mm diameter
Clay	less than	-	0.002mm diameter

The texture of a soil is the relative proportions of sand, silt and clay. It is the most important single characteristic of a soil. Many other soil characteristics depend on the texture because the texture determines the amount of surface area present on which reactions can occur, and the size and volume of spaces in which water and air can move.

In the field the texture is estimated by taking a hand full of the soil, and adding water until it is sufficiently moist to be completely friable (crushed easily in the hand), but not dripping wet.

The moist soil mass is then worked in the hand, and with experience the texture class can be determined with surprising accuracy.

There are 13 texture classes as follows:-

A - Sand
X - Loamy sand
B - Sandy loam
C - Sandy clay loam
D - Clay loam
E - Sandy clay
F - Clay
G - Cracking clay
I - Silty clay
J - Silty clay loam
K - Silty loam
L - Loam
S - Silt

Only the first 8 texture classes are common in the plateau soils of Zambia. As the texture classes are made up of different overlapping proportions of three different components, the definitions of the classes are rather complicated. Below is a table of the 8 texture classes commonly found in Zambia, with a rough description of their composition. However, it is much easier to refer to the "texture triangle" (see Fig.16-1).

Code Symbol	Name	Approximate Composition
A	Sand	> 85% sand < 10% clay
X	Loamy sand	70 - 90% sand < 15% clay
B	Sandy loam	> 50% sand < 20% clay
C	Sandy clay loam	> 45% sand < 28% silt 20 - 35% clay
D	Clay loam	20 - 45% sand 27 - 40% clay
E	Sandy clay	> 45% sand > 35% clay
F	Clay	< 45% sand < 40% silt > 40% clay
G	Cracking clay	as above

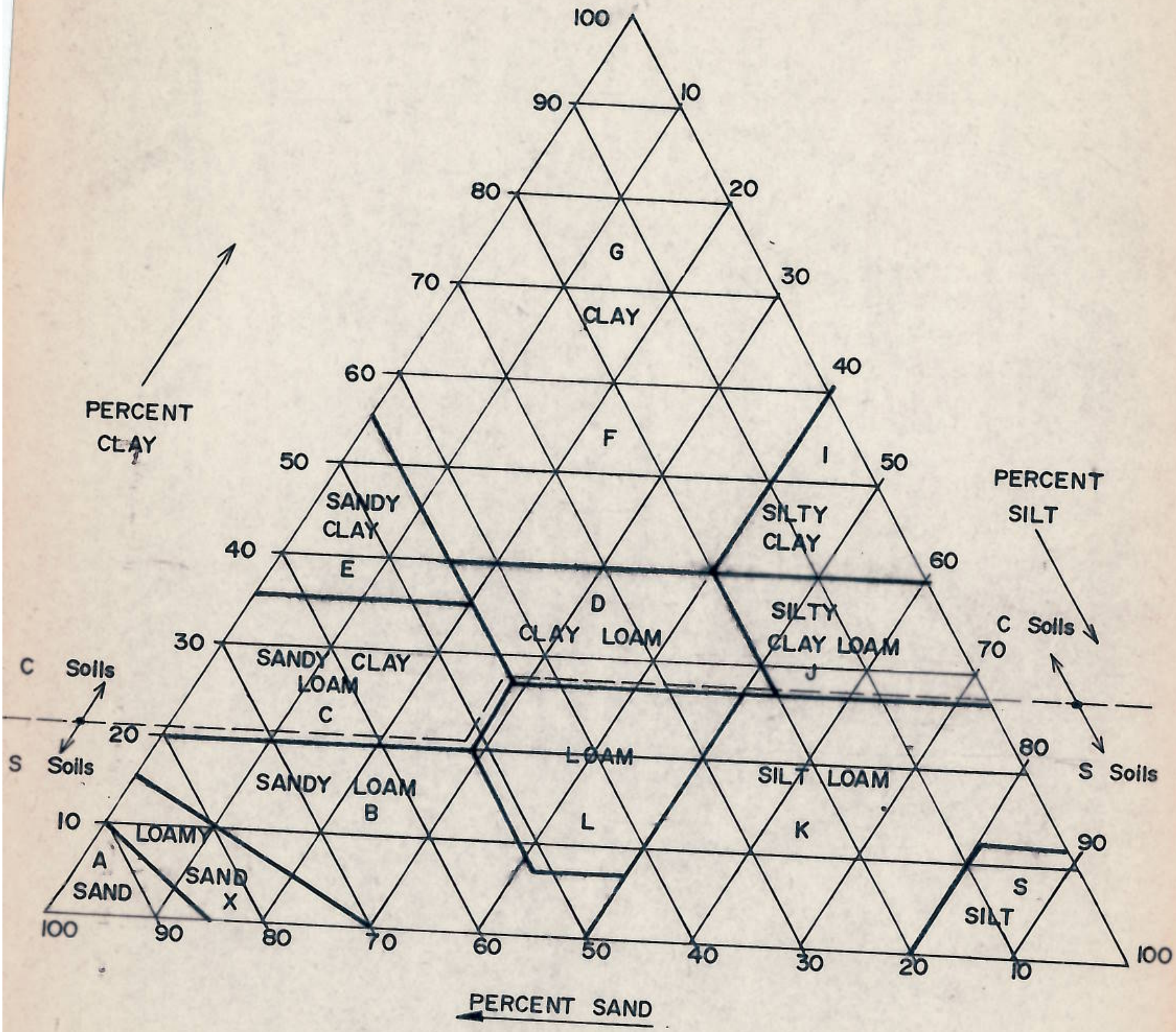
The following tests are a guide to the texture classes. However, only experience can really teach you the classes. Practice with the "Field Texture Kits" which have samples of each class is recommended at frequent intervals.

A - Sand:- Noncohesive. The soil particles do not stick together or only do so to a slight degree. Does not form a "rats tail". It may just be possible to make a ball but the ball will collapse very easily.

X - Loamy sand:- Very slightly cohesive. A "rats tail" may be formed, but will not bend without breaking and cannot support its own weight.

N/B. Organic matter and fine roots may interfere with the testing of these two texture classes.

B - Sandy loam:- Slightly cohesive. May be slightly sticky and plastic. Forms a stable ball. A "rats tail" of pencil thickness will hold its own weight. The "rats tail" can be bent but breaks before a U - shape is reached.



"Texture Triangle" showing the percentages of clay(0·002mm & less), silt(0·002 - 0·05mm), and sand (0·05-2·0mm) in the basic textural classes·

C - Sandy clay loam:- Sticky and plastic, with sand easily felt in the wet mass. A "rats tail" can be bent beyond a U - shape but breaks before a full Circle is reached.

D - Clay loam:- This texture class has a very soft and smooth feeling in the hand because of the high silt content. It has a "soapy" feel. The "rats tail" behaves the same as with sandy clay loam; breaking before a full circle is reached.

E - Sandy clay:- Sticky and plastic. The moist soil is quite hard to work in the hand, and sand can easily be felt in the wet mass. A "rats tail" just cracks when a full circle is formed.

F - Clay:- Sticky and very plastic. Hard to work in the hand No or very little sand can be felt. A "rats tail" forms a ring without cracking.

G - Cracking clay:- Clay (sometimes with a clay loam topsoil) which shows cracks on the surface more than 1cm wide and extending atleast to 50cm depth. Do not confuse this with smaller cracks formed in many soils after water has been standing on the surface.

The above "rules" are really only guides. A soil containing coarse sand may be mistakenly downgraded. Fine sand in the soil can lead to a sandy clay loam being mistaken for a clay loam, or even a clay. Only field experience and checking your estimation against the field texture kits can lead to accurate texture determination.

In the land capability code, four textures are determined and recorded. These, in order, are as follows:-

1. Texture of the layer from the surface to 20cm. This is the texture of the first two cans augered.

2. Texture of the layer between 20cm and 40cm. This is the texture of a mixture from the third and fourth cans.

3. Texture of the layer between 40cm and 60cm. This is the texture of a mixture from the fifth and sixth cans.

4. Texture of the bottom 30cm (the last 3 cans).

HINDRANCE TO CULTIVATION

Where gravel, stones, boulders, or rock outcrops occur at or within 20cm. of the soil surface and are sufficient to hinder or prevent cultivation of the soil, they are indicated by the following symbols placed after the soil texture symbols in the code. A symbol is also given to termite mounds sufficiently large and compact to interfere with cultivation.

g - gravels, stones or patches of gravel or stones

m - termite mounds.

r - rock or laterite outcrops, including loose rock fragments and boulders.

The coverage is indicated by a number following the letter, as follows:-

Code symbol	Hindrance	Coverage
-	None	Less than 1%
g1	Gravel or stones	1 - 5%
g2	" "	5 - 10%
g3	" "	More than 10%
m_1	Termite mounds	1 - 5%
m_2	" "	5 - 10%
m_3	" "	More than 10%
r_1	Rock/laterite outcrops	1 - 5%
r_2	" "	5 - 10%
r_3	" "	More than 10%

Gravel includes quartz or other rock fragments and concretions between 2mm and 75mm in diameter. Stones are fragments 75mm - 250mm in diameter. Boulders are more than 250mm in diameter. Large outcrops of rocks or laterite are indicated by a seperate mapping unit or a symbol on the map.

LIMITING MATERIAL

The nature of the material limiting effective soil depth is indicated by the following symbols:

H - Hardpan. This is a layer of compact soil, usually found in the subsoil of solonetzic (sodium affected) soils. The layer is dense and hard, both when dry and wet. It is not merely a subsoil layer which is very hard when dry but which would become soft or friable when moist; nor is it a densely packed gravel or concretionary layer, which is indicated by another symbol.

P A R T F I V E

LAND CAPABILITY SURVEYING.

L - Laterite. This includes sheet laterite (ironpan) or densely-packed ironstone concretions sufficiently hard or compact to restrict root development or seriously reduce moisture-holding capacity.

R - Weathered rock or rock. Weathered or partially decomposed rock sufficiently dense to restrict root development or with sufficiently little weathered rock present to restrict moisture-holding capacity as well as hard rocks.

Z - Gravel or stones, usually of quartz.

If two kinds of limiting material occur within the soil profile down to 120cm, the symbol for the most limiting material will be given. A water-table is not recorded as a limiting factor in the upper line of the code. This information is provided in the symbol for wetness given in the lower line of the code.

All of the soil and land characteristics considered so far, are recorded above the line of the code, in the order given. Those that follow are recorded below the line of the code.

SLOPE

The slope of the land surrounding the sampling point, or the average slope within the mapping unit, is measured using an Abney level. Slopes are recorded as percentage slopes.

Since the Abney level reads in degrees and minutes, the reading must be converted to percentage slope using the table below:-

Code symbol	Percentage slope	Degrees and minutes
O	< 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

The existence of active erosion is an indication of the risk of further erosion occuring when the land is under cultivation. Therefore any evidence of erosion taking place at or near an augering site should be recorded.

Visible evidence of soil erosion in the vicinity of the sampling point, or within the mapping unit, is therefore recorded in the code. The symbols used are as follows:-

--	No apparent erosion
E1 -	Slight erosion. Slight loss of topsoil by sheet erosion
E2 -	Moderate erosion. Loss of topsoil by sheet erosion or light gullies at very wide intervals not sufficient to interfere with cultivation on a normal field scale.
E3 -	Severe or very severe loss of topsoil by sheet erosion, exposing the subsoil; or presence of many small and or/large gullies sufficient to hinder or prevent normal cultivation.

Sheet erosion is recognised by the following signs:

a) Small heaps of soil around tree trunks.
b) Grass tussocks standing on little mounds of soil a few centimetres high.
c) Stones or gravel particles standing on little mounds of soil above the ground level.
d) Streaks of sand separated out from the topsoil (see Fig.16-2).

Rills and gullies are obvious and easily recognised.

COLOUR

Although written in the code after the wetness symbol, the soil colour will be considered first here, because the determination of the wetness factor depends to a large extent on the soil colour.

Colour is the most obvious and easily determined of soil characteristics. Although it has little direct influence on the functioning of the soil, one may infer a great deal about a soil from its colour, if it is considered in combination with other observable features.

The red colour of soil is usually related to iron oxides, which are relatively unstable under moist conditions. Thus a red colour usually indicates good drainage and good aeration. Strongly red soils are often found on convex slopes underlain by pervious rocks. However, some red soils owe their colour to inheritance from the parent material, and not to soil forming processes.

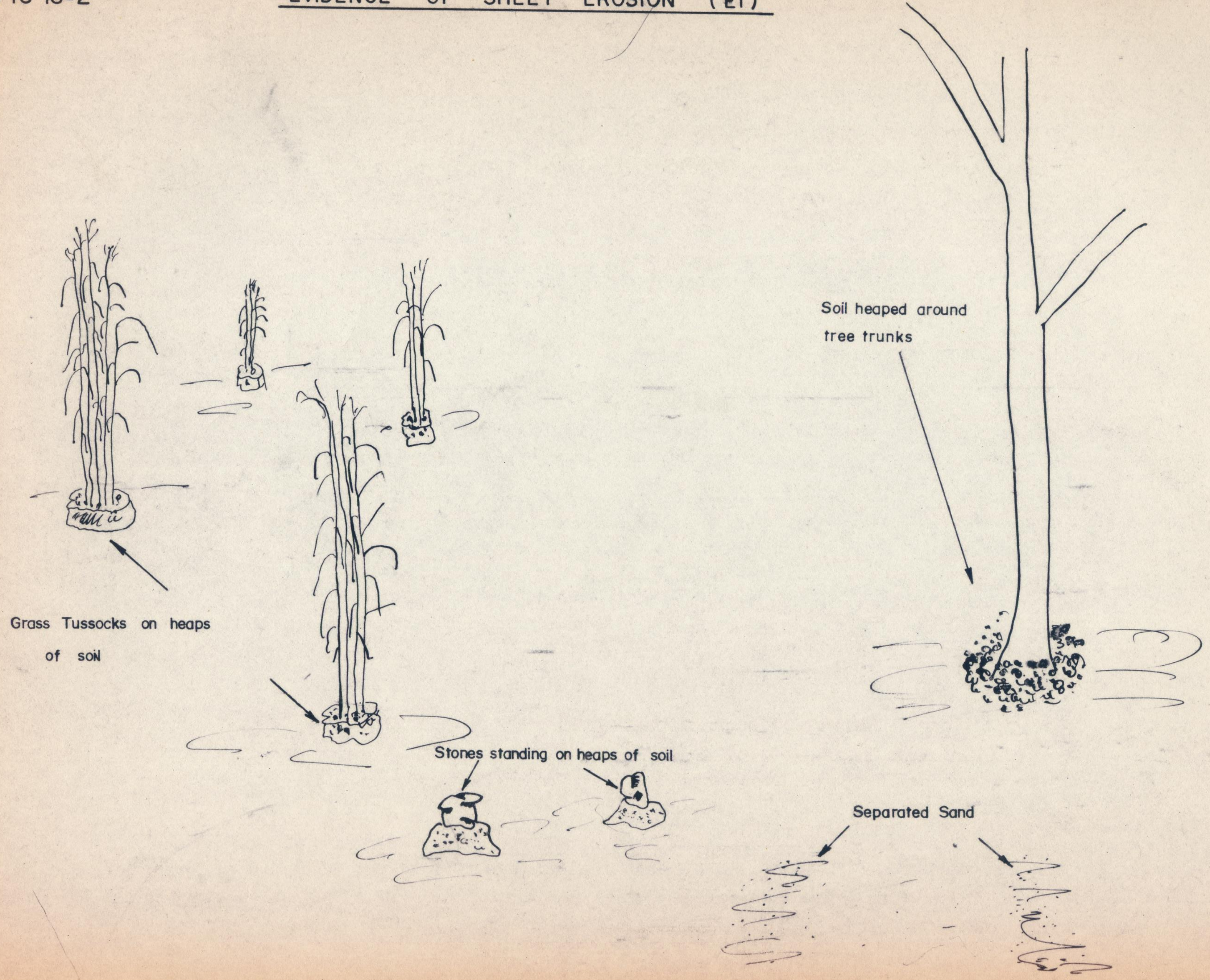
The yellow colour in soils is also largely due to iron oxides. Yellow colours in the deeper horizons usually indicate a somewhat more poorly drained soil than do red colours. Where associated red and yellow soils are developed from the same kind of parent material, the yellow soils commonly occupy the less convex and more moist sites.

Well-drained yellowish sands owe their colour to the fact that small amounts of organic matter or iron oxides are mixed with large amounts of nearly white sand.

Grey and whitish colours of soils are caused by several substances, mainly quartz, some types of clay minerals, and reduced iron compounds. A grey colour frequently indicates poor drainage.

FIG 16-2

EVIDENCE OF SHEET EROSION (E1)



Imperfectly and poorly drained soils are nearly always mottled with various shades of grey, brown and yellow, especially within the zone of fluctuation of the water table.

Soil colour with the drainage characteristics vary markedly in most Zambian plateau soils. This is the most obvious change as one follows a catena from a dambo to a ridge.

Soil colour is measured by comparison with a chart. The one generally used is the Munsell colour chart. It consists of some 175 different coloured papers (or "chips"), systematically arranged, according to their Munsell notations, on cards carried in a loose-leaf book. The arrangement is by hue, value, and chroma-the three simple variables that combine to give all colours. Hue is the dominant basic colour. Value refers to the relative lightness of the colour. Chroma is the relative purity or strength of the colour.

In the soil colour chart, all colours on a given card are of a constant hue, designated by the symbol in the upper right hand corner of the card. Vertically, the colours become successively lighter, i.e. their value increases. Horizontally they become less grey from left to right i.e. their chroma increases.

The Munsell charts thus give a numerical notation for each colour. The symbol for hue is the letter abbreviation of the colour of the rainbow (R for red, YR yellow red, Y for yellow), preceded by numbers. Within each letter range, the hue becomes more yellow and less red as the numbers increase. The middle of the letter range is at 5; the zero point coincides with 10 point of the next redder hue.

The notation for value consists of numbers from 0, for absolute black, to 10 for absolute white.

The notation for chroma consists of numbers beginning at 0 for neutral grey, and increasing as the greyness decreases.

In writing the Munsell notation, the order is hue, value, chroma. The value and chroma are written as a fraction with the value figure on top and the chroma figure below:

5YR5/8 ---- 8 = Chroma

|......... 5 = Value

|......... 5YR = Hue

In the land capability code, the colour is written in brackets, after the wetness classification, thus: (5YR 5/8)

Soil colour names are also given on the charts, and if a name is to be used then only the correct name given should be used. Never make up your own names.

To measure the soil colour in the field, a piece of soil is taken from approximately 50cm depth, or from just above the limiting layer where this is between 20 - 50cm. The sample is broken to expose a clean, untouched face, moistened (but not made wet), and the colour is determined from the soil colour chart. Rarely will the colour of the sample be perfectly matched by any colour in the chart. The probability of having a perfect matching of the sample colour is less than one in one hundred. It should be obvious, however, which colours the sample lies between, and which is the closest match.

If the sample is mottled, the greyest or palest soil colour present should be recorded, but the other dominant colour should also be recorded in the remarks column of your field notebook.

WETNESS

The determination of the wetness (or drainage) factor of a soil is one of the most important, yet most difficult, operations in land capability surveying. If, after a rainstorm, the soil drains freely, then even if the soil pores have been temporarily full of water, the soil will rapidly return to "field capacity". A soil is said to be at field capacity when all the water free to drain under gravity has drained away leaving the capillary water stored in the soil for plant use. At field capacity the large pores are full of air, which is vital for proper root development, whilst the smaller pores are full of water.

If, however, a soil does not drain freely after a rainstorm, it will remain waterlogged for an extended period. This waterlogging is not necessarily seen as standing surface water. Any prolonged accumulation of water in the rooting region is also waterlogging. The waterlogging may either to due to the slow downward percolation of water from the surface, or to a temporary rise in the ground water table.

The effect of waterlogging on the plant is to restrict the supply of air to the roots. This stunts plant growth, and if severe and prolonged will prevent the growth of most plants altogether. A soil that suffers from waterlogging during the growing season must therefore be downgraded in the land capability classification.

The problem is that we do most of our soil surveying in the dry season, when almost all soils are dry. The degree of wetness or the height of the water table during the wet season (the growing season) must therefore be infered from other soil characteristics. The characteristics that provide clues to the soils drainage properties are the colour of the subsoil, the presence of and depth of mottling, the occurence of rusty root channels, the vegetation, the physiographic position, and occasionally the texture and the parent material.

When inspecting a pit or auger core, there are some general soil colour features that should be studied carefully. Well drained soils usually have matrix colours of red to strong brown. Poorly drained soils have an overall grey, dark grey or olive grey apparance. In addition, the presence of mottles usually indicates wetness, and the depth of mottling indicates the degree of wetness. Red mottles are often formed in the capillary fringe (zone above the ground water table, with almost full satturation due to the capillary rise of the water).

Mottling is caused by the alternate wetting and drying of a soil. In most of Zambia the potential evaporation of water from the soil in a year exceeds the rainfall. This means that the soil is subjected to alternate wetting and drying regimes. Poor drainage and the accompanying low oxygen content in a soil leads to reducing conditions. The result is that iron and manganese occur in the reduced state, and the compounds formed give the characteristic grey and bluish colour. Good drainage leads to good aeration with consequent oxidising conditions. The oxidised iron and manganese compounds are yellow, red or brown in colour.

If conditions are part oxidising and part reducing, due to fluctuating water content or water table, some of the iron will be oxidised and compounds with yellow brown, and red colour will be formed. Quite commonly, under such conditions, part of the matrix is reduced and part oxidised, and the characteristic colours are mixed. This is mottling.

If the overall conditions are reducing (water logged), with occasional oxidising conditions, there will be red or brown mottles in a grey matrix. If the overall conditions are oxidising (more freely draining), with occasional water-logging, there will be grey mottles in a yellow or brown matrix.

Care must be taken to recognise relic mottle. These are mottles caused by a previous wet regime, still remaining although the soils drainage characteristics have changed. Other soil and land features such as colour and vegetation can give clue here.

Colour chromas (the last number in the colour notation) provides help in determining the wetness. In leached sandy soils, especially in the high rainfall areas, pale colours when accompanied by low chromas, indicate wetness. Chromas below 4 in 5YR or redder soils are not an indication of wetness.

The following symbols are used in the code to indicate wetness charateristics:

Code symbol	LUB Class	Description
-	No wetness	The soil is well to vely well drained. Water is removed sufficiently quickly from the soil surface and rooting zone that plant growth is not restricted by water-logging.

W1	Slight wetness	The soil is moderately well drained. It is wet for short periods following heavy rainfall, or the water table rises to between 60-90cm from the ground surface during the rainy season. Drainage is sufficiently impeded to prevent the cultivation of deep-rooting crops or crops particularly sensitive to wetness (e.g. cotton, virginia tobacco, some vegetables).
W2	Moderate wetness	The soil is imperfectly drained. It is wet for considerable periods during the growing season. Conditions are too wet for normal dry land crops unless these are cultivated on high ridges or beds, or unless artificial drainage is provided.
W3	Severe wetness	The soil is poorly to very poorly drained; i.e. it is wet for most or all of the growing season, preventing the cultivation of dry - land crops (without artificial drainage). Cultivation of rice, and dry season grazing may be possible.

The diagnostic features of the wetness class are given in the tables, which may be read as a key. The diagnostic features are listed along the top of the table. By selecting the observed features, reading from left to right, the choices are progressively narrowed down until the drainage class is determined. This table has been found to be effective in most parts of Zambia except Western Province where it is not applicable.

WETNESS CLASSIFICATION TABLE

N/S = Not Significant.

MUNSELL COLOUR AT 50cm.		DEPTH OF MOTTLES	RUSTY ROOT CHANNELS	POSITION AND VEGETATION	SUBSOIL TEXTURE	OTHER CHARACTERISTICS	WETNESS CLASS
HUE	CHROMA						
10R 2.5YR 5YR	N/S	N/S	N/S	N/S	N/S	N/S	–
7.5YR	4 or more	None	N/S	N/S	N/S	N/S	–
		0–90cm	N/S	N/S	N/S	Weathered rock at depth	–
						No weathered rock at depth	W_1
	3 or less	N/S	N/S	N/S	N/S	N/S	W_1
10YR	4 or more	None	N/S	Crest or upper slope	N/S	When colour suspected due to parent mat.	–
						When colour suspected from wetness	W_1
				Mid or lower slope	A or X	e.g. Barotse sands	–
					B and heavier	N/S	W_1
		60–90cm	N/S	N/S	N/S	N/S	W_1
		0–60cm	None	Upland veg. lower slope	N/S	N/S	W_2
				Dambo	N/S	N/S	W_3
			In top 20cm.	N/S	N/S	N/S	W_3
	3 or less	N/S	None	Upland veg. lower slope	N/S	N/S	W_2
				Dambo	N/S	N/S	W_3
			In top 20cm.	N/S	N/S	N/S	W_3

MUNSELL COLOUR AT 50cm. HUE	CHROMA	DEPTH OF MOTTLES	RUSTY ROOT CHANNELS	POSITION AND VEGETATION	SUBSOIL TEXTURE	OTHER CHARACTERISTICS	WETNESS CLASS
2.5Y	4 or more	None	N/S	N/S	A or X	e.g. Barotse sands	–
					B and heavier	N/S	W_1
		60–90cm	N/S	N/S	N/S	N/S	W_1
		0–60cm	None	Upland veg. lower slope	N/S	N/S	W_2
				Dambo	N/S	N/S	W_3
			In top 20cm.	N/S	N/S	N/S	W_3
	3 or less	N/S	None	Upland veg. lower slope	N/S	N/S	W_2
				Dambo	N/S	N/S	W_3
			In top 20cm.	N/S	N/S	N/S	W_3
5Y N/–	3 or more	None or below 30cm.	None	Upland veg. lower slope	N/S	N/S	W_2
				Dambo	N/S	N/S	W_3
			In top 20cm.	N/S	N/S	N/S	W_3
		0–30cm	N/S	N/S	N/S	N/S	W_3
	2 or less	N/S	None	Upland veg. lower slope	N/S	N/S	W_2
				Dambo	N/S	N/S	W_3
			In top 20cm.	N/S	N/S	N/S	W_3

CHAPTER 17

RECORDING

However much hard work you do in the field, it is all useless unless your results are properly recorded in your field notebook.

On the first page of the book, the following information should be recorded:-

1. Survey Title
2. Description of the boundaries/Farm number
3. Date of the survey
4. Surveyors name
5. Air photograph references
6. 1:50,000 sheet numbers
7. Grid north to magnetic north declination
8. Area (hectares) and level of survey.

It is also a good plan to have an abbreviated copy of the land capability code in the front of your notebook. The number of paces you take per 100 metres should also be recorded.

At the top of each page, the following information should be recorded:-

1. Traverse number
2. Traverse bearing
3. Map reference and description of location of starting beacon
4. Description of finishing point
5. Date

For each change in bearing, start a new page. For each new traverse, start a new page.

For each auger site the following information should be recorded:- Number; Distance; Land Capability code; Classification; Remarks.

The pit number consists of the traverse number followed by the number of the pit along the traverse. Thus 6-12 means pit number 12 along traverse number 6.

The distance is the cumulative distance from the beacon. At each change in bearing you start recording from zero again.

The land capability code has been described in full already.

The classification can be either decided upon in the field or filled in later in the office. With experience it is possible to classify each soil on the spot, and this is the course recommended.

The remarks column is probably the most important, yet the most neglected. In it you should record the presence of, and distance along the traverse of, outcrops, gravel, slope breaks, vegetation changes, soil colour changes, streams, gullies, physiographic position (crest, mid slope, lower slope etc.) mottle colours, gravel percentage, nearby features such as hills, dambo heads, etc, footpaths and roads crossed, cut lines, villages, frequency of outcrops or anthills, and any other observable features. It cannot be stressed strongly enough that the remarks column is vital and must be used.

The first two pages of a typical field notebook should thus appear as follows:-

<table>
<tr>
<td>PAGE 1

Mutambalika survey, Serenje District.
Area bounded by GNR, Chabatalala r, Mulembo r, and Makolongo r.

August 1978

Surveyor: A,N,Other.

Air Photo Ref: Serenje 1977, Nos. 51-56

1:50,000 sheet No.1330A2

Mag to grid declination: 6°30' West

450 hectares approx.

Semi-detailed survey.</td>
<td>PAGE 2

TR 1
94° mag from corner on GNR, map ref.178512 sheet 1330A2 to Mumba village.

1-1 0m 1 X B C C — / AE_1 - (5YR $\frac{5}{8}$) S2e crest

1-2 300m 1 B C C C — / A — (5YR $\frac{5}{8}$) S1

420m footpath

1-3 600m 2 X B C — R / AE_1 - (7.5YR $\frac{5}{8}$) S2de

1-4 740m 2 X B C — R / AE_1 - (7.5YR $\frac{5}{8}$) S2de slope break

1-5 900m 1 B C C D — / A-W_1 (10YR $\frac{5}{8}$) S2w lower slope</td>
</tr>
</table>

An alternative to using a field notebook is the use of proforma sheets. A proforma sheet for land capability surveys is shown overleaf. One sheet is used for every five augering sites, so that you must carry 10 or 12 sheets with you each day, depending on how long your traverse is. The blank spaces on the sheet (e.g. pit number, distance along traverse, etc) are filled in as appropriate. Where symbols are given, the appropriate symbols are simply ringed. All the symbols are the standard symbols described in chapter 15.

The use of proforma sheets has two main advantages. Firstly, nothing can be forgotten, whereas with a note book it is easy to leave out one or two characteristics. Secondly, the proforma sheet can be filed back at the office for easy reference. Notebooks are easily lost, and one notebook may contain the results of several surveys, which are difficult to find later on.

The disadvantage of proforma sheets is that you have to carry a bulky clipboard and sheets with you in the field.

If you intend to use proforma sheets, the sheet shown overleaf can be typed onto a stencil in your provincial office, and duplicated.

LAND CAPABILITY SURVEY PROFORMA SHEET

SHEET NO: ....

SURVEYOR: .... SURVEY AREA: .... DATE: ....

TRAVERSE NO: .... BEARING: .... FROM: .... TO: ....

1. Pit number					
2. Distance along traverse	m	m	m	m	m
3. Texture 20cm	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.
40cm	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.
60cm	A, X, B, L C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.
90cm	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.	A, X, B, L, C, D, E, F, G.
4. Depth to limiting layer cm.					
5. Limiting material	H, L, R, Z.	H, L, R, Z.	H, L, R, Z.	H, L, R, Z.	H, L, R, Z.
6. Effective 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.
7. Hindrance to cultivation	-, g1, g2, g3.	-, g1, g2, g3.	-, g1, g2, g3.	-, g1, g2, g3.	-, g1, g2, g3.
	-, m1, m2, m3.	-, m1, m2, m3.	-, m1, m2, m3.	-, m1, m2, m3.	-, m1, m2, m3.
	-, r1, r2, r3.	-, r1, r2, r3.	-, r1, r2, r3.	-, r1, r2, r3.	-, r1, r2, r3.
8. Slope Abney reading					
Class	0, A, B, C, D, E.	0, A, B, C, D, E.	0, A, B, C, D, E.	0, A, B, C, D, E.	0, A, B, C, D, E.
9. Erosion class	0, E1, E2, E3.	0, E1, E2, E3.	0, E1, E2, E3.	0, E1, E2, E3.	0, E1, E2, E3.
10. Colour at 50cm.					
11. Mottling depth in cm.					
12. Wetness class	0, W1, W2, W3.	0, W1, W2, W3.	0, W1, W2, W3.	0, W1, W2, W3.	0, W1, W2, W3.
13. LUB code					
14. LUB class					
15. Remarks.					

CHAPTER 18

LAND CAPABILITY CLASSIFICATION

The LUB land classification system is designed to indicate the relative suitability of land for rainfed medium and large scale commercial farming. For arable land, maize, tobacco and to a lesser extent, soyabeans, sunflower and groundnuts are the main crops considered; use of ox or tractor cultivation, adequate use of fertilizers, pesticides and weed control measures are assumed, together with a high level of management or technical supervision, which will ensure that the land does not deteriorate under arable use. For non-arable land, it is assumed that grazing will be the major use, and that this will be practiced in such a way that the land does not deteriorate, whether under intensive or extensive grazing management.

It is stressed that the LUB system only takes into account the physical factors on the land, and that it only considers economic factors in very broad terms; no social factors are taken into consideration.

a. Types of land

There is a primary division into four types of land:-

1. Arable land
2. Marginal arable land.
3. Grazing land
4. Unsuitable land

A short description of each type of land follows below:-

1. Arable Land

It is suitable for intensive use on a sustained economic basis. The farmer is free to choose annual or semiperennial crops. The soils in this class have a certain degree of self control, which means they are buffered against changes in the environment like too little or too much rain. The highest long term production will be obtained under a suitable crop rotation.

2. Marginal Arable Land

It does not support a long term intensive use of the land for arable crops without great risk of poor yields in dry or wet years, limited freedom of choice of crops or management, or a high degree of environmental control. Introduction of ley (grass or grass legume) in the rotation is generally recommended. The net income over a period of years tends to be low.

3. Grazing Land

This class includes land that is not suitable for sustained arable cropping. It will however, support cattle under a suitable grazing policy.

4. Unsuitable land

This is land with too severe limitations for arable cropping or grazing. It may be suitable for wildlife, recreation, building sites or other non agricultural uses.

b. Land classes

Below the "type of land" level, only arable land and marginal arable land are subdivided into land classes. The IUR system distinguishes 3 clayey ('C') and 4 sandy ('S') land classes, according to certain site or soil limitations. The distinction between clayey ('C') and sandy('S') classes is a function of the topsoil texture.

'C' land classes have a topsoil texture of sandy clay loam or heavier.
'S' land classes have a topsoil texture of sandy loam or lighter.

A short description of each land class follows below:-

Classes C1,S1: Good arable land

Land capable of being maintained at a high level of productivity under an intensive cropping system. There are no special limitations, but good management should include normal soil conservation practices, adequate use of fertilizers and lime as well as a suitable crop rotation.

Classes C2,S2: Moderately good arable land

Land capable of being maintained at a high level of productivity under an intensive cropping system, but requiring special attention to soil conservation or crop management because of moderate limitations, or land capable of being maintained at only a moderate level of productivity due to limitations of depth, texture, wetness etc. Response to improvement in management is high.

Classes C3,S3: Poor arable land

Land with severe limitations for cultivation which either greatly increase the cost of production, or reduce yields to marginal levels, or severely restrict the range of crops than can be grown satisfactorily.

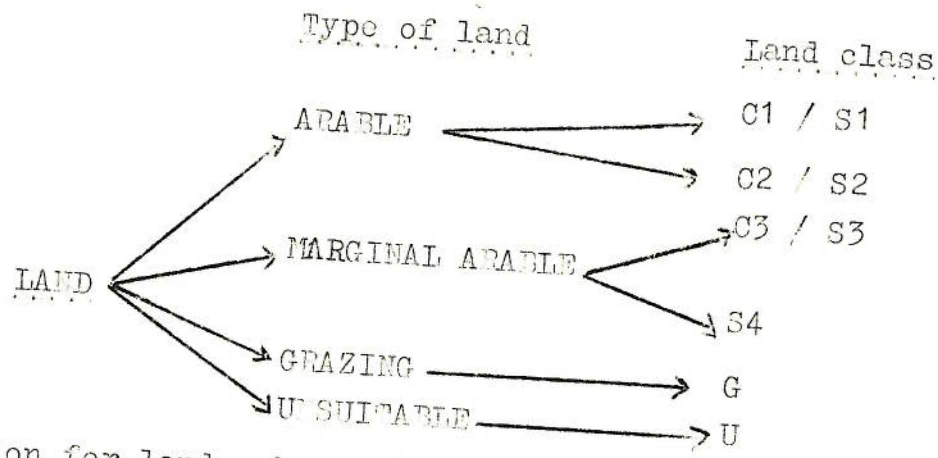
Class S4: Very poor arable land
(no C4)

This class is restricted to deep Barotse sands or other very deep sands occuring in moderate to high rainfall areas. These soils are easily cultivated but because of extremely low fertility and droughtiness, the range of crops that can successfully be grown is severly limited. It would be uneconomic to apply improvements to such soils which would make them suitable for medium or large scale commercial farming of general crops. This class has only one serious limitation; its texture. No other limitation can downgrade to S4.

c. Land subclasses

Further subdivision of land into subclasses is provided by including a symbol reflecting the kind of limitation. In cases with more than one limitation they are ranked according to their seriousness. As a rule not more than two symbols are given, even if there are more than two limitations. The only two land capability classes without limitation are C1 & S1.

Below is a summary of the LUB land capability classification system:-



Limitation for land sub-classes.

d - Depth to limiting layer.

e - erosion.

g - gravely or stoney topsoil
m - termite mounds
r - rock or laterite outcrops.
} - Hindrances to cultivation.

s - slope

t - texture

w - wetness

CRITERIA FOR DETERMINING ARABLE LAND CLASSES

The information recorded in the field notebook in the form of the LUB code is used to determine the land capability classification of the soil.

The 'C' or 'S' classification is determined by the topsoil texture.

Then, each of the items listed as limitations above are considered in turn. The tables that follow are used for this. Note that if a soil is downgraded, for example, to S2w and also to S2d, then the classification will be either S2wd or S2dw, depending on which limitation is considered the more serious. It is not downgraded two classes to S3 because of the two limitations. The class is that of the worst limitation.

The symbols g, m, and r refer to hindrances to cultivation. Thus, C2dr means a soil with an effective depth of between 60cm and 90cm, with scattered rock outcrops covering between 1% and 5% of the area. It DOES NOT mean an effective depth of 60cm to 90cm over a limiting material of rock.

CRITERIA FOR DETERMINING ARABLE CLASSES

DEPTH

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

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

HINDRANCE TO CULTIVATION

Hindrance to Cultivation	Class
-	S1/C1
m_1	S2m/C2m
m_2	S3m/C3m
m_3	Gm
r_1	S2r/C2r
r_2	S3r/C3r
r_3	Gr
g_1	S2g/C2g
g_2	S3g/C3g
g_3	Gg

EROSION

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

WETNESS

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

Texture: See separate table

N/B: Topsoil textures A,X,B,L,K,S. = "S" Soil e.g. S2d
Topsoil textures C,D,E,F,G,I,J = "C" Soil e.g. C2d

CRITERIA FOR DETERMINING ARABLE LAND CLASSES - SOIL TEXTURE

Texture 0 - 20cm	Texture 20-40cm	Texture 40-60cm	Texture 60-90cm	Class
A	A	A	A,X	S4t
			B +	S3t
		X +	A	S4t
			X +	S3t
	X +	A	A,X	S4t
			B +	S3t
		X	A	S4t
			X +	S3t
		B +	A,X	S3t
			B +	S2t
X,B,K,L	A	A	A,X	S4t
			B +	S3t
		X	A	S4t
			X +	S3t
		B +	B	S2t
			C +	S1
	X	A	A,X	S4t
			B +	S3t
		X	A	S4t
			X +	S3t
		B +	A,X	S3t
			B +	S2t
	B	A	A,X	S4t
			B +	S3t
		X	A	S4t
			X +	S3t
		B +	A,X	S3t
			B	S2t
			C +	S1
C,D,E,F,J,I	A,X	A	A,X,B	Gt
			C +	G3t
		X +	A	Gt
			X,B	C3t
			C +	C2t
	B	A	A,X,B	Gt
			C +	C3t
		X	A,X	Gt
			B +	C3t
		B +	A,X	C3t
			B +	C2t
	C +	A	A,	Gt
			B	C3t
			C +	C2t
		X	A	Gt
			X,B	C3t
			C +	C2t
		B	A,X	C3t
			B	C2t
			C +	C1
		C +	A,X	C2t
			B +	C1
G	G	Any	Any	C3t

N/B: With shallow soils take the best texture class possible for the group of classes available.

\+ means " and heavier", e.g. C + means " C and heavier".

CHAPTER 19

PLOTTING THE FIELD RESULTS

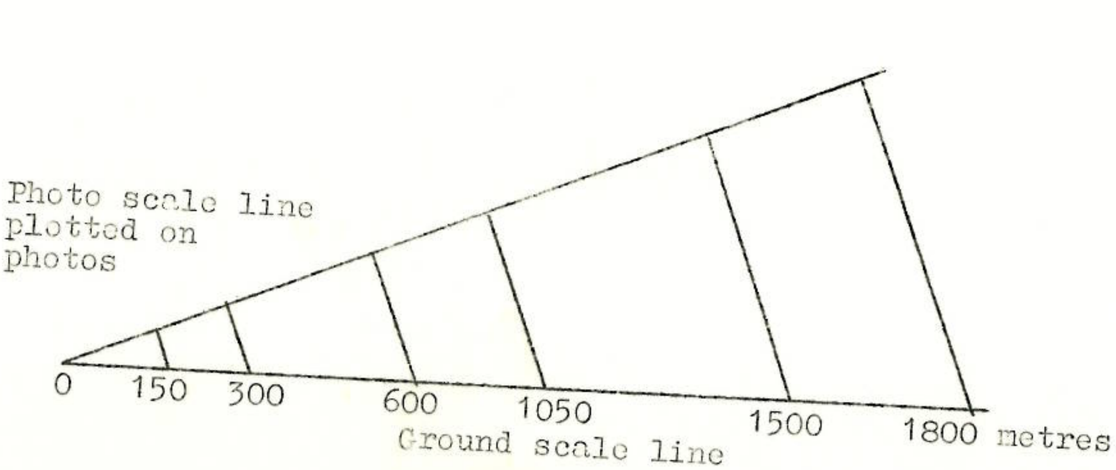
Having carried out a field survey, the information must be plotted to produce a map. You have already got your intended traverse lines drawn on alternate air photos from your traverse planning. Whilst in the field you will have noted your position at all times, so that if you deviated from the traverse line, you were aware of this, and marked your position on the photo. You will also have written in your field note book the position of all features such as villages, paths, roads, dambos etc. Armed with this information, you can now draw the correct line of your traverse on the photo, and mark along it the correct position of each augering point.

It is most important to realise that the distance you measure in the field will not always convert to the expected number of centimetres on the photo. The scale of the photo is not always constant (see section on built-in errors of air-photos), and your chain or cycleometer may have travelled over ant-hills or outcrops, around thickets and trees, and may therefore not give an exact straight line measurement.

When plotting the position of each pit, therefore, copios use must be made of the features noted in the remarks column of your field notebook. If a path was crossed, and this path is seen on the air photo, then the next pits will be measured from that known point (i.e. the path). If one pit was augered 50m before a village, then on the photo measure 50m back from the village.

Where there are long distances between recognisable features, the difference between the ground scale (the distances measured in the field plotted at the quoted photo scale) and the same distance measured on the photo, may be significant.

To overcome this difficulty, the information contained on the traverse line is first plotted on a piece of paper at ground scale. The length of the line on the photograph is then measured, and this distance is drawn on the same sheet as the ground scale, but at an angle to it. All the ground scale positions are plotted on the photo scale line by joining up the ends of the two scale lines, and then drawing a line from each ground scale point to the photo scale line, parallel to the end line.



The positions of the augering points at the photo scale can now be transferred to the photo. If the photo is fairly free of traverse lines, this operation can be carried out in chinagraph directly on the photo.

ANY ERROR IN PLOTTING WHERE AN AUGERING WAS CARRIED OUT MAY RENDER THE SURVEY USELESS.

If you cannot decide where a pit should be plotted, you must be prepared to return to the field to check your navigation. When, and only when, you are certain that each traverse and pit is properly plotted, you may prick through the photo with a pin, and write in ink on the back of the photo the pit number, traverse number, and the soil classification. This leaves a permanent record, and means that the front of the photo may be cleaned for future use by other officers.

The photographs and field notebook are now ready for the photo interpretation of the land capability map, which is the end result of the survey.

The final photo interpretation is when the land capability boundaries are drawn onto the alternate blank air photos. It is always carried out under the stereoscope. The interpretation of boundaries is a job requiring, above all else, experience. It is only with experience in viewing air photos that you learn to recognise the indistinct slope breaks, the slight changes in vegetation, the various tonal differences, and the other indications of changes in soil or land characteristics. It is only with experience in the field that you learn what those varying patterns actually mean in a given area.

It is for that reason that the final photo interpretation is not dealt with in this manual. That skill will only come with practice and practice.

A successful student should, by this stage, be capable of planning and carrying out the field work of a land capability survey. At the completion of the field work he should be capable of plotting the field results accurately onto the air photos. These should then be taken to the Planning Officer or Soil Surveyor who should help and guide the student in the final photo interpretation.

Good Luck!

CHAPTER 20

EXERCISES.

This chapter contains some sample exercises. During a training course, the course leader should give the students exercises during the course. At the end of the course a test can be set to assess the progress made by the students during the course. The exercises given here are merely suggestions. It is hoped that a course leader would devise his own exercises along similar lines.

CHAPTER 4

A map gives the magnetic to grid declination as 6°15', measured in 1964. The annual change is 12' East.

1. What was the magnetic to grid declination in 1976?
2. What was the magnetic to grid declination in 1980?

CHAPTER 5.

Example: Convert 1:100,000 scale to a simple statement.
Answer - 1cm. on map equals 1km. on the ground.

Problems:

1. Convert the following scales to simple statements:

a. 1:250,000

b. 1:500

c. 1:20,000

d. 1:1,000,000

e. 1:3,000,000

f. 1:5,000

g. 1:30,000

CHAPTER 6.

1. The horizontal distance from peg A to peg B is 100 metres. Peg A is 1 metre higher than peg B.
   i. What is the gradient from A to B?
   ii. What is the percentage slope from A to B?
   iii. What is the degree of slope from A to B?
2. The distance from peg C to peg D is 260 metres. Peg C is 6.5 metres lower than peg D.
   i. What is the gradient from C to D?
   ii. What is the percentage slope from C to D?
   iii. What is the degree of slope from C to D?

3. A slope was measured with an abney level to be $2^{o}30'$.

   i. What is the ratio slope?

   ii. What is the percentage slope?

   iii. If you travel a horizontal distance of 192 metres up the slope, how high will you have risen vertically?

CHAPTER 7

Refer to the map shown in Fig.7-1.

1. What is the full map reference of Kaseba Chibundama village?
2. What square does Kapakata hill lie in?
3. What is the name of the village at 249933?

CHAPTER 8 AND 9

1. Set up the mirror stereoscope
2. Base-line the aerial photographs provided
3. Examine the aerial photographs under: 1. The mirror stereoscope
   2. The pocket stereoscope.
4. Identify and mark on the photographs all hills, crests, dambos, depressions and cleared lands.

CHAPTER 10

Plan and mark on the aerial photographs provided traverses for a semi-detailed survey of the area.

At what average distance along each traverse would you auger?

Mark the augering points on your traverses.

CHAPTER 16

1. During a survey a layer of gravel was encountered at the following depths:-

   a. 60cm
   b. 20cm
   c. 30cm
   d. 40cm
   e. 80cm

   a. If the auger entered the gravel layer easily, what are the effective depths?

   b. If partially weathered rock, not gravel, was encountered what would the effective depths be?

   c. If sheet laterite was encountered, what would the effective depths be?

   d. If the auger could not enter the gravel layer, what are the effective depths?

2. Give the wetness class of the following soils:-

    1. Colour at 50cm 7.5YR4/6. Grey mottles below 70cm. Mid slope. Upland vegetation. No rusty root channels. Subsoil texture sandy clay loam.

    2. Colour at 50cm 10YR4/2. Red mottles below 50cm. Lower slope/dambo fringe. Upland vegetation. No rusty root channels. Subsoil texture clay.

    3. Colour at 50cm 10YR5/8. No mottles. Lower slope. Upland vegetation. No rusty root channels. Sub-soil texture sandy clay.

    4. Colour at 50cm 2.5YR4/8. Red and grey mottles below 60cm. Mid slope. Upland vegetation. No rusty root channels. Subsoil texture sandy loam.

    5. Colour at 50 cm 7.5YR6/8. Grey mottles below 70cm. Weathered rock at 90 cm. Mid slope. Upland vege-tation. No rusty root channels. Subsoil texture sandy clay.

    6. Colour at 50cm 5Y3/3. Red mottles below 50cm. Lower slope. Sparse forest vegetation. No rusty root channels. Subsoil texture clay.

    7. Colour at 50cm 2.5Y3/3. No mottles. Lower slope/dambo fringe. Sparse forest vegetation. No rusty root channels. Subsoil texture sandy clay.

    8. Colour at 50cm 2.53/3. No mottles. Lower slope/dambo fringe. Sparse forest vegetation. Rusty root channels in top 20cm. Subsoil texture sandy clay.

    9. Colour at 50cm 5YR5/8. Few faint grey mottles below 60cm. Upland vegetation. No rusty root channels. Subsoil texture sandy clay loam.

    10. Colour at 50cm 2.5Y5/6. No mottles. Mid slope. Upland vegetation. No rusty root channels. Subsoil texture sandy loam.

    11. Colour at 50cm. 2.5Y5/6. No mottles. Mid slope. Upland vegetation. No rusty root channels. Subsoil texture loamy sand.

    12. Colour at 50cm 2.5Y5/6. Red mottles below 60cm. Mid slope. Upland vegetation. No rusty root channels. Subsoil texture loamy sand.

3. Give the land capability classification of the following soils:-

    1. 1 AAAX - -
       AE_1W_1(7.5YR5/6)

    2. 1 AXBC m1 - -
       0 - - (2.5YR4/8)

3. 1 GGFF ---
O–W_3 (5Y6/2)

4. 3 BC – – r1R
BE_2– (7.5YR4/8)

5. 1 CCCE m1 –
O–W_3 (10YR2/2)

6. 2 AMB – – L
AE_1W_1 (10yR6/8)

7. 1 ABBB – –
O–W_2 (10YR5/4)

8. 4 C – – – R
B – – (5YR5/8)

9. 2 BCC – r2R
B – – (10R4/8)

10. 1 BCCC – –
A – – (7.5YR6/8)

11. 1 CEFF – –
A – – (5YR5/8)

12. 1 BCCE g2 –
A – – (5YR5/6)

13. 1 CCEC – –
CE_1 – (7.5YR4/6)

14. 2 CCEE – R
O – – (5YR4/8)

15. 1 FFFF m2–
A–W_2 (10YR5/3)

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GLOSSARY OF TERMS

The purpose of this glossary is to help students with unfamiliar words. In addition to words used in this manual some other words commonly used in soils are included, as well as definitions of some geological terms often found in soil survey reports.

ABNEY LEVEL	A small hand-held instrument for measuring slopes.
ACIDITY	The hydrogen ion activity in a solution, expressed as a pH value.
ACID SOIL	A soil with a pH of less than 7.0 (measured in water) or less than 6.5 (measured in calcium chloride).
ADSORBTION	The attachment of a particle, ion, or molecule to a surface.
ABSORBTION COMPLEX	The various substances in the soil that are capable of absorbing. These are mainly clay and humus.
AEOLIAN	Formed by wind action.
AEOLIAN DEPOSITS	Fine sediments transported and deposited by wind.
AERATION	The process by which atmospheric air enters the soil. The rate and ammount of aeration depends upon the size and continuity of the pore spaces and the degree of waterlogging.
AEROBIC	Conditions having a continous supply of oxygen.
AGGREGATE	A cluster of soil particles forming a ped.
AGGREGATION	The process by which particles from aggregates.
AIR PHOTO	A photograph of the earths surface taken from an aeroplane. The air photos used in Zambia are taken with the camera pointing vertically downwards.
AIR PHOTO INTERPRETATION	The study of air photos so as to recognise land features and characteristics by deduction of patterns, tones etc. on the photo.

ALKALINE SOIL — A soil with a pH of more than 7.0 (measured in water) or more than 6.5 (measured in calcium chloride).

ALLUVIAL SOIL — A general term for those soils developed on fairly recent alluvium.

ALLUVIUM — A sediment deposited by streams and varying widely in particle size. The stones and boulders when present are usually rounded or sub rounded. Some of the most fertile soils are derived from alluvium of medium or fine texture.

ANAEROBIC — Conditions that are free of oxygen. In soils this is usually caused by excessive wetness.

ANION — An electrically charged element or group of elements carrying a negative electrical charge.

ARABLE LAND — Land suitable for use on a long term economic basis for annual or semi-perenial cultivated crops.

ARENACEOUS ROCKS — Medium - grained sedimentary rocks, dominantly made up of grains of sand size, i.e. 0.1mm - 2.0mm diameter.

ARKOSE — Sedimentary rocks with particles of sand class size containing notable quantities of feldspar grains, in addition to quartz, and to a lesser extent, micas.

ASSOCIATION — A group of two or more related soils with similar drainage, parent material, and position.

AUGER — A tool used for boring into the soil and withdrawing small samples for field or laboratory examinations.

AVAILABLE WATER CAPACITY — The weight percentage of water which a soil can store in a form available to plants. It is equal to the moisture content at field capacity minus that at the wilting point.

BACK BEARING — Whenever a bearing has been taken along a particular line, the back bearing is the bearing which would result by looking along the same line of sight but from the opposite end. It is therefore 180^o different from the bearing and the formula is: back bearing = bearing $\pm 180^o$.

BASE LINE — A line either demarcated through the bush, or drawn on a map, used as a reference from which other traverses or lines are located.

BASEMENT COMPLEX — Precambrian (older than 450 million years) complex of igneous and metamorphic rocks.

BASIC ROCKS — Quartz - free igneous rocks containing feldspars. The term does not mean basic or alkaline in the chemical sense.

BASALT — A fine - grained basic igneous rock

BEACON — A reference mark established so that a given point can be found in future. On soil or land capability surveys beacons usually consist of a long stick supported by three other sticks acting as legs, or a blaze on a tree.

BEARING — A direction indicated as an angle measured clockwise from the direction of north.

BLAZING — Cutting a patch of bark off a tree to make a beacon.

BOULDERS — Rock or mineral fragments with a diameter greater than 25cm.

CALC-SILICATE SCHIST — An impure metamorphic limestone with crystals in a parallel arrangement.

CATENA — A sequence of soils of about the same age, derived from similar parent material and occuring under similar climatic conditions, but having different characteristics due to variations in topography and drainage.

CATION — An electrically charged element or group of elements carrying a positive electrical charge.

CATION EXCHANGE — The sum total of exchangable cations that a soil can adsorb. Expressed in milli-equivalents per 100 grams of soil.

CAPILLARY WATER — The water held in the small pores of a soil that is capable of movement after the soil has drained.

CEMENTED — See INDURATED

CHAIN — A length of metal links, usually 20 metres or 30 metres long, with a handle at each end and intermediate tags indicating length. Used for measuring distance in the field.

CHITEMENE CULTIVATION — Cultivation restricted within a larger clearing to patches on which chopped branches and trunks have been collected and burnt. After a few years cultivation the land is allowed to revert to bush.

CHROMA	The relative purity or strength of a colour.
CLASTIC	Composed of broken fragments of rocks and minerals
CLAY	The mineral fraction of a soil with a particle size of less than 0.002mm diameter.
CLAY MINERALS	Those constituents of clay which give it its plastic properties. They are produced by weathering of silicates. There are four main groups: kaolinite, illite, montmorillonite and vermiculite.
CLINOMETER	A small hand held instrument that gives a direct reading of percentage slopes.
CLOSED TRAVERSE	A traverse where the finishing point is accurately identified by reference either to a known feature or the starting point of the traverse.
COHESIVE	Sticking together
COLLOID	Organic and inorganic matter with very small particle size and a correspondingly large surface area per unit of mass.
COLLUVIUM	A deposit of rock fragments and soil material accumulated at the base of steep slopes as a result of gravitational action.
COMPASS (MAGNETIC)	An instrument for determining bearings by means of a magnetised needle or card that always points towards magnetic north.
CONCAVE SLOPE	A slope that curves inwards
CONTOUR	An imaginary line joining together points of equal elevation above sea level.
CONTROL SECTION	That part of the soil profile which in deep soils lies between 25cm and 100cm from the surface.
CONVEX SLOPE	A slope that curves outwards
CRAB	The effect in aerial photography where, in order to prevent a cross wind blowing the aircraft side ways away from its intended course, the aircraft turns slightly into the wind, and thus flys in a crab-like" attitude. The camera in the aircraft should be rotated to compensate.
CREEP	Slow mass movement of soil and soil material down steep slops. The process takes place due to gravity, facilitated by satturation with water

CREST	The top of a ridge
CROP SUITABILITY	A classification of the suitability of of land for the production of a specific crop or crops.
CRYSTAL LATTICE	The orderly arrangement of atoms in a crystaline material.
CYCLEOMETER	A wheel, usually with a circumference of 1 meter, attached to a handle and a revolution counter. Used for measuring distances in the field.
DAMBO	A low lying, gently sloping treeless tract of country which is seasonally waterlogged by seepage from surrounding high ground assisted by rainfall, and which frequently contains the natural drainage channel for the removal of excess surface run-off.
DEGRESS (OF ARC)	If a full circle is divided into 360 equal segments, the angle between two adjacent divisions is one degree of arc.
DETAILED SURVEY	A survey with a high intensity of field observations (each observation representing from 1ha to 9 ha), mapped at a large scale. (1:10,000 to 1:30,000) used for farm planning and irrigation scheme planning.
DIORITE	A coarse grained intermediate igneous rock containing little quartz and consisting mainly of plagioclase.
DOLERITE	A medium grained basic igneous rock.
DOLOMITE	Limestones with more than 15% magnesium carbonate ($Mg CO_3$)
DRAINAGE	A measure of the frequency and duration of periods when a soil is free of sattuteration.
DRIFT (air photos)	The effect in aerial photography where a cross wind blows the aircraft off course.
DRIFT (Soil)	Deposits of gravel, sand, alluvium etc. having been transported from another place.
EFFECTIVE DEPTH	The thickness of soil available for satisfactory root development.
ELEVATION	The height of a point or area above sea level.
ELUVIATION	The removal of soil material in suspension or solution from a layer of the soil; unually the loss of material in solution is referred to as "leaching".

EROSION	The wearing away of the land surface by running water wind, or other agents.
1) GULLY EROSION	The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths.
2) RILL EROSION	An erosion process in which numerous small channels of only several centimetres in depth are formed
3) SHEET EROSION	The removal of a fairly uniform layer of soil from the land surface by runoff water.
EROSION CLASS	Visible evidence of erosion at or in the vicinity of the sampling point is assessed as slight, moderate or severe.
EVAPORATION	The conversion of a liquid into a vapour, without necessarily reaching the boiling point.
FELDSPARS	A group of rock - forming silicate minerals.
FERTILITY	The ability of a soil to provide the proper nutrients in the proper ammounts for the growth of plants.
FIDUTIAL MARK	Reference marks around the edge of an air photo. By joining opposite fidutial marks the principal point of the photo may be located by the intersection of the diagonals.
FIELD CAPACITY	The amount of water held in a soil after gravitational water has drained away.
FLIGHT LINE	The path taken by the aircraft when taking air photos. It is plotted by joining together the positions of the principal points of the photos.
GABBRO	A coarse-grained igneous rock consisting of plagioclase, pyroxene and olivine.
GNEISS	A coarse - grained rock in which granular minerals (quartz, feldspars, garnets, etc) alternate with bands in which schistose minerals (mica, chlorite, amphibole, etc) predominate. The rock splits normally in slabs more than 10cm thick.
GRANITE	A coarse-grained igneous rock consisting essentially of quartz, feldspar, and commonly mica and biotite.
GRAVEL	Rock particles measuring from 0.2cm to 7.5.cm in diameter.
GRAZING LAND	Land unsuitable for the long-term production of arable crops, but suitable for grazing cattle.

GRID LINES	A series of vertical and horizontal lines on a map used to define positions by means of grid references.
GRID NORTH	The direction from a point of a line parallel to the vertical grid lines on a map of that area.
GRID REFERENCE	A method of defining the position of a point on a map. Vertical and horizontal grid lines are numbered. By quoting the numbers of the lines which intersect at the point, an accurate reference of the position of that point is given.
GROUND WATER	Water that fills all the unblocked pores of an underlying material below the water table.
HINDRANCE TO CULTIVATION	Gravel, stones, boulders, rock or laterite out-crops occuring within 20cm of the soil surface, or termite mounds in sufficient quantities to hinder or prevent normal agricultural cultivation practices.
HORNEBLENDE	A silicate mineral widespread in metamorphic and igneous rocks.
HORNEBLENDE SCHIST	A rock consisting of crystals of horne-blende in a parallel arrangement.
HUE	The dominant spectral (rainbow) colour of a soil e.g. red, yellow, etc.
HUMUS	The well decomposed, fairly stable part of the organic matter of a soil.
IGNEOUS ROCKS	Rocks which have been formed by the con-solidation of molten rock material.
ILLUVIAL HORIZON	A horizon that receives material in solu-tion or suspension from some other part of the soil.
ILLUVIATION	The movement of material from one horizon and its deposition in another horizon of the same soil.
INCLUSIONS	Soils which cover less than 20% of the area of a mapping unit.
INDURATED	Soil material cemented into a hard mass that will not soften on wetting.

INFILTRATION RATE — The maximum rate at which water can enter a soil.

ION — Electrically charged atom or group of atoms.

IRON STONE — Another name for laterite.

IRRIGABILITY — The suitability of an area of land for the production of crops under irrigation.

IRRIGATION — The artificial application of water to an area to replace or supplement rainfall.

KALAHARI SANDS — (Barotse sands). Deep, loose, wind and water sorted sands with a very low clay and silt content, even at depth.

LAND — Land is a wider term than soil. In addition to soil it includes geology; water supply; location in relation to centres of commerce, populations, and other land; the size of the area; plant cover; activities of man; relief; communications; etc.

LAND CAPABILITY CLASSIFICATION — The system used in Zambia to indicate the relative suitability of the land for rain-fed medium and large scale ox or tractor cultivation under a high level of management.

LATERITE — A highly weathered material rich in secondary oxides of iron, aluminium or both. It is nearly devoid of bases and primary silicates, but it may contain large amounts of quartz and kaolinite. It is either hard or capable of hardening on exposure to wetting and drying.

LATITUDE — A distance around the world, measured in degrees of arc north or south from the equator.

LEACHING — The removal of material in solution from the soil.

LEGEND — An explanation of symbols on a map.

LEVEL OF SURVEY — The degree of intensity of a survey as determined by the intensity of field work and reflected in the scale at which the map is published. e.g. reconnaissance, semi-detailed, detailed surveys, etc.

LIME (agricultural) — A material containing the carbonates, oxides and hydroxides of calcium and or/ magnesium, used to neutralize soil acidity.

LIMESTONE — A sedimentary rock composed primarily of calcium carbonate. If dolomite (magnesium carbonate) is present in appreciable quantities it is called a dolomitic limestone.

LIMITING MATERIAL	Rock, laterite, gravel, hardpan, etc. which is limiting to crop root development.
LOAM	The textural class name for soil having a moderate amount of sand, silt, and clay.
LONGITUDE	A distance around the world measured in degrees of arc east from a line joining the north pole and south pole and passing through Greenwich in London, U.K.
LUB CODE	"Land Use Branch Code". A short hand code, used to record the various soil and land characteristics observed in the field.
MAGNETIC DECLINATION	The difference between magnetic north (the direction a compass points) and true north (the direction of the north pole), or between magnetic north and grid north (the direction of the vertical grid lines on topographic maps).
MAGNETIC NORTH	The direction in which a compass needle points at any place.
MAPPING UNIT	Each seperate soil or association of soils shown on the map and identified by a symbol.
MAP REFERENCE	see GRID REFERENCE
MARGINAL ARABLE LAND	Land that will not support long term intensive use for arable crops without great risk of poor yields, limited freedom of choice of crops, or much environmental control.
MATCH LINES	Lines drawn on air photos such that the line on one photo matches the corresponding line on the stereo pair, or on the adjacent photo from an adjacent run.
MATRIX	Material within which large particles are embedded.
METAMORPHIC ROCKS	Sedimentary rocks which have been altered by earth movements and/or molten material.
METAQUARTZITE	A metamorphosed arenaceous rock in which the constituent grains have recrystalised and developed an interlocking mosaic texture, with little or no trace of cementation.
MICA	A transarant rock with a perfect cleavage, producing flakes that are flexible and elastic.

MIOMBO WOODLAND	A two-storeyed woodland with an open or partially closed canopy of semi-evergreen trees 15-20m high, characterised by species of Brachystegia, Isoberlinia, Julbernardia, and Marquesia. The forest floor is covered by a more or less dense cover. Most Miombo woodland is secondary regrowth.
MOSAIC	A composite photographic representation of and area made up from individual aerial photographs.
MOTTLING	Spots of different colour or shades of colour interspersed with the dominant soil colour.
MUDSTONE	An argillaceous rock which does not form a plastic mass when wet, which may disintergrate when immersed in water, but does not fracture along a bedding plane.
MUNSEL COLOUR	A system of different coloured papers or chips, arranged on pages in a loose-leaf book. Each chip is indentified by numbers and letters representing the hue value, and chroma of the colour. Soil colours may be determined by comparison of a moist fragment of soil with the colour chips.
NEUTRAL SOIL	A soil with a PH of 7.0 (measured in water) or 6.5 (measured in calcium chloride).
ORGANIC MATTER	Plant or animal material, living, dead, and decayed, occuring in soil.
OVERLAP (air photos)	The area shown on one photo which is also shown on the adjacement photo.
OXIDATION	Chemical combination with oxygen, or the removal of hydrogen from a system.
PARENT MATERIAL	The unconsolidated more or less chemically weathered mineral or organic matter from which soil is developed.
PED	An individual natural soil aggregate such as a crumb, prism, or block, in contrast to a clod, which is a mass of soil brought about by digging or other disturbance.
PERCOLATION	The process whereby water moves through the soil in response to the force of gravity and the downward pull of soil pores.
pH	A measure of the acidity or alkalinity of the soil.
PHYSIOGRAPHIC POSITION	Position within the relief of an area
PLATEAU	A relatively flat area of high elevation underlain by essentially horizontal strata.

PLINTHITE	Laterite that has not become hardered.
PORES	The spaces between the mineral or organic particles in a soil.
PORPHYRY	An igneous rock containing conspicuous crystals in a glassy or fine - grained matrix.
POTENTIAL EVAPOTATION	The amount of water, measured in milimetres, that it is estimated is lost from the soil by evaporation and evapotranspiration each month.
PRINCIPAL POINT	The centre point of an air photo, assumed to be the point vertically beneath the aircraft when the picture was taken.
PSAMMITE	The same as arnaceous rock.
QUARTZ	A silicate mineral. The hardest common mineral.
QUARTZITE	Metamorphic rock formed from sandstone
REACTION (Soil)	The degree of acidity or alkalinity of a soil, usually expressed as pH value.
RECONNAISSANCE SURVEY	A survey where each field recording represents from 45ha. to 150ha, and mapped at a scale of from 1:50,000 to 1:100,000. Can be used for general area planning and feasibility studies but not for project or farm planning.
REDUCTION (Chemical)	The removal of chemicaly combined oxygen from or the addition of hydrogen to a system.
RELIEF	The irregularity of a land surface; the difference in elevation between the highest and lowest points in an area.
ROCK	Any naturally formed mass of mineral matter forming an essential part of the earth's crust.
RUN (air photo)	One of the successive trips across an area taken by the aircraft whilst taking air photos.
RUSTY ROOT CHANNELS	A deposition of red oxidised iron around roots and within root channels in a soil. It is indication of waterlogging.
SALINITY	The presence of soluble salts in a soil.
SAND	A soil particle between 0.05mm and 2.00mm in diameter.
SANDSTONE	A sedimentary rock consisting of consolidated sand.

SCALE	The ratio of a distance measured on a map or air photo, and the corresponding distance measured on the ground.
SCHIST	A metamorphic rock that contains an abundance of orientated platy minerals; The rock can be split with relative ease parallel to the flat surface of the plates.
SEDIMENTARY	Formed by the accumulation of sediments.
SEDIMENT	Material that has been deposited by settling from a transportation agent such as water or air.
SEMI-DETAILED SURVEY	A survey where each field recording represents from 10ha to 45ha, and mapped at a scale of from 1:30,000 to 1:50,000. Can be used for project or farm planning, but not for intensive schemes such as irrigation projects etc.
SHALE	Thinly layered sedimentary rock composed of consolidated mud, clay, or silt.
SILT	A soil seperate consisting of particles between 0.05mm and 0.002mm in diameter.
SILTSTONE	A sedimentary rock consisting primarily of consolidated silt particles (a type of shale).
SLATE	Finely layered, compact metamorphic rock which splits readily into sheets.
SLOPE BREAK	The position where either a change in steepness of slope or form of slope takes place. Often corresponds with a change in soil characteristics.
SLOPE CLASS	The steepness of the slope at a soil observation site is measured, and according to the percentage slope is classified as an A,B,C,D, or E slope.
SOIL	The collection of natural bodies occupying parts of the earth's surface that support plants and that have properties due to the intergrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time.
SOIL BOUNDARY	The division between two soil types in the field. It is often diffuse as there is usually a zone of transition between two soil types.
SOIL COLOUR	The dominant colour of the soil in any given horizon, measured on Munsell standard colour charts. For land capability classification the colour is taken of moist soil at 50cm deep.

SOIL HORIZON — A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil forming processes.

SOIL MAP — A map showing the distribution of soil types. A soil map is different from a land capability map and the two should not be confused.

SOIL PHASE — A subdivision of a soil series or other unit of classification having characteristics that effect the use and management of the soil but which do not vary sufficiently to differentiate it as a seperate series, e.g. a variation in such things as degree of slope, degree of erosion, etc.

SOIL PROFILE — A vertical section of the soil through all its horizons.

SOIL SERIES — The basic unit of soil classification, consisting of soils which are essentially alike in all major profile characteristics, except the texture of the surface horizon and depth of the soil.

SOIL SURVEY — The systematic examination, description, classification, and mapping of soils in an area.

SOIL TYPE — The lowest unit in the soil classification, being soils alike in all characteristics including the texture of the surface horizon.

SOUR SOIL — A popular term used by farmers to refer to strongly acid soils.

STEREOSCOPE — An instrument for viewing adjacent pairs of air photos similtaneously, so as to obtain a stereoscopic (three dimensional) image of the area.

STEREO MODEL — That area of overlap on two adjacent air photos that provides a stereoscopic image when viewed under the stereoscope.

STEREO PAIR — Two adjacent air photos having a 60% overlap so that they can be viewed under a stereoscope.

STEREOSCOPIC VISION — The mental process which fuses the images of the two eyes into a three dimensional impression.

STONES — Rock fragments measuring 7.5cm to 25cm diameter

STRIKE — The direction of the general trend or run of geological or topographic features.

STRUCTURE — The combination of primary soil particles into units or peds, which are classified on the basis of shape, size and distinctness.

SUBSOIL — That part of the soil below the plough layer.

SWEET SOIL — A popular term used by farmers to refer to near neutral soils.

SYENITE — A coarse grained intermediate igneous rock characterised by the presence of alkali feldspars.

TEXTURE — The relative proportions of different sized groups of soil grains.

TILT (air photos) — The effect where the aircraft taking air photos rocks from side to side in flight so that the photos are slightly oblique instead of vertical.

TOPOGRAPHIC MAP — A map showing the physical features of an area, especially the relief and contours of the land.

TOPOGRAPHY — The physical features or configuration of a land surface.

TOPSOIL — The upper 20-25cm of the soil profile, with a concentration of living and dead organic matter. (may be thinner if erosion is severe)

TRAVERSE — A line crossing an area on a planned bearing that is followed whilst making soil observations at intervals along the line.

TRUE NORTH — The direction of the north pole at any point.

UNSUITABLE LAND — Land with too severe limitations for either arable cropping or grazing.

UTM COORDINATES — Grid references given in the Universal Transverse Mercator system, as used on the 1:50,000 topographic maps used in Zambia.

VALLEY — A generally elongated depression of the land surface which contains a stream.

VALUE — The relative lightness of a colour

VERNIER SCALE — A device for measuring subdivisions of a scale by means of a second (vernier) scale moving in relation to the main scale.

WATERLOGGED — Saturated with water.

WATER TABLE	The upper surface of ground water or that level below which the soil is saturated with water.
WEATHERING	All physical and chemical changes produced in rocks, at or near the earth's surface, by atmospheric agents.
WEATHERING MEDIUM	The medium within which weathering is taking place
WEATHERING ROCK	Soft, partly decomposed rock encountered at depth in a soil profile.
WETNESS CLASS	The degree of wetness within the rooting range during the rainy season (the growing season). A poorly drained soil will remain fully or partially waterlogged in the root region for long periods. This restricts the amount of air around the roots, and results in poor crop growth. Four wetness classes are defined in the land capability system.
WILTING POINT	The percentage of water in the soil when permanent wilting of plants occurs.
