LAND USE PLANNING

SECTION 1
SOIL CONSERVATION

Conservation is the protection of soils on the farm in order to produce the best possible return, over the longest possible period.

THE MECHANICS OF EROSION

Terminology

EROSION — Erosion is a levelling process with soil particles being carried, washed or rolled down a slope by the force of gravity. Natural erosion has always occurred, but 'accelerated' erosion takes place when the process is influenced by man. When conditions of climate and topography are such that natural erosion occurs faster than usual, then these same conditions will also cause particularly severe accelerated erosion.

AGENTS — Agents are the factors that loosen or break down the soil particles. The main agents are wind, water, frost and chemicals. Wind and water are the most important agents and, of the two, water has the greatest effect.

ERODIBILITY — This is the vulnerability or susceptibility of a soil to erosion. It is a function of both the physical characteristics of that particular soil, and the treatment of the soil.

EROSIVITY — This is the potential ability of rain to cause erosion. It is a function of the physical characteristics of the rainfall.

General

The factors that affect soil loss may be summarised as follows:

SOIL LOSS = RAIN x SOIL x (SLOPE & LENGTH) x CROP x PRACTICES

This constitutes the

UNIVERSAL SOIL LOSS EQUATION

Soil loss	=	Rainfall erosivity factor	x	Soil erodibility factor	x	Topographic factor	x	Crop management factor	x	Practices
A		**R**		**K**		**LS**		**C**		**P**

Let us consider each of these factors in turn:

A = Soil loss

When all the remaining factors in the equation are multiplied together they result in the total soil lost from any set of conditions. Soils in the sugarcane industry vary considerably in depth, texture, structure, permeability, organic matter content and other properties. A good, deep soil that weathers quickly is capable of standing more of a topsoil loss than a shallow soil on a hard parent material. The 'A' factor will therefore have a different value for different soils. In the case of a soil that is shallow and weathers slowly, the other factors must be more stringently controlled where possible.

R = Rainfall factor

Rainfall cannot be controlled. Whatever management practice or layout method is used, it will be subjected to local rainfall conditions.

Although rainfall cannot be changed, one can study the history of rainstorms for the area and try to estimate patterns and the likelihood of a particular rainfall occurring in the future.

Measurement of rainfall is a sampling method only; the degree of accuracy will depend on the method used for measuring. There are various elements in the Rainfall Factor that will have an effect on the Erosivity of the rainfall.

Quantity: The total amount of rain that falls in a particular storm will give a very broad idea of the possible damage that can be expected.

Rainfall intensity: There is a good deal of experimental evidence linking Rainfall Intensity and Total Energy of a storm with the soil loss measurement from the same storm. These factors can be measured with a recording rainfall intensity gauge and the soil loss can then be calculated.

Two interactive processes take place when rain falls onto a bare soil surface:

Raindrop splash: The falling rain strikes the soil with a large amount of Kinetic Energy. It breaks up the soil aggregate, forming loose particles.

Run-off water: As soon as the infiltration rate of the soil is exceeded by the falling rain, water will begin to move over the soil surface, taking with it the particles already loosened by the falling rain.

There can be 60 to 70 times more energy in rain splash than in water run-off. If the energy of the raindrops is dissipated before they reach the soil surface (by the use of a cover mulch or trash), a large portion of possible damage to the soil will be avoided.

K = Soil erodibility factor

For a given rainstorm, if all other factors are equal, erosion will be dependent on the soil type. Soil erodibility factors can therefore be assigned to the different soils in the sugar belt.

These factors are dependent on:

• soil grading • structure • organic matter content • permeability.

A very sandy soil with a low clay content and poor structure will require less energy to break it down to its constituent parts than a soil with a high clay and organic matter content, and good structure. The former will be highly erodible and the latter will generally be resistant to erosion.

LS = Topographic factor

The steeper the slope, the greater the danger of a high soil loss. As the length of slope also increases, so again does the danger increase, because of the larger amount of water that will become available to cause separation of soil particles and the transportation of those particles.

C = Crop management factor

The importance of the crop management factor in the soil loss equation has already been noted in the effect of covering the soil to reduce splashing by raindrops. Values for the various practices such as trashing, burning, strip cropping and minimum tillage will differ, as will those which affect the timing of operations such as planting. If planting is done at a time which allows maximum crop canopy to be reached before the arrival of high intensity rains in January and February, then the date of planting will have a more beneficial (lower) value than if planting were done when the canopy could not develop before heavy and intense storms occur.

P = Practices factor

Differing conservation practices such as contour row planting and the use of graded water carrying terrace banks will also greatly assist in the reduction of soil loss. These factors must be taken into account when trying to assess how much soil will be lost from a hillside under certain rainfall conditions.

The Universal Soil Loss Equation (USLE)

By analysing existing practices, the equation can be used to calculate soil losses that are acceptable in terms of the total crop cycle.

SOIL EROSION CONTROL

(a) Rainfall erosivity cannot be changed by man; he must therefore take extra precautions against erosion where R is high.

(b) The soil erodibility factor (K) is mostly a function of the physical properties of the soil. The farmer can control the erodibility of his soil to some extent by good management of the crop.

(c) Slope and slope length are physical factors of the topography. Because it cannot (easily) be altered, the farmer must take the slope of his land into account when he designs soil conservation systems and decides on management practices for his crop. Slope length can be altered by the farmer when designing mechanical conservation layouts, but for this he needs to understand the effect it will have on erosion.

(d) Soil cover and management practices are the most important factors in controlling soil and water losses.

Control measures

1. **Mechanical protection of lands:** earth moving and soil shaping measures, e.g. storm drains, terraces and waterways.

2. **Biological control:** all the factors which reduce erosion by management of crops, e.g. strip cropping, trashing and minimum tillage.

These two types of control measure are not alternatives but are complementary.

PRACTICAL FIELD AND FARM CONSERVATION

Mechanical conservation works

The primary purpose of mechanical works is to gather the water flowing over the surface of the land before it can cause serious damage, and to conduct this water at a safe velocity off the land to an area where it can do no harm.

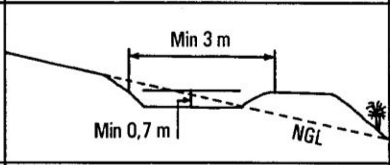
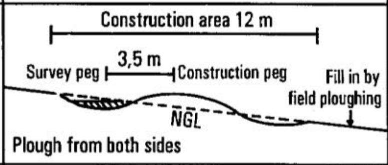
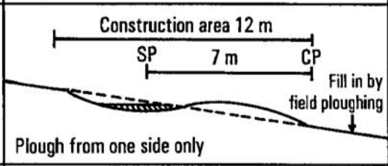
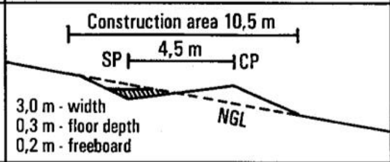
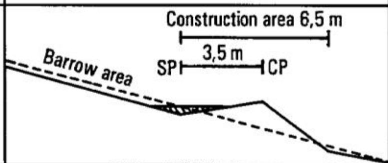
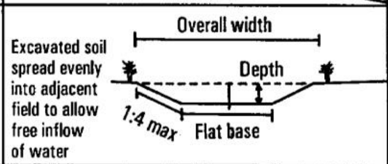
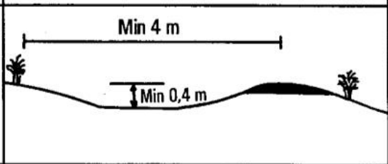
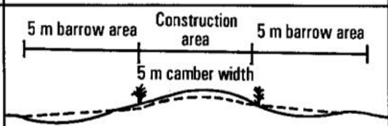
Storm drains These structures are placed above the land and serve to divert storm water which would otherwise flow onto the land from higher ground.

Terraces These are situated within the arable land and serve to collect surface run-off water and discharge it into a stabilised waterway. Each terrace is designed to carry only the water that runs off the area of land immediately above it but before the next terrace. There are various types of terraces, e.g. broad based, bench and improved bench.

Waterways These are the depressions into which the terraces usually discharge. The depressions can be natural or artificially constructed, but they must have a stable vegetative cover.

The most vulnerable time, when the erosion hazard is at its maximum, is during the plough-out or bare fallow period. It is important to try, through management methods, to limit this to a minimum and also to restrict the fallow period to a time of year when high intensity storms do not generally occur. Nevertheless, protection in the form of mechanical structures must be provided for this period, however short, and we can now look at these in some detail in Figure 1.

Figure 1. Mechanical conservation works.

STRUCTURE	TYPE	CROSS-SECTION (not to scale)	GRADIENTS	SURFACE	USE
STORM WATER DRAIN			From 1:500 to 1:150 Dependent on length, catchment size and soil type	Soil	To catch water from unprotected catchments above layout scheme.
TERRACES	BROAD BASE up to 5%		1:250 to 1:150 Dependent on length and soil type	Soil	To control inter-panel erosion during fallow period. To allow movement of vehicles over the structure.
	BROAD BASE up to 12%		1:250 to 1:150 Dependent on length and soil type	Soil	To control inter-panel erosion during fallow period. To allow movement of vehicles over the structure.
	BENCH Shallow soils <400 mm deep		1:250 to 1:150 Dependent on length and soil type	Soil	To control inter-panel erosion during fallow period.
	IMPROVED BENCH Moderate Deep soils >400 mm deep		1:250 to 1:150 Dependent on length and soil type	Soil	To control inter-panel erosion during fallow period. To allow movement of vehicles from the panel above to the road.
WATERWAYS	NATURAL Grassed		Up to 30% up and down slope	Planted with creeping grass: Revets	To collect concentrated flows of water from terraces. Placed in natural drainage lines.
	ARTIFICIAL Grassed		Up to 20% across slope	Planted with creeping grass: Revets	To collect concentrated flows of water from terraces. Can be placed across slopes. (Avoid if possible.)
ROADS	CREST		Variable up to 8%	Hardened	Cane extraction.
	TERRACE	See 'TERRACES' above	1:250 to 1:150	Hardened	Cane extraction.
	DIAGONAL	See 'BENCH TERRACE' above	Constant 8-12% maximum	Hardened	Where crests are over 10%. Cane extraction.

Spacing

Two major considerations in the spacing of structures are:

• slope • soil type.

The steeper the ground, the closer the terrace spacing must be to control soil and water losses. Also, the more erodible the soil, the closer the terraces must be to reduce the distance that the run-off water will flow.

Management factors play an important part in the spacing of terraces. These factors can be listed as follows:

- minimum tillage
- strip cropping
- burning
- trashing
- time of planting.

A full design for a hillside is accomplished using a nomograph. The nomograph allows certain management options to be used in the determination of panel widths (Figure 32).

Strip cropping and minimum tillage

Strip cropping is the practice of replanting one or alternate inter-terrace panels during any one season. In the event of terraces being overtopped by excessive run-off, strip cropping helps considerably in the overall protection of hillside areas against soil loss.

However, strip cropping on its own is not a complete protection system. Greater protection can be obtained if the replant areas are re-established using minimum tillage practices, thereby eliminating panels under bare fallow. At present, however, strip cropping, even when combined with minimum tillage, cannot be recommended for complete conservation of soil and water.

EXAMPLES OF FIELD LAYOUTS

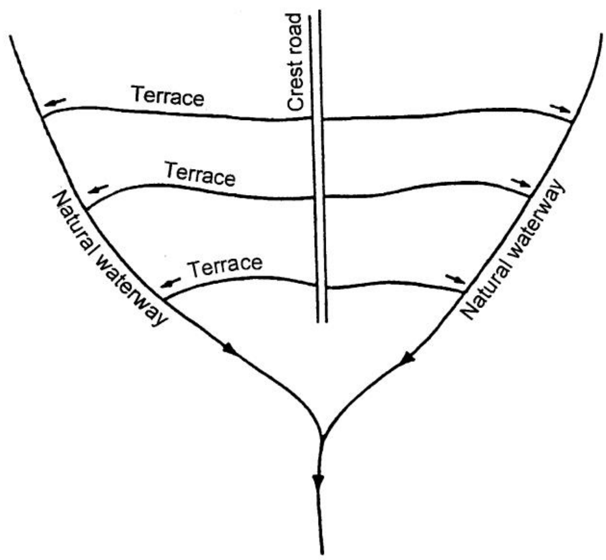


Figure 2. Sloping ridge.

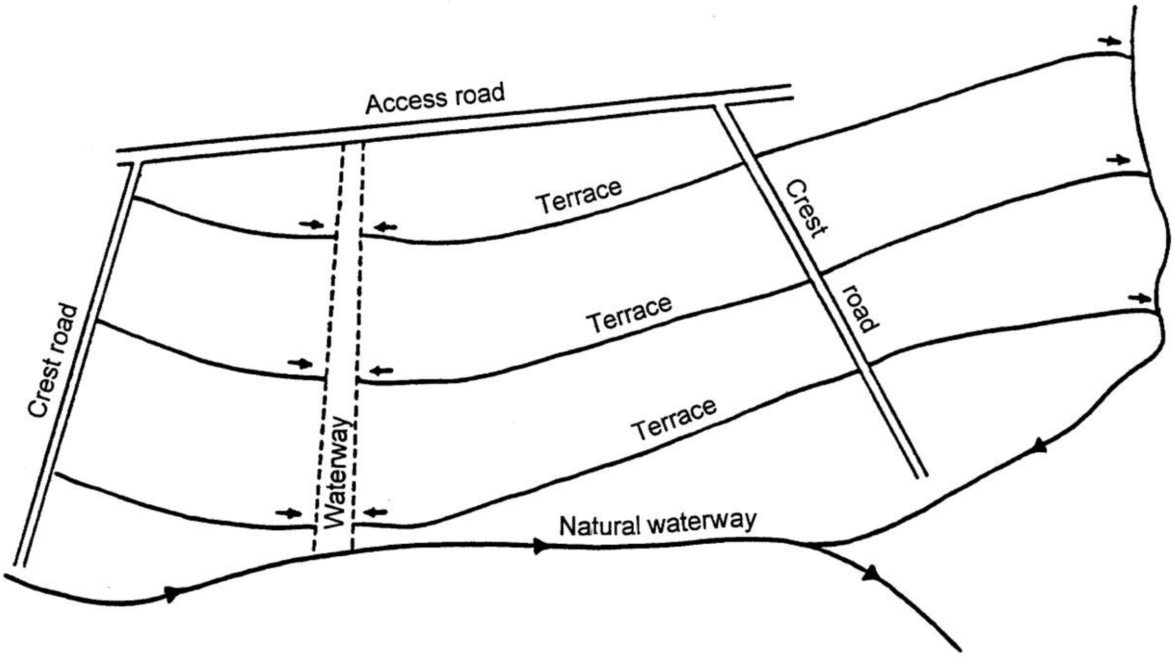


Figure 3. Sloping ridge with waterway.

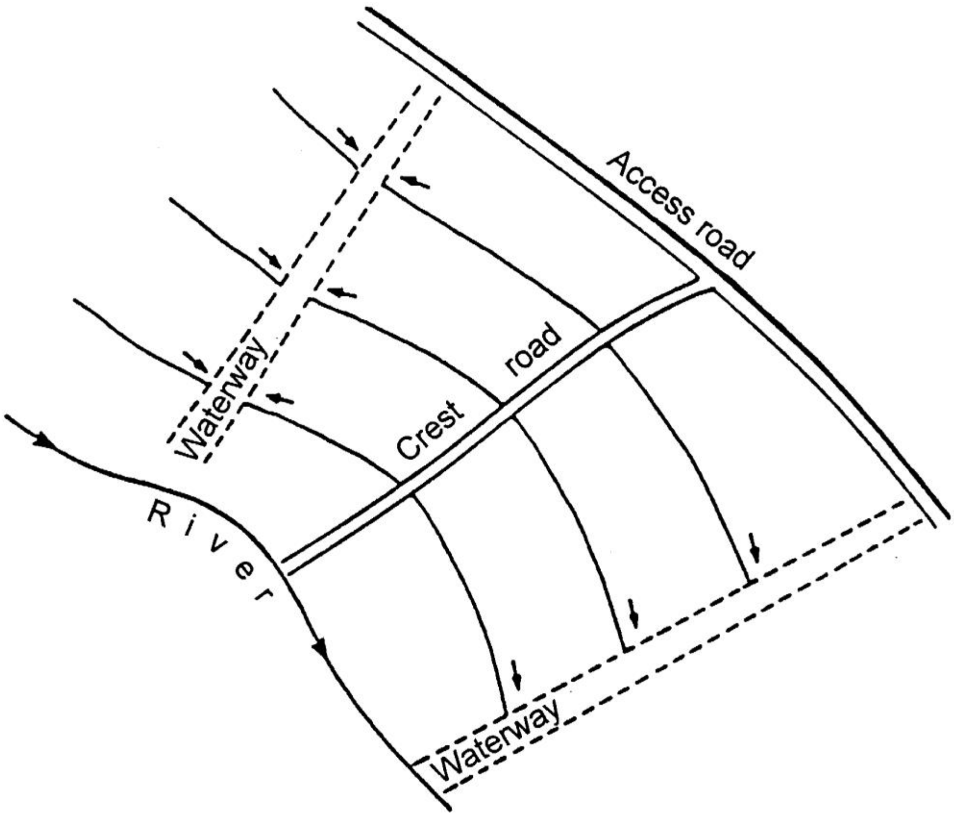


Figure 4. Riverine slope.

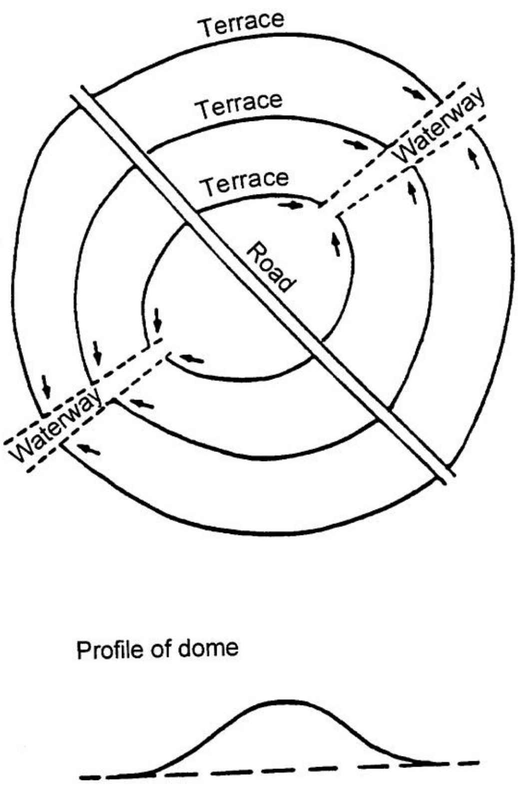


Figure 5. The dome.

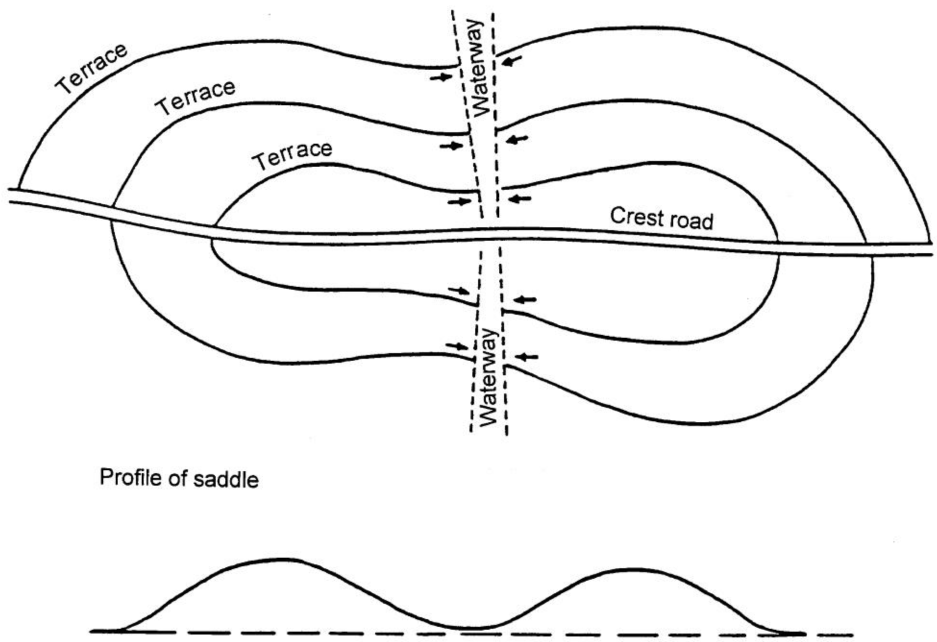


Figure 6. The saddle.

SECTION 2

PEGGING AND CONSTRUCTION OF STRUCTURES

Introduction

Before pegging out works in the land, the design should be properly planned on a map. Very often the original plan will have to be modified when pegging in the field, because of obstructions such as rocks, which do not show up on the aerial photograph.

The principles of pegging

(a) Peg the top terrace first, or establish a 'key' terrace.

(b) In a parallel system, peg the masterline (key) terraces first.

(c) Positions needing special attention (e.g. waterways, crest roads) should be marked by means of double pegs.

(d) To give smoother curves, a certain amount of 'streamlining' of the lines of pegs may be done.

(e) The line of pegs should be replaced as soon as possible by a scratch mark made by a tractor and plough.

THE USE OF LEVELS

A level is an essential piece of equipment when laying out land according to a farm plan. It is used for:

- siting waterways
- ensuring terraces or roads have the required grade or slope
- ensuring open or pipe drains have the required grade or slope
- checking construction of irrigation ditches or supply canals.

Of the various types of levels available, the two most commonly used are the **Tilting level** and the **Abney level**.

THE TILTING LEVEL

Description

The tilting level consists of a telescope which is attached to a baseplate. The telescope rotates on this baseplate, the level of which can be adjusted by three footscrews. The level has a tilting screw which is used to adjust the tubular bubble before each observation.

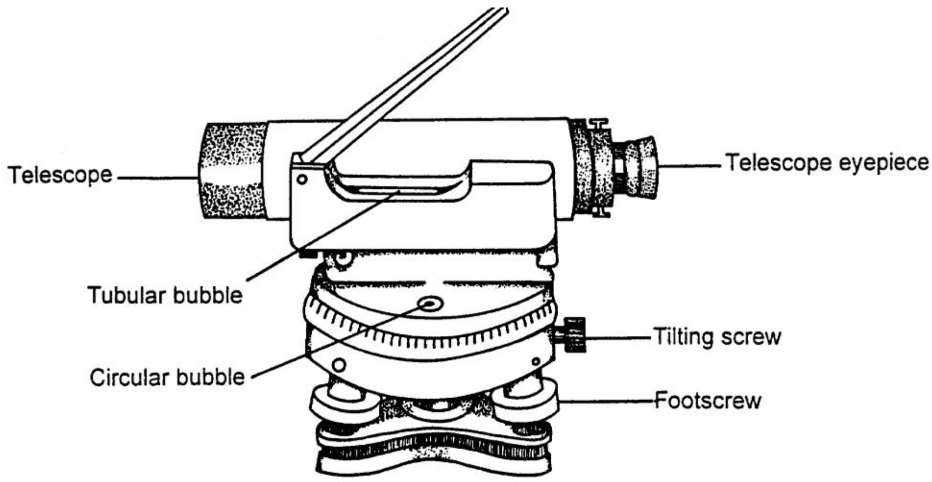


Figure 7. The tilting level.

Accessories

- A tripod
- A staff marked out in hundredths (1/100) of a metre.

Setting up the Tilting level

1. Fix the level onto the tripod by means of the central screw, making sure that this is not too tight.

2. Tread two legs of the tripod into the ground, leaving the third leg free and pointing uphill.

3. Insert the third leg into the ground in such a position as to bring the bubble in the circular spirit level roughly to the central position.

4. Rotate the telescope until it lies over two of the three footscrews.

5. Turn these footscrews (either both inwards or both outwards) until the bubble in the circular level comes to the centre.

6. Rotate the telescope through 90 degrees so that it lies between the first two footscrews and over the third. Adjust this footscrew until the bubble is again centred in the circular level.

7. It is essential that the bubble is centred in the tubular level by using the tilting screw before every observation.

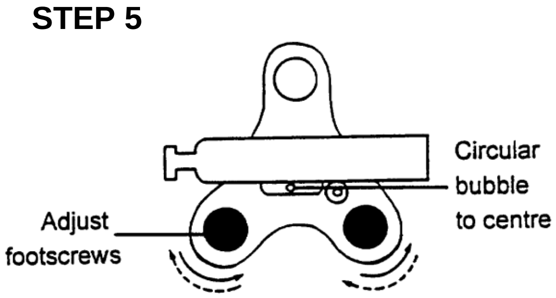


Figure 8. Adjusting the footscrews.

Viewing through the telescope

When looking through the telescope one sees a long vertical crosshair, a long horizontal crosshair, and two shorter horizontal lines. The two shorter lines are the stadia hairs.

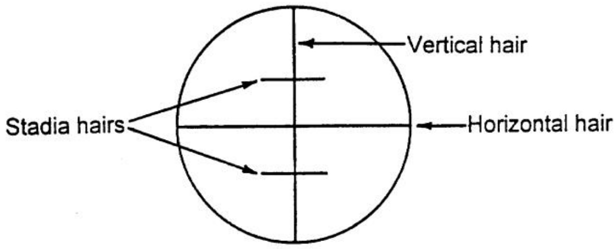


Figure 9. Position of hairs on the telescope.

The vertical crosshair is for lining up with the staff, and the horizontal crosshair is for reading levels. The stadia hairs are used for measuring distances, as follows:

The reading at the top hair *minus* the reading at the bottom hair *times* 100
equals the distance (in metres) between the level and the staff.

Sighting on the staff

The staff is divided into metres, which are denoted by a change in colour of the marking, e.g. the 1st and 3rd metres are black, and the 2nd and 4th metres are red.

Each metre is further divided into tenths, and each 1/10th is in turn divided into tenths (i.e. 1/100th of a metre). These divisions are clearly marked in the manner shown below:

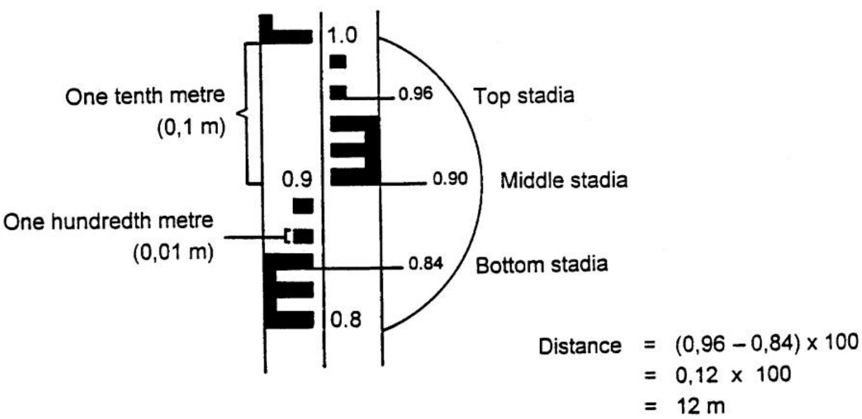


Figure 10. Divisions on the staff.

Checking the Tilting level

All machinery requires regular maintenance and checking, and this applies also to the Tilting level. A fair amount of wear and tear can cause any instrument to need adjustment, so it is important to check the level regularly to avoid errors in layout work which, in the extreme, can cause water to run in the wrong direction! At the least, errors can cause inefficiency in the most carefully designed layout.

Checking can be easy and half an hour taken to check the level before starting any levelling work can save having to re-do several days' work, or possible trouble for the life of the cane crop through inaccurate layout.

The line of sight through the telescope should remain horizontal for all positions of the telescope. This is known as collimation, and the process is as follows.

Collimation

1. Set up the level on any convenient piece of ground.

2. Position the staff on a peg 15 metres away from the level and take a reading.

3. Move the staff to a peg 15 metres from the level in the opposite direction from the level to the first reading, so that the level is midway between the two peg positions. Take a second reading.

4. The difference between the two readings will give the difference in level between the two positions. Because the level is midway between the two staff positions, this difference will be accurate even if the level is out of adjustment as the error will be compensated for (Figure 11).

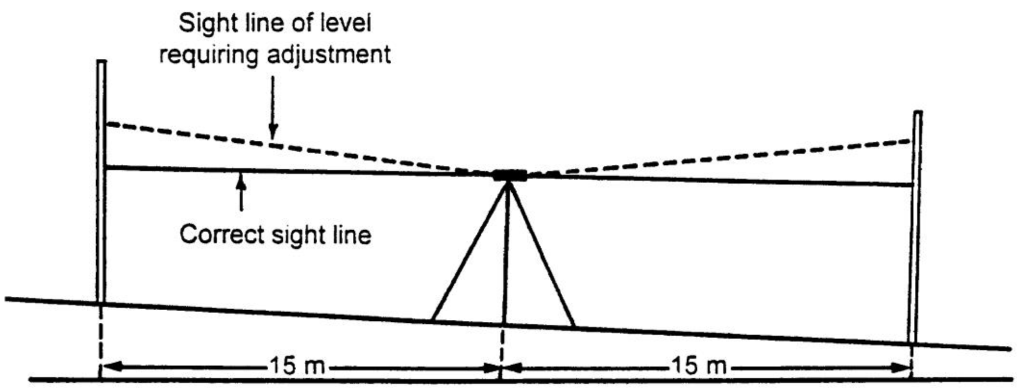


Figure 11.

5. Now set the level up within a 2 metre radius of the second staff position. Take a reading.

6. Move the staff back to the first staff position. Take a reading.

7. If the level is correctly adjusted, the difference between these two readings should be the same as that for those taken with the level midway between the staff positions. If not, the level requires adjustment by a trained technician before it can be used for field work (Figure 12).

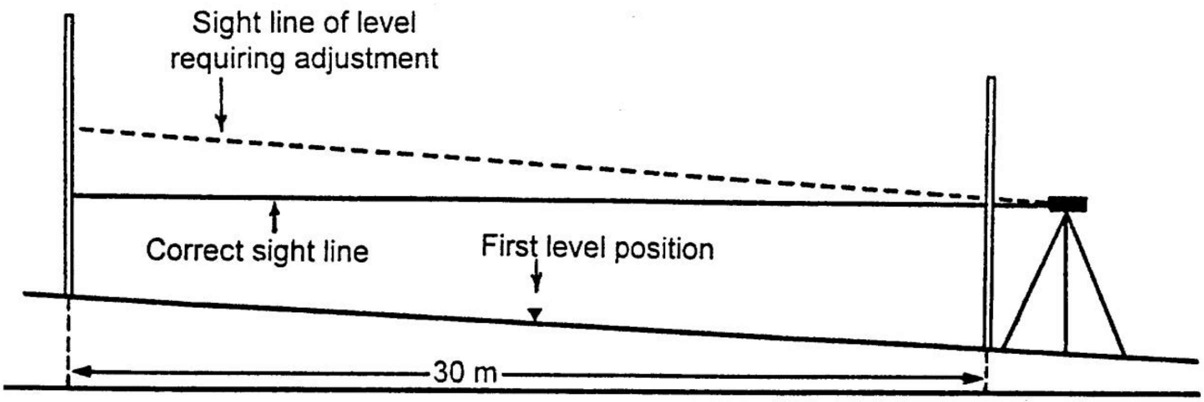


Figure 12.

NOTE:

With the level very close to the second staff position it can be assumed that there is no error in reading the staff at that position, but with the staff at the first staff position any error will be magnified and can easily be seen in the variance between results from the two staff positions.

Using the Tilting level

To peg a level line:

1. Set up the level as described before.

2. Instruct the staff-bearer to move away for an appropriate distance, keeping as best he can at the same level. He should then position the staff upright on the ground, taking care not to place it in a rut or on top of a mound.

3. Take a reading on the staff, and drive in a peg at this position.

4. Leaving the level where it is, instruct the staff-bearer to move on for another convenient distance, and then position the staff so that the same reading can be observed through the level.

5. Pegs are driven in at each new position of the staff, and a line joining them will be horizontal.

To peg a graded or sloping line:

A line with a grade of 1:150 has a fall of 1 metre in 150 metres. This distance is too far to take an accurate reading, so it is convenient to divide it up into lengths of 15 metres, during which length it will fall 0,1 metre.

To peg a falling line:

Instruct the staff-bearer to move off for about 15 metres (paced out). Then sight on the staff as before, and record the sighting. The staff-bearer then moves off another 15 metres, and positions the staff so that the reading is 0,1 metre greater. This is recorded, and the process repeated.

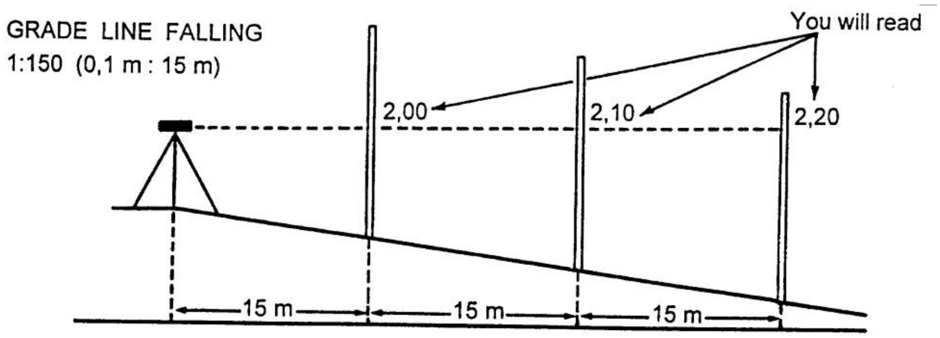


Figure 13.
Note: When a grade line *falls*, the reading on the staff *increases*.

To peg a rising line follow the same procedure, but position the staff to read 0,1 metre less every time.

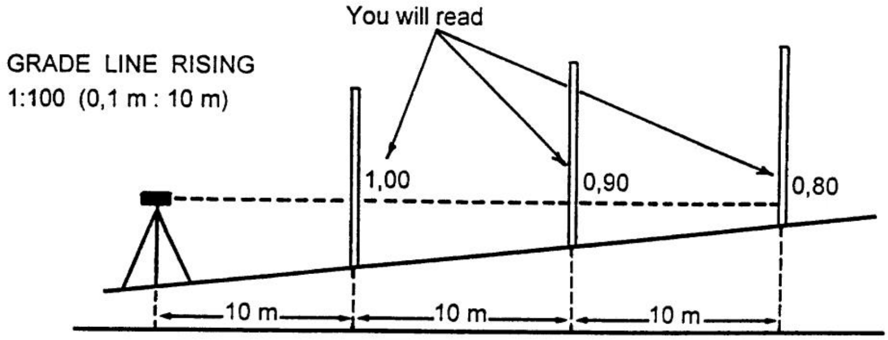


Figure 14.
Note: When a grade line *rises*, the reading on the staff *decreases*.

Moving the instrument

When pegging a line of any length, it will become necessary to move the level to a new position to ensure that the staff is kept in sight. Make sure that the staff-bearer stays in his last position while the level is moved nearer. Take a new reading on the staff, and then proceed as before.

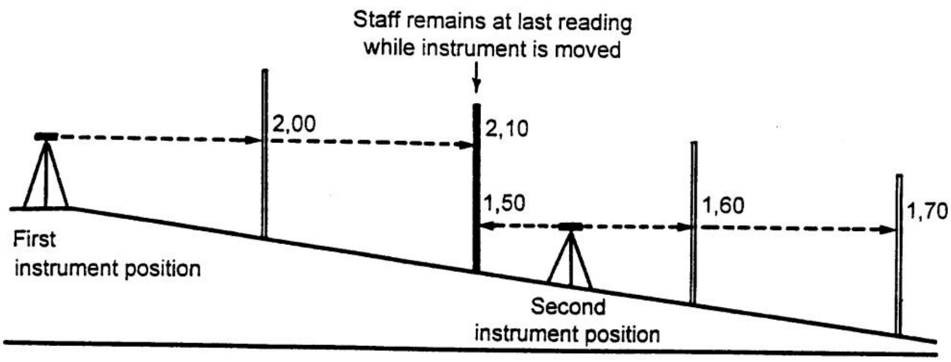
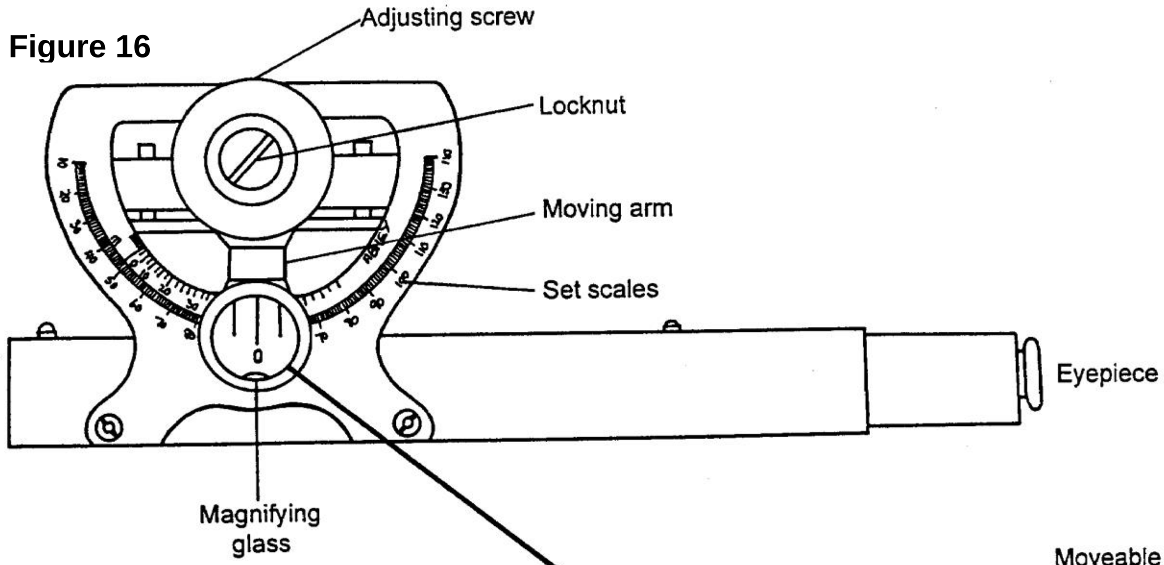


Figure 15.

THE ABNEY LEVEL

Figure 16



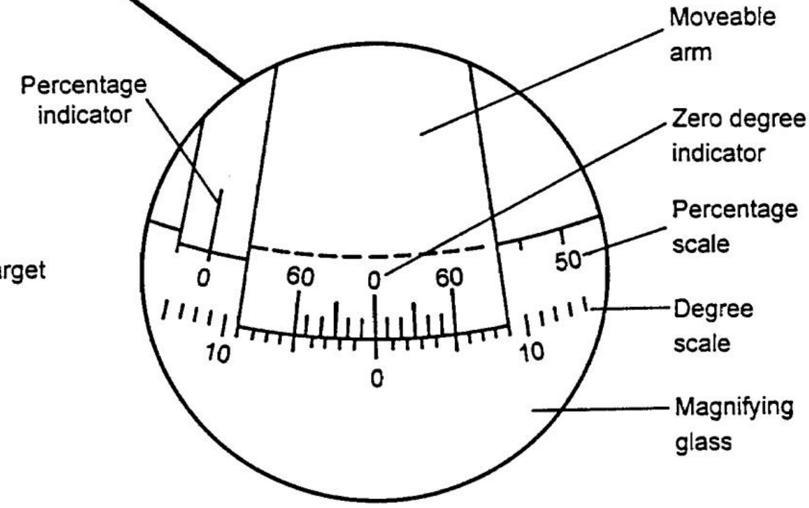
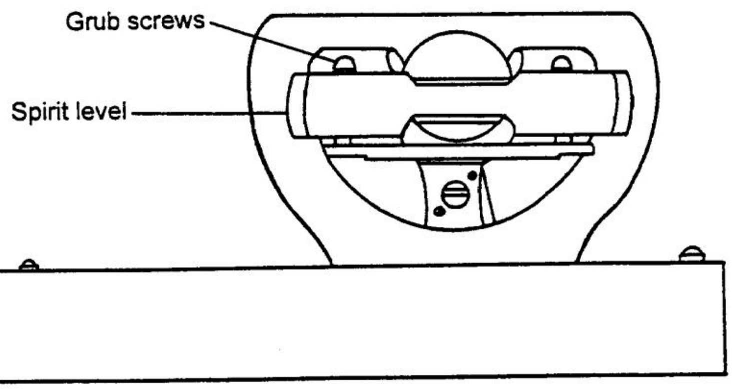


Figure 17

ACCESSORIES:

- Supporting rod
- Sighting rod with adjustable target
- Length of string

Figure 18



THE ABNEY LEVEL

The Abney level is simpler and quicker to use than the Tilting level, but is not as accurate or versatile, although it can be used in conjunction with untrained staff as the staff-bearer never gets out of earshot. An Abney level costs about R350 plus VAT.

Description

The Abney consists of a telescope and an adjustable tubular spirit level which is connected to a vertical scale marked out in degrees and percentages.

Setting up the Abney level

1. Rest the level on the supporting rod.

2. For the uses described below, ensure that the pointer on the scale is set at zero.

Viewing through the telescope

On looking through the telescope, one sees a horizontal index line and a reflected image of the tubular spirit level.

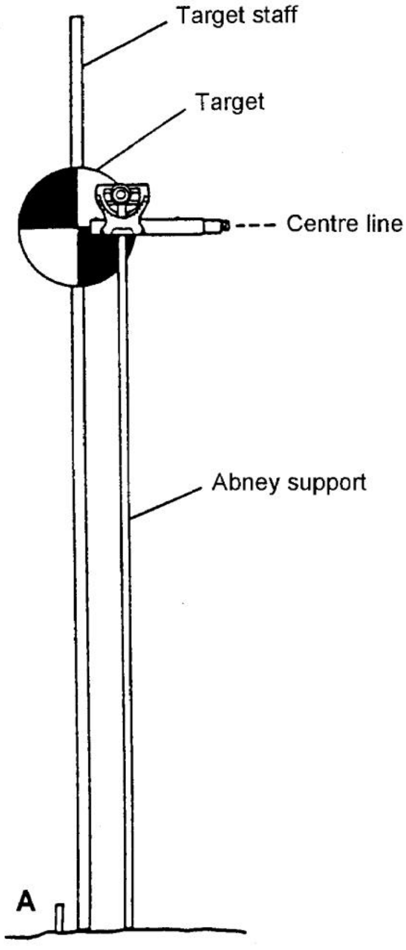


Figure 19

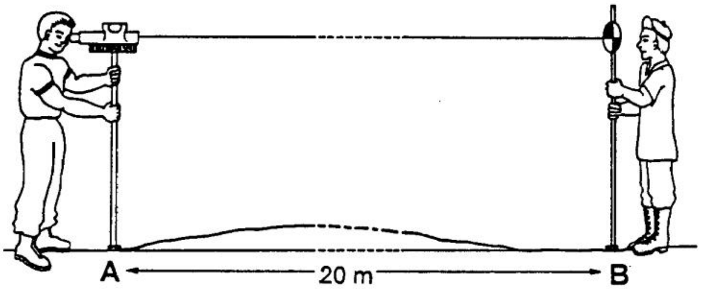


Figure 20

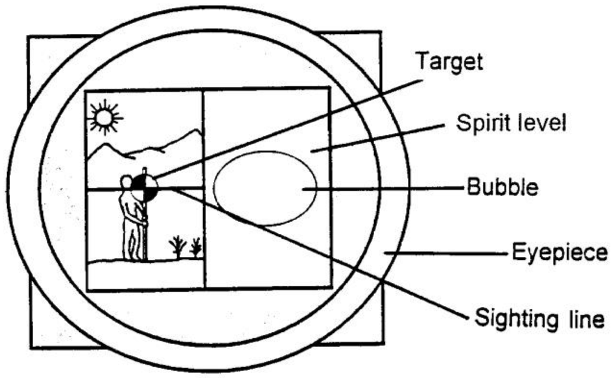


Figure 21

Setting up the target on the levelling rod

Make a mark on the reverse of the levelling rod at the same height as the Abney level when it is on the supporting rod. Other marks can be made according to desired grades.

CHECKING AN ABNEY LEVEL

1. Loosen locknut (Figure 16). Turn adjusting wheel to get '0' pointer on moving arm, in line with '0' mark on lower set scale. Tighten locknut.

2. Find a reasonably flat piece of ground with a hard surface, at least 20 metres long.

3. Mark a point 'A' on the ground with a peg. Place Abney on support at peg 'A', bring target staff alongside and adjust target to height of centre of Abney (Figure 19).

4. Send target staff off 20 metres (Figure 20). Sight through Abney. Move target staff up or down slope until target is intercepted as shown in Figure 21. Mark this with a peg as point 'B'.

5. Move Abney to 'B' and target to 'A'. If bubble, sighting line and target are still aligned (Figure 21), no error exists and the Abney can be used in the field.

6. If the bubble, sighting line and target centre are not aligned, adjustments must be carried out.

7. With Abney and target still at 'B' and 'A' respectively, turn target staff around to look at the reverse side. Line up bubble and sighting line. Then mark this intercept in pencil on the back of the staff ('Y' in Figure 22).

8. Measure the distance 'X' to 'Y'. Mark half this distance on the back of the staff, loosen target and bring to this mark.

9. Sight from 'B' to 'A' through the Abney and adjust the horizontal bubble on the Abney by using the 'grub' screws (Figure 18) until the bubble, sighting line and target centre are aligned.

10. Return the target to point 'X' (Figure 22).

11. Sight from 'A' to 'B' through the Abney. Move the target staff up or down the slope until the target is intercepted and mark this point 'C' with a peg.

12. Resight from 'C' to 'A' checking that the bubble, sighting line and target centre are still aligned. If this is correct then the Abney has been successfully adjusted and is ready for use in the field.

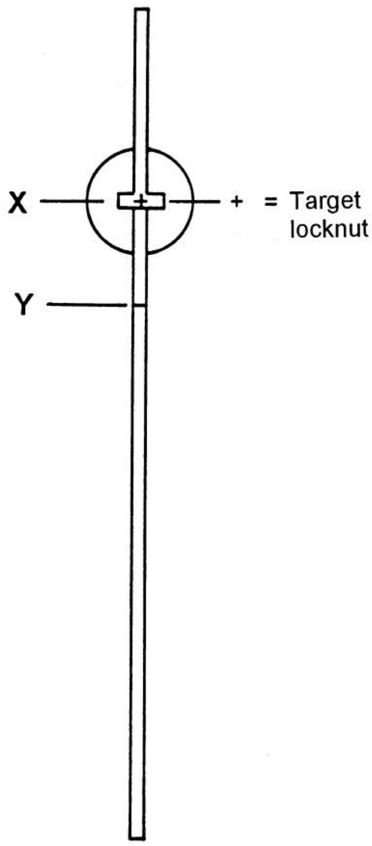


Figure 22

USING THE ABNEY LEVEL

To peg a level line:

1. Set up the level on the supporting rod.

2. Send off the staff-bearer to an appropriate distance away.

3. Set the tubular spirit level at ‘0’ on the scale.

4. Set the target on the staff to the marked height of the instrument.

5. Direct the staff-bearer to such a position that the index line viewed through the telescope coincides with the line on the target, with the bubble in the tubular level in the centre.

6. Have the position of the target staff pegged.

7. Move the level to the new position and repeat without altering the position of the target.

To peg a graded or sloping line:

1. Take a convenient length of cord or string. For example, for a slope of 1:200 (0,1 metre in 20 metres) use 20 metres of string.

2. Attach this cord at the same height to both the supporting rod and the target rod.

3. Make additional marks on the target rod. For example, for a grade of 1:200, mark a line either 0,1 metre above or below the original mark, depending on whether the grade will rise or fall.

To peg a falling line the target is moved to the line 0,1 metre above the original line. The staff-bearer moves off and, keeping the string taught, positions the target staff so as to line up the centre of the target with the index line viewed through the level, keeping the bubble in the centre. He then drives in a peg and moves on, while the level is repositioned at the place he has just left.

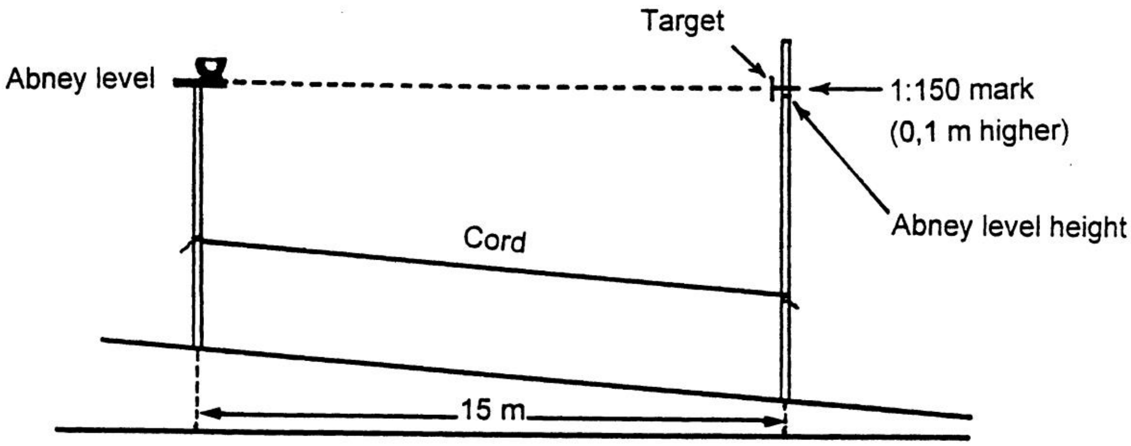


Figure 23.
Note: When a grade line *falls*, the target is set at the *higher mark*.

To peg a rising line set the target at the line 0,1 metre below the original line, and proceed as before.

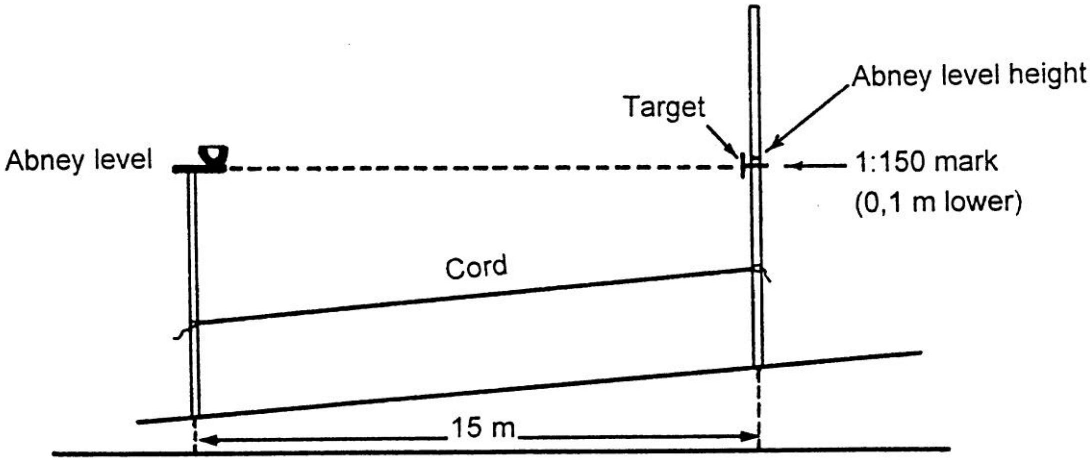


Figure 24.
Note: When a grade line *rises*, the target is set at the *lower mark*.

HOW TO LOCATE A WATERWAY USING EITHER AN ABNEY OR TILTING LEVEL

1. Peg a level line across the lowest part of a natural depression.
2. The line will be V-shaped, with the apex of the V pointing uphill. Remove all the pegs except the one at the apex.
3. Repeat the process, working uphill. The line of pegs marking the apexes will mark the waterway.

CONSTRUCTION OF STRUCTURES

Terrace construction

The following is a guide to the construction of terraces and storm water drains, using implements commonly found on sugarcane farms.

The examples outlined are well tried methods, but they can be adapted by growers to suit their own conditions.

SLOPES OF UP TO 15%

Using a 2-furrow reversible disc plough (see Figure 25).

SLOPES STEEPER THAN 15%

Using a blade terracer or bulldozer

1. The first cut is taken with the blade tilted into the slope and its upslope corner on a line ‘B’, which is 3 m upslope from the pegged grade line ‘A’. Soil is thrown down the slope.

2. For cut 2, the blade is tilted so that it removes the bank left by cut 1 and dumps the loose soil into the cut made.

3. Cut 3 moves the soil heaped by cut 1 further down the slope and deepens the channel.

4. Cut 4 moves the soil heaped by cut 2 downslope into the cut left by 3.

5. Cut 5 moves the heap left by cut 4 onto the previous heaps.

6. Cut 6 deepens the channel, forming a heap of loose earth downslope of the blade. The blade is tilted so that the base of the channel is angled into the slope slightly.

7. Cut 7 removes the high bank left by cuts 4 and 6.

8. Cut 8 commences with the upper edge of the blade running along line ‘B’ and, followed by cuts 9 and 10, moves soil heaped by cuts 5, 6 and 7 progressively down the slope to form a cambered road.

On very steep slopes it may be necessary to work downhill at first, due to excessive crabbing of the tractor. This results in an improved bench terrace. A shallow layer of soil is borrowed from the field up to 17 metres above the road line and moved downhill onto the road line pegs. This provides a bank on which the tractor can work across the slope to shape the road and channel.

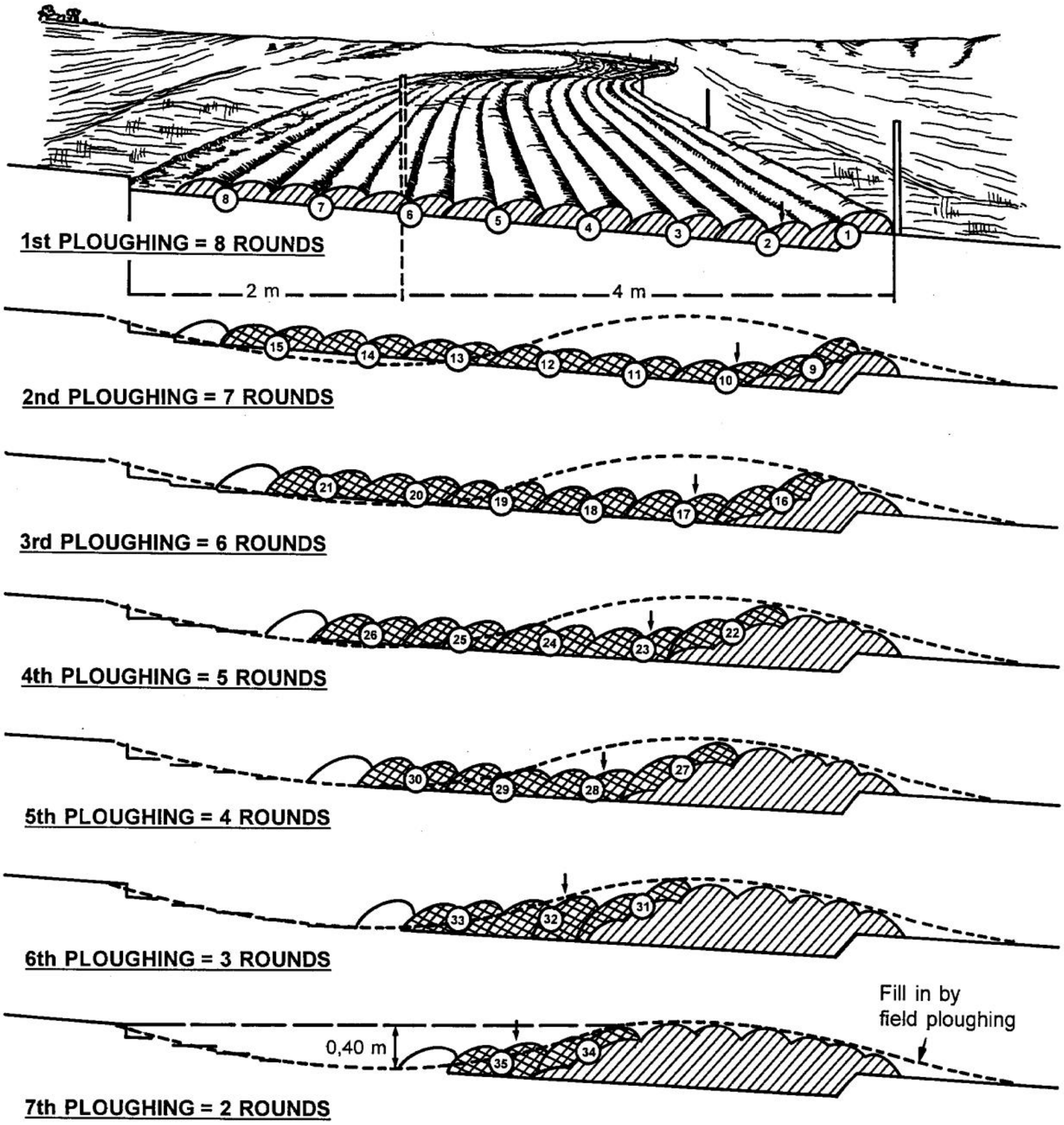


Figure 25. Method for terrace construction, ploughing from the upper side only.

Method after setting channel stakes: set a second row of stakes at 15 m intervals, 4 m below channel stakes. This row marks first ploughing. Use a two-furrow reversible plough.

Waterway construction

After locating the waterway, the specified width pegs are located opposite each centre line peg.

(a) **Using a reversible plough**

Start ploughing from the top end of the right hand side width line going down the slope, turn at the bottom end and plough up along the same width line. Make a shallow cut, moving in a high gear to fling the soil as far away from the centre line as possible. Continue ploughing until the centre line is reached.

Repeat the same procedure on the left hand side. After completing the left side, return to the right side and continue the process until the required depth and base width is reached.

On the second pass, and all subsequent passes, straddle the soil from the first pass, second pass, etc. to ensure the movement of soil away from the centre line without building up large shoulders along the width lines.

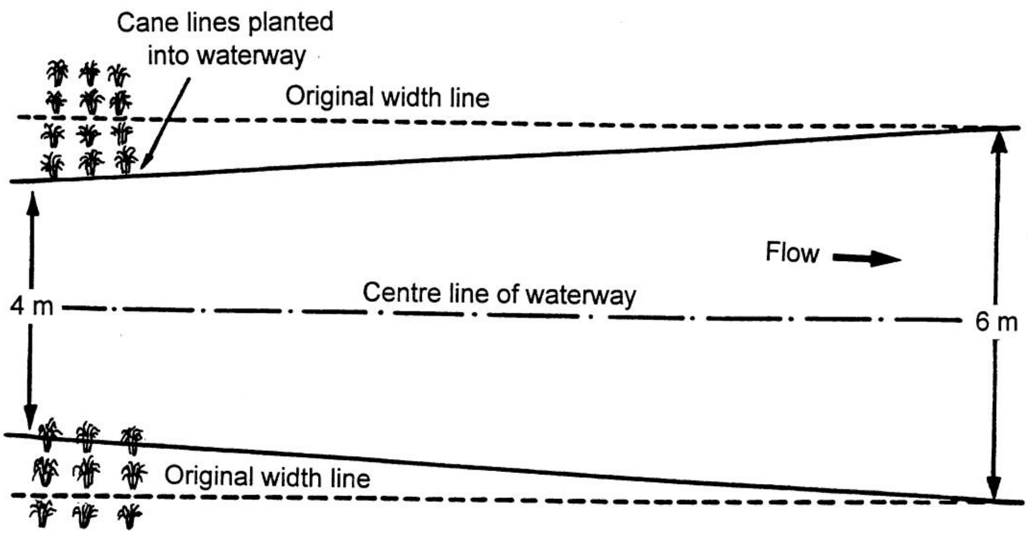


Figure 26.

Once the waterway has been completed and stabilised, the cane lines can be pulled into the waterway at the top of the waterway to give the required waterway dimensions (Figure 26).

For example:

Top width = 4 m
Base width = 6 m.

(b) **Using a bulldozer**

Where slopes are too steep for a tractor and plough to negotiate up and down, a bulldozer can be used to construct the waterway, cutting outwards from the centre line across the slope (see Figure 27).

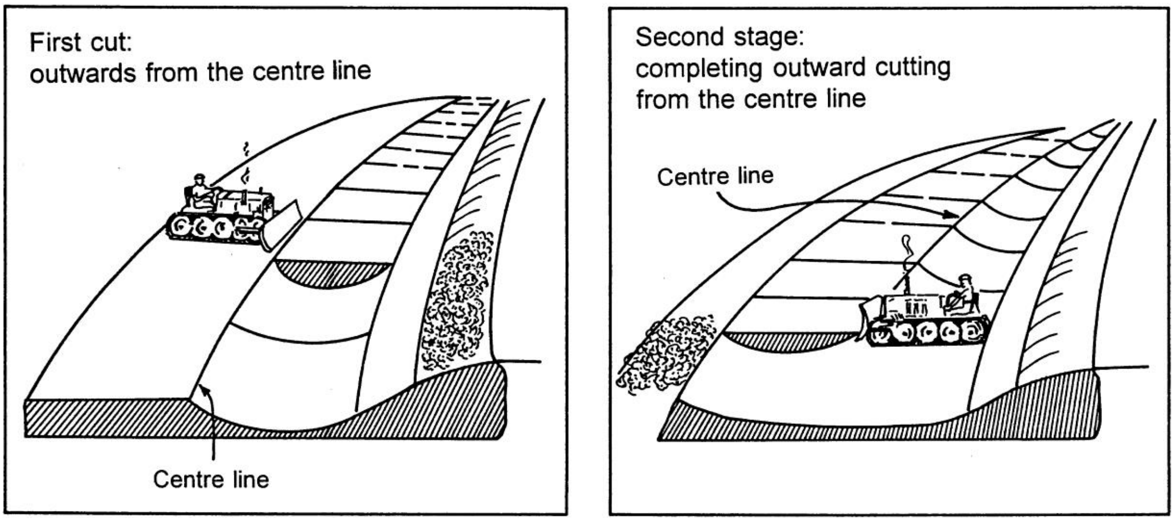


Figure 27.

(c) **Using a dam scoop**

The dam scoop is used to remove soil to the required depth, and depositing this soil in the field, i.e. in low spots. This method is ideal for large waterways where using a plough would be expensive.

Revets

Water checks made from bundles of cane tops fastened in rows across the waterway, with their butt ends facing upslope, are very effective (see Figure 28). Flow is retarded without being dammed, as the water runs over the leaves downstream. Each bundle is conveniently secured in place by wooden pegs driven through them into the ground. The revet should not be of a permanent nature.

Establishment

Directly after a waterway has been shaped, it should be planted with a suitable grass or with strips of grass (*Cynodon* or *Stenotaphrum* species). Aim to produce a suitable grass cover before the summer storms. A useful technique is to peg grass runners into the ground with forked sticks (Figure 29).

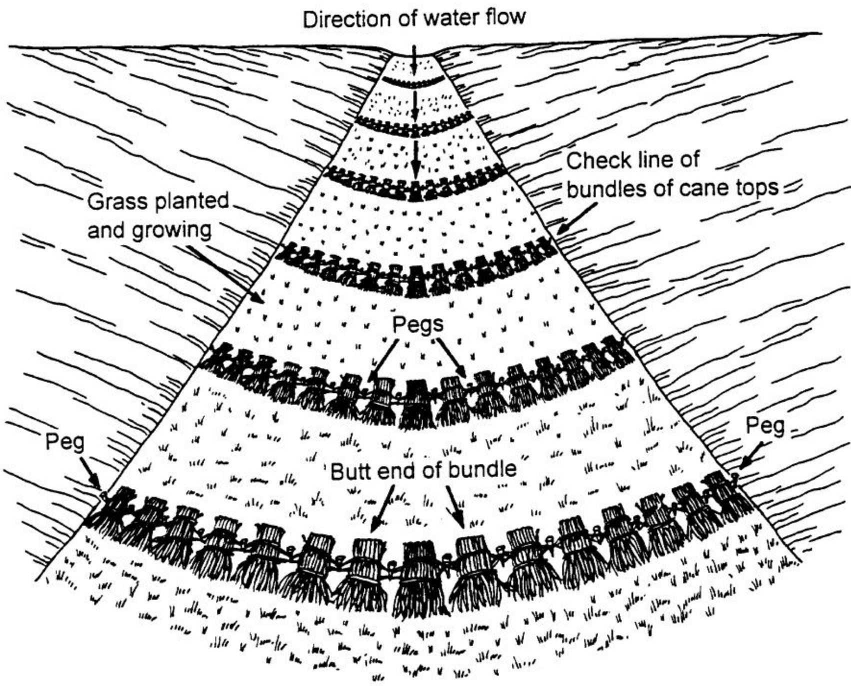


Figure 11.

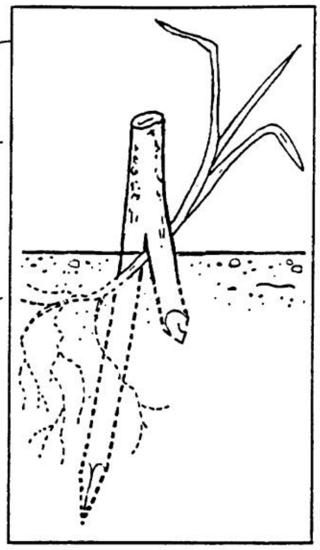


Figure 12.

Row alignment

When all the required conservation works have been constructed, the field can be laid out for planting. The location, alignment, and type of infield terraces influence the choice of row alignment. Thus, while rows could traverse broad-based terraces quite easily, a similar layout could obviously not be adopted in the case of bench terraces.

Parallel terraces

The need for total mechanisation may call for the construction of parallel terraces by extensive land-forming operations or other sophisticated techniques. In such cases row alignment presents no problems.

Master line method

This technique involves planting in the direction of flow of the conservation terraces and is based on the premise that each individual row or interrow will drain freely into a terrace channel or waterway. It also creates the smallest possible number of short rows, all of which start either from a crest road ending in a terrace channel, or from a terrace bank ending in a waterway. The maximum number of complete rows between terraces is therefore obtained by this method.

A master line can be pegged between two terraces by one man and three assistants (Figure 30). Two assistants, holding the ends of a length of light rope or strong cord, walk along adjacent terraces, starting at the crest and moving towards the waterway. The rope in each case stretches to a man walking in the centre of the panel. The assistants on the terraces must ensure that their line is kept at right angles to the contour and reasonably taut.

The man in the centre establishing the master line moves between the two men on the terraces. He usually starts close to the upper terrace, if ridging equipment is adjusted to work down the slope, or close to the lower terrace if the reverse is true. As the terraces converge, the man in the middle maintains his distance from the upper terrace by taking in slack line with his lower hand. As they diverge he keeps the lower part of the line taut while playing out line with his upper hand.

Pegs are put in by a third assistant, 20 to 30 metres apart, along the line followed by the marker. This line of pegs is the 'master' line and can easily be followed by the tractor driver when drawing the first planting furrow. All other planting furrows are drawn parallel to this one.

When ridging out planting lines it is beneficial to curve the ridges up the slope when emerging from the field onto a crest road, and down the slope to a waterway. This improves road drainage and avoids ponding between lines at the waterway end.

On slopes where construction of broad-based terraces is feasible, the 'master' line technique may be adapted to facilitate mechanisation. This is accomplished by pegging master lines to peg a 'grand master' line. All planting lines are then drawn parallel to this, so reducing the number of short rows, while planting continues right across the terrace in between.

Flat cultivation

This implies no deep furrowing or ridging for either the plant rows or interrows and involves only the formation of a shallow depression left by the press wheel of the mechanical planter. This technique may be especially desirable in the interests of total mechanisation over broad-based terraces. In fields of regular configuration, short rows are eliminated entirely and the terraces alone take care of inter-terrace run-off.

One method of aligning rows is to establish a 'grand master' line for the whole field by means of trial pegging and adjustment. Curvature of parallel rows often needs adjustment as well and this may entail changes in gradient.

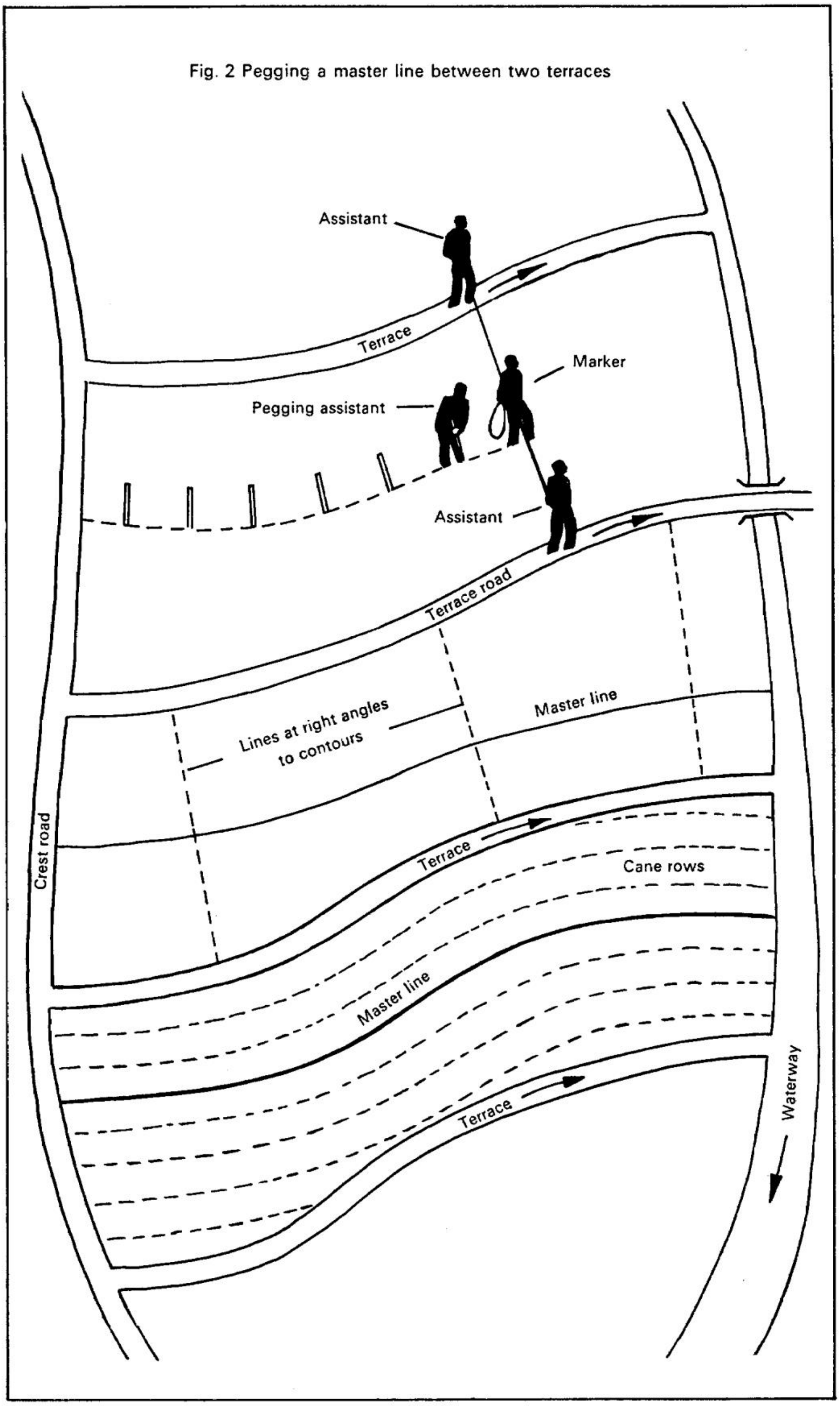


Figure 30. Pegging a master line between two terraces.

CONSTRUCTION COSTS
FOR CONSERVATION WORKS AND FARM ROADS

The following figures can be used as guides in determining construction costs.

1. **Terraces**, using a 58 kW tractor and reversible two-furrow disc plough

Annual tractor utilisation	=	800 hrs
Length of terrace construction	=	2 000 m
Rate of work	=	0-15% slope - 3 hrs/100 m
		15-25% slope - 4 hrs/100 m

2. **Waterways**, using a 58 kW tractor and reversible two-furrow disc plough

Annual tractor utilisation	=	800 hrs
Length of terrace construction	=	1 000 m
Rate of work	=	0-15% slope - 1½ hrs/100 m
		15-25% slope - 2 hrs/100 m

Shaping of the waterway, using a grader blade

Rate of work: 2 hrs/100 m

NB. Should a different tractor/plough combination be used, these costs will vary.

3. **Roads**

(a) Crest roads - the cost of building crest roads using a tractor and two-furrow reversible plough will be the same as costs for terrace construction on 0-15% slopes.

(b) Diagonal roads - the cost of building diagonal roads using a tractor and two-furrow reversible plough is the same as costs for terraces, but an additional amount of 30% should be added to those figures due to the maintenance of the channel.

Generally, conservation works will occupy about 10% of the cane area, and will cost in the region of 7% of the total production. For example, a farm yielding 10 500 tons will require about 735 tons of cane to pay for the **total** implementation of the Land Use Plan. This cost would normally be spread over a 10-year period.

SECTION 3

DRAFTING A LAND USE PLAN

INTRODUCTION

In order to obtain maximum economic crop production it is necessary to relate agronomic practices and mechanisation to the climate and topography of a farm unit. The optimum cane yields obtainable on different soil types and from different land use classes are seldom the same. Strong, deep dolerite soil will have a better potential for crop growth than a shallow granite soil. Valley bottom areas with deep wet soils produce more cane than areas of shallow soil on hilltops. The sugarcane grower has to recognise that different parts of his farm require different types of management and he must integrate these into a balanced working plan, whereby each unit of land produces its economically optimum yield. With all the variables in sugarcane growing to consider, it is essential to follow a prepared plan.

**The preparation of a Land Use Plan will cost less than 0,5%
of the total cane production,
but will contribute to improved yields by at least 5%.**

Steps in farm planning

The four main steps involved in the preparation of a farm plan are:

1. Complete farm assessment
2. Setting objectives and targets
3. Final physical plan
4. Implementation programme.

1. COMPLETE FARM ASSESSMENT

(a) Initial planning tools

Aerial photographs - can be used to provide a three-dimensional assessment of the farm. The entire sugar industry has been photographed at a scale of 1:30 000. Enlargements of these contact prints give an approximate scale of 1:6 000. Because of distortions within these photographs they cannot be used for measuring exact areas.

Form line maps - stereoscopic models are prepared from aerial photographs. All distortions occurring in individual photographs can be eliminated by these means. Stereoscopic interpretation permits lines of equal elevation at 10 m vertical intervals (form lines) to be drawn. These are true to scale and represent specific elevations in relation to known reference points (Appendix 1).

Converging form lines indicate that slopes are increasing in steepness; diverging form lines indicate that slopes are decreasing in steepness. Form line maps permit an interpretation to be made of the topography, and they can be used to establish where crest and drainage lines occur.

Quota maps - produced from aerial photographs, these maps at a scale of 1:6 000 show field boundaries, cane breaks and other physical features. They are true to scale and show field numbers and sizes (Appendix 2).

Form line development maps - the combination of the form line map and the quota map gives a map from which slopes and topography changes can be measured for individual fields. The positions of roads can be checked, and modified where necessary to follow gradients suitable for crop extraction.

Orthophotography - by using sophisticated cameras and other equipment it is possible to scan a stereoscopic model and produce an orthophotograph which is free of distortion. By printing or scribing farm lines onto the photograph an ortho-map is produced. It has the visual appearance of a photograph but is true to scale.

Soil maps - produced from soil surveys of the sugar industry carried out by Dr Beater, these maps at a scale of 1:6 000 show soil parent materials and are used to determine erodibility classes for calculation of vertical intervals in terrace spacing (Appendix 3).

(b) **The present situation**

Records are needed of:

- Slopes
- Planting method
- Soils
- Herbicides
- Climate
- Harvesting
- Field boundaries - field sizes
- Cropping details - ratoons, number and age in months
- Crop records - past performances, tonnage cut, age at cutting
- Daily quotas
- Present extraction methods and routes
- Present methods of operation
- Mill details.

(c) **Analysis of the situation**

Having collected all the information about the farm, it is now possible to analyse it and determine the potential of the farm. If large areas of flat hilltops occur, with gently sloping hillsides, it may be possible to lay out a parallel system to fit the present mechanised operations better than the existing layout. It might be that a minimum tillage system would be suited to an area where steep slopes and poor soils predominate; or it might be that there are large areas of good valley bottom land which would be better suited to a separate management system. From the analysis it is possible to establish a **potential** for the farm.

The **potential** is the maximum possible production which can be attained from the unit which is being studied, if all the factors like rainfall, temperature, crop husbandry or management, field layout, mechanisation or labour utilisation are at their highest possible level. In an industry where the potential is in the region of 9 tons per annum per 100 mm of rainfall, and the recorded average is between 4 and 5 tons per annum per 100 mm rain, there must be a lot of room for improvement on the majority of farms.

2. SETTING OBJECTIVES AND TARGETS

These will vary from farm to farm, but should always be defined. They might not be aimed at getting the farm up to potential but they must be clear in the grower's mind, so that he has a goal and can start planning how to achieve his objectives.

Let us assume that a grower has set his **objective** as getting the farm to produce its **potential**. Decisions must now be made, using the available data on the farm, as to what **physical plan** and **production plan** should be used.

(a) Physical plan

The first step will affect the second. Generally the physical plan will to a large extent be dependent on the topography and soils present, and to a lesser extent on the region. From the form lines and soil maps, a decision in this respect can be made. Obviously, items other than these two will have to be taken into account; these being factors such as total size of the farm, available machinery or cash, which will play a part in the decision as to which system to use. If the Production Plan envisages the use of minimum tillage or strip cropping, it will affect the spacing of structures to some extent, but not the type of layout to be used.

(b) Drawing the plan

The major components of the physical plan such as waterways, terraces and roads, are drawn onto the form line map.

Requirements:

- Quota map
- Photograph - enlarged to 1:600 or contact prints
- Soils map
- Form lines or orthophoto
- Clear overlay (tracing paper).

First step

The clear overlay is placed over the quota map. The farm boundary and ‘no cane’ areas are highlighted. The overlay with this information on is removed.

Second step

The overlay is now placed over the form line map or, if available, the orthophotograph, and secured with adhesive tape.

(i) Measuring the slope

The average slope is measured as a percentage by finding a set of uniform form lines. The surface interval (horizontal distance) is measured from the top form line to the bottom form line.

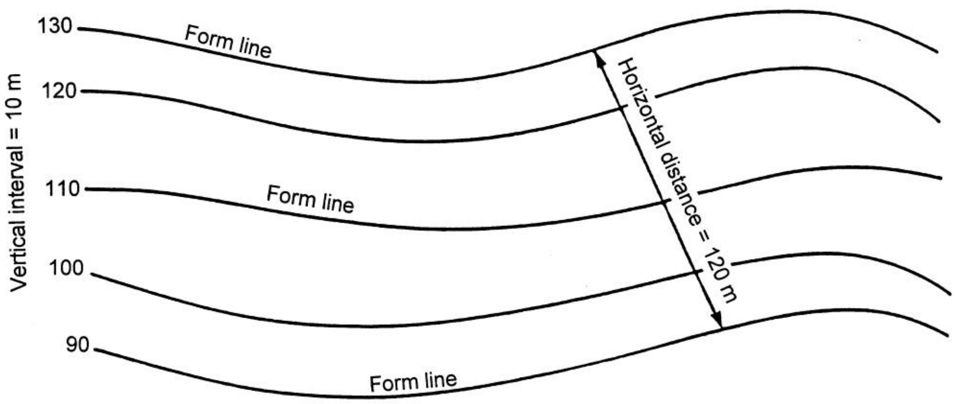


Figure 31.

The vertical interval is measured. This is the vertical distance between the top form line and the bottom form line.

The formula Fall ÷ Distance x 100 is then used to calculate the % slope.

Example:

Fall	=	40 m (VI)
Distance	=	120 m
$\frac{40}{120}$ x 100	=	33%

(ii) Drainage lines

The major drainage lines are seen on the map as indentations in the form lines towards the crest areas, with the drainage line cutting the form line on the apex of each form line curve. Each of the natural depressions will have a grassed waterway sited along its length and the decision as to its necessity will be taken on the farm visit.

(iii) Crest lines

The major crest lines are drawn onto the overlay, especially those that have a 10% slope and less, as these could be ideal areas for positioning crest roads.

(iv) Crest areas

Large flat crest areas are isolated, and parallel strips running along the length of these crests are sited. These parallel strips can be sited on slopes of up to 8% provided the soils are strong and trashing is practised.

(v) Valley bottom areas

Define areas of different management categories. For example, the valley areas where slopes are flat, generally alluvial and mostly wet, and the hillside areas where soils are shallower and drier. The slope changes are indicated by a widening of the form lines. These areas are cut off from the hillside areas by the valley bottom cut off roads (VBCOR), which are not at any particular gradient, but merely follow the breakpoint of the slope. They are spill-over structures carrying no water.

Third step

Terraces: The soils map and % slopes previously calculated are used to determine the terrace spacings. The soils are broken up into three main categories: resistant to erosion, moderately resistant and susceptible to erosion. By deciding the soil category of the farm and looking at % slope, the nomograph can be used to set panel spacing for the options available (Figure 32).

With this information it is now possible to mark the terraces on the overlay. The form lines shown on the map represent a true horizontal line giving points of equal elevation. Therefore, a graded terrace bank designed to carry water will gradually diverge from the form line as it goes towards the waterway. With an average gradient of between 1:100 and 1:150, terrace banks will drop 1,0-0,7 m for every 100 m of length (Figure 33).

Roads: Crest roads follow crest lines until they become steeper than 8%. For cane to be extracted satisfactorily from steep areas it becomes necessary to maintain this grade in the form of diagonal roads. At a slope of 8%, the horizontal distance between 10 m vertical interval form lines is 120 m. As the form lines come closer together, indicating a steepening of the slope, the only way that the 120 m length can be maintained is by angling the road across the slope.

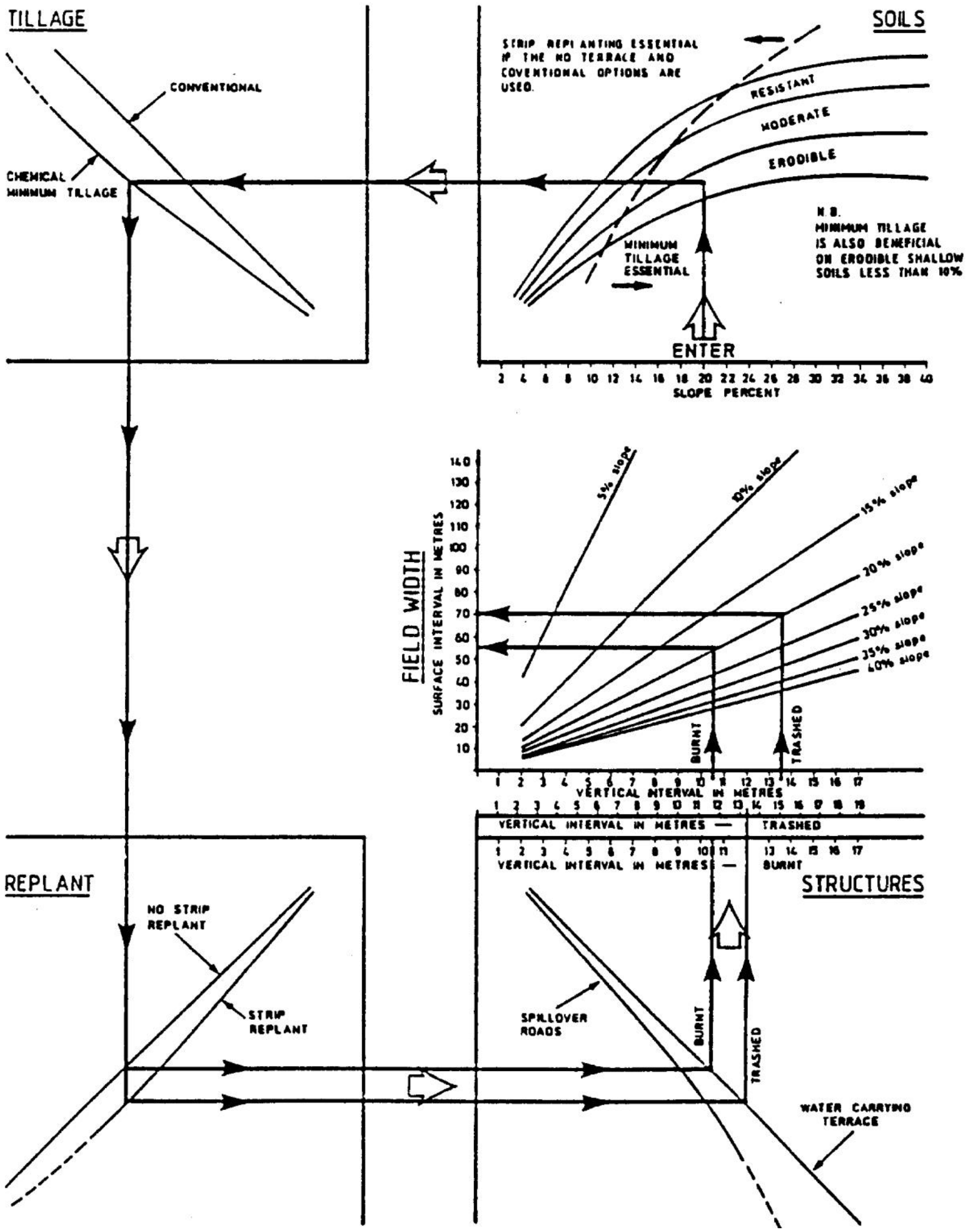


Figure 32. Nomograph for sugarcane field spacing.

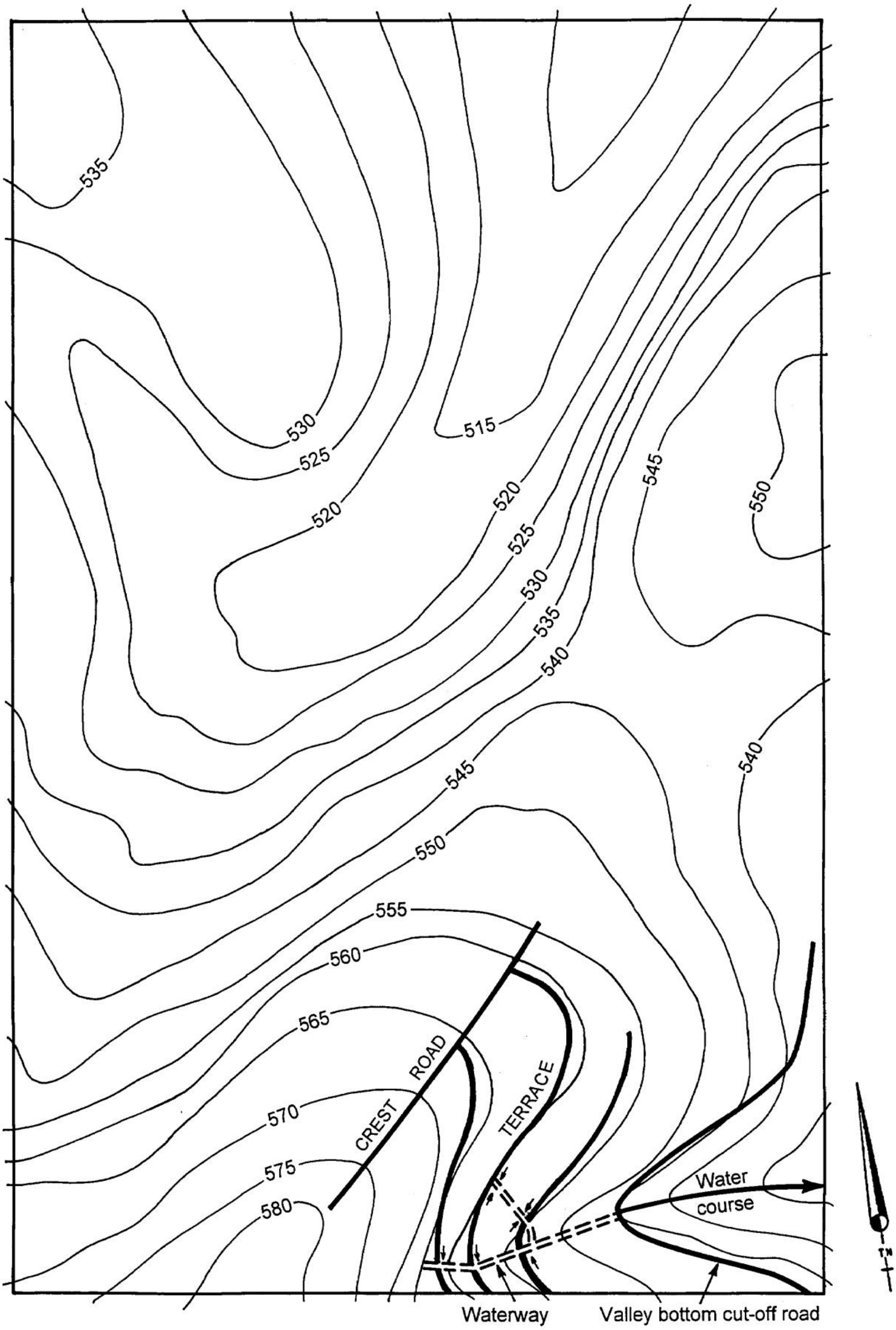


Figure 33. Form lines (scale 1:6 000).

Extraction routes: The position of diagonal extraction roads will depend on various factors. These are specific to each farm and need assessing at the time that the farm is planned.

(c) **The Production Plan**

In most cases different potentials exist for different areas on the farm. If a factor such as large areas of wet valley bottoms has influenced the layout, then these areas must be taken care of by differing management methods in the **production plan**. Look at the physical plan and set targets.

Targets

Let us assume that a farm has been analysed and it shows that:

97	hectares are Hilltops
180	hectares are Hillsides
60	hectares are Valley Bottoms
337	hectares Total

From all the available information the best yields will be obtained from the following:

Hilltops:	use variety 'A'	cut at 20 months of age
Hillsides:	use variety 'B'	cut at 16 months of age
Valley Bottoms:	use variety 'C'	cut at 12 months of age.

The present management of ratoons is good but, by using better seedcane and planting in spring, at least one extra ratoon could be expected above the present average of five (Appendix 5).

Variable and unforseen conditions will play a part in modifying the cane growing cycle. Heavy or light rains, incidence of pests and diseases, and reductions in quota could all have an effect on whether the target is achieved, and could throw the cycle out of balance.

At all times the aim must be to set realistic targets and to try for a balanced yearly operation. If a large replant programme is undertaken in one season, its effect will be felt at other times during the crop cycle.

3. CHECKING THE PHYSICAL PLAN

Before the plan can be accepted, it must be compared with the original layout to see if it represents a real improvement. In cane farming operations, transport and infield work are two major items that need to be considered. The effects of improved soil protection and any change in the area under cane must also be assessed.

(a) **Transport efficiency**

Using the quota map, the yield likely to be obtained from each field must be set. Cane row alignment within each field can be drawn on the map. Extraction roads are now also drawn, together with suitable loading zones. Where single loads are hauled to a transhipment zone, the siting of these zones is often critical.

In most situations, distances to the zone should not exceed 1 km when hauling single stacks. For double stacks, a 2 km haul should be the maximum. The distance along the cane row from the centre of the field to the nearest road, added to the distance measured along the most practical route to the loading zone, provides an estimate of the average haulage distance from the field to the zone.

Multiplying estimated yield by this distance gives an estimate of the transport requirement in tons-kilometre. The sum of these products for all fields gives an indication of the total work to be done in moving the crop.

This exercise should be carried out for both the old and the new layout, and a comparison made between the travel distances.

(b) **Infield machine efficiency**

The time spent by machines in a field on productive work as a proportion of total time (including turning time) gives an index of machine efficiency for that field. This ratio is called the Field Machinery Index (FMI).

$$FMI = \frac{Pt}{Pt + Tt}$$

where Pt = production time
Tt = turning time

For a constant field area, the FMI increases as the average row length increases. This can be affected by changing the shape of the field. Irregularly shaped fields generally cause the FMI to be lower than it would be in fields that are laid out on the contour and have fairly long, approximately parallel sides.

(c) **The final plan**

The plan after assessment and with extraction routes included is now ready for final draughting (Appendix 4).

4. IMPLEMENTATION

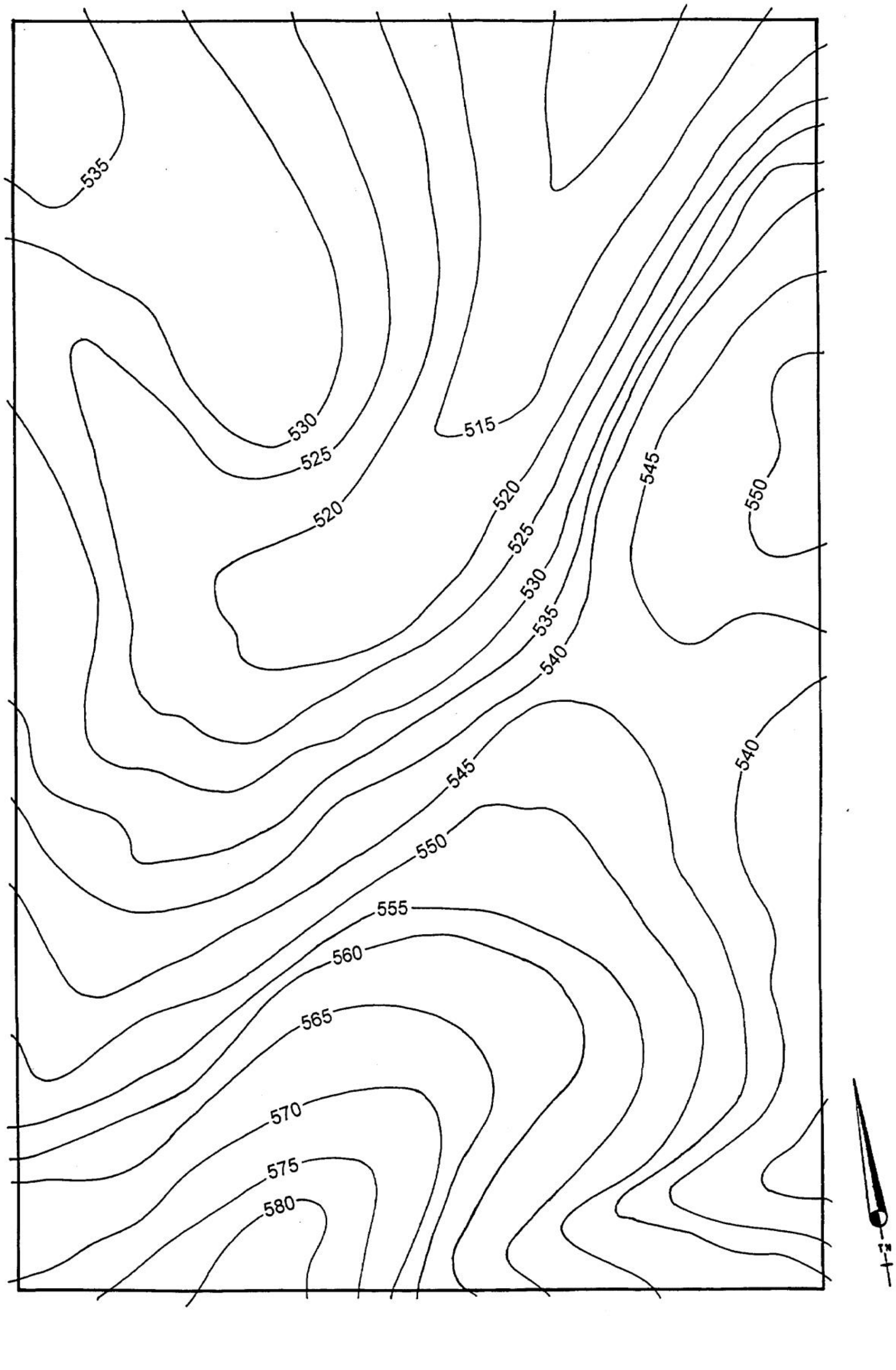
The implementation of a plan will take a number of years, and will depend on various conditions. Certain aspects of the layout, such as some of the structures and waterways being established as fields are cut and ploughed out, will influence the time taken to complete implementation. If a structure has to be left incomplete because it connects up through a field of standing cane, it can be finished off when that field comes round for re-establishment.

There are a lot of works which will be dependent on Ratoon Management factors such as the Cutting Programme and Replant Programme. With the use of overlays, specific decisions can be taken as to which area can be worked on, keeping the targets in mind. Some fields may have to be ploughed out prematurely to fit in with the change in layout, and to tie up with a block already due for ploughout.

The total works involved must be analysed and then an Annual Work Programme set.

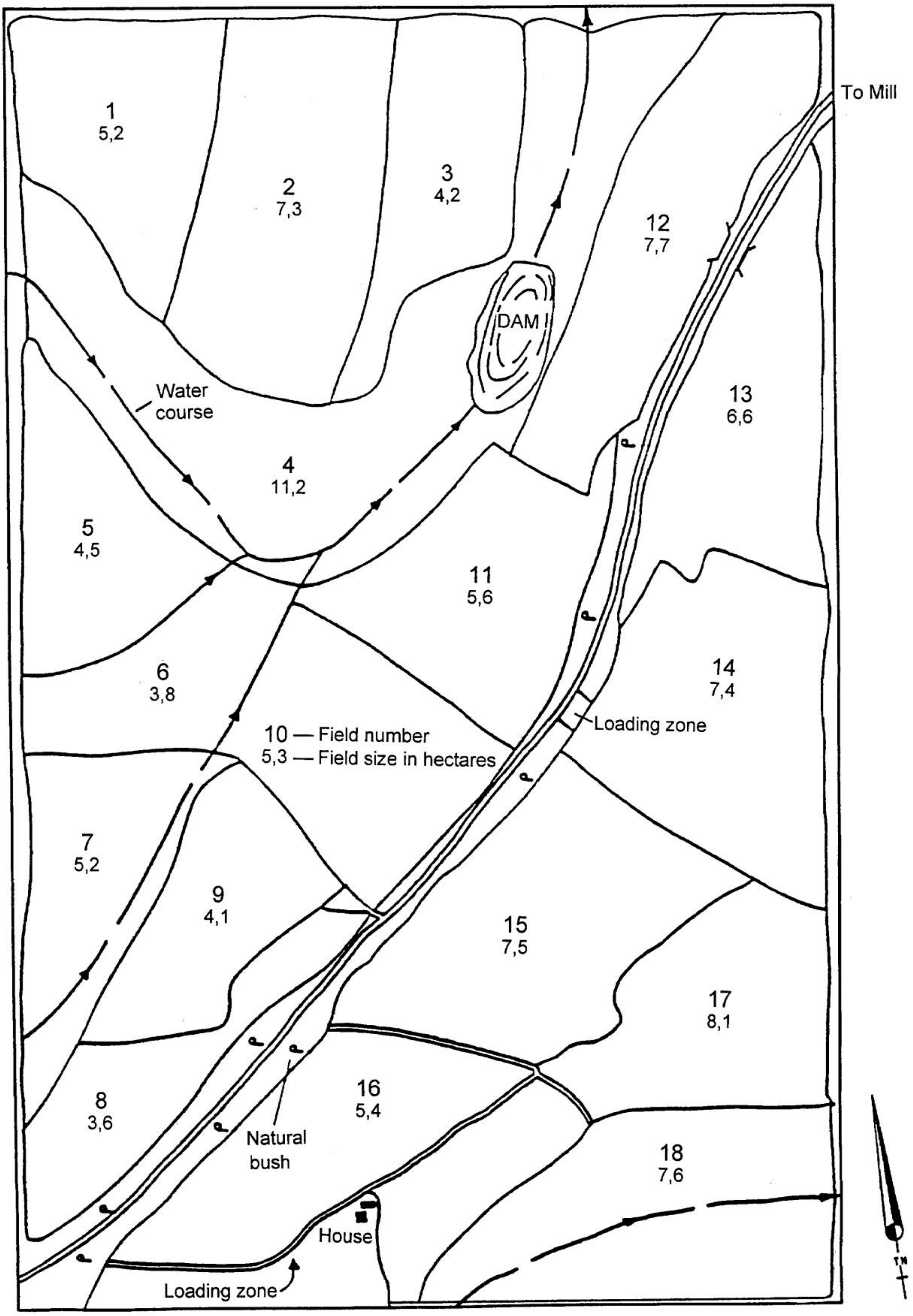
APPENDIX 1

FORM LINES (scale 1:6 000)



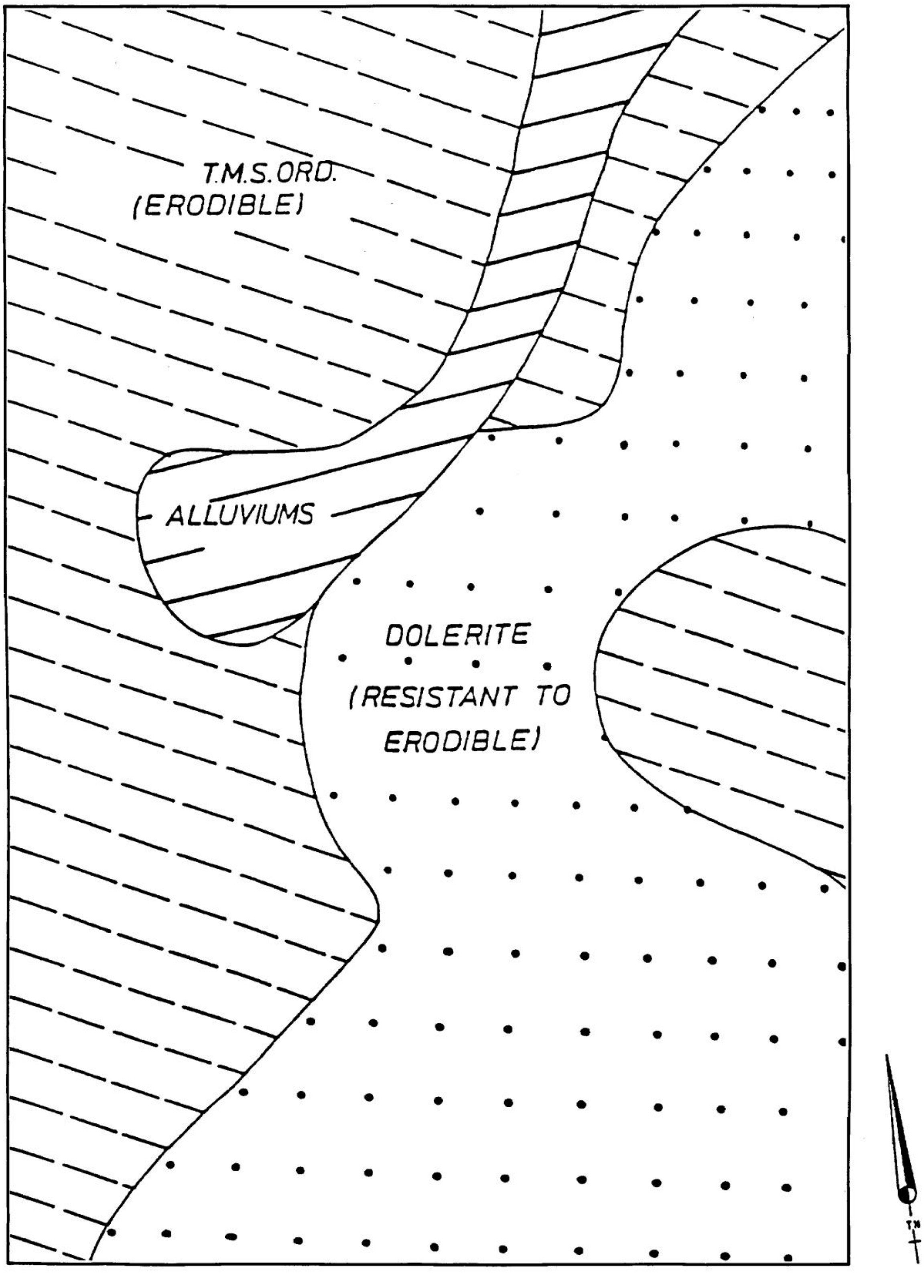
APPENDIX 2

QUOTA MAP (scale 1:6 000)



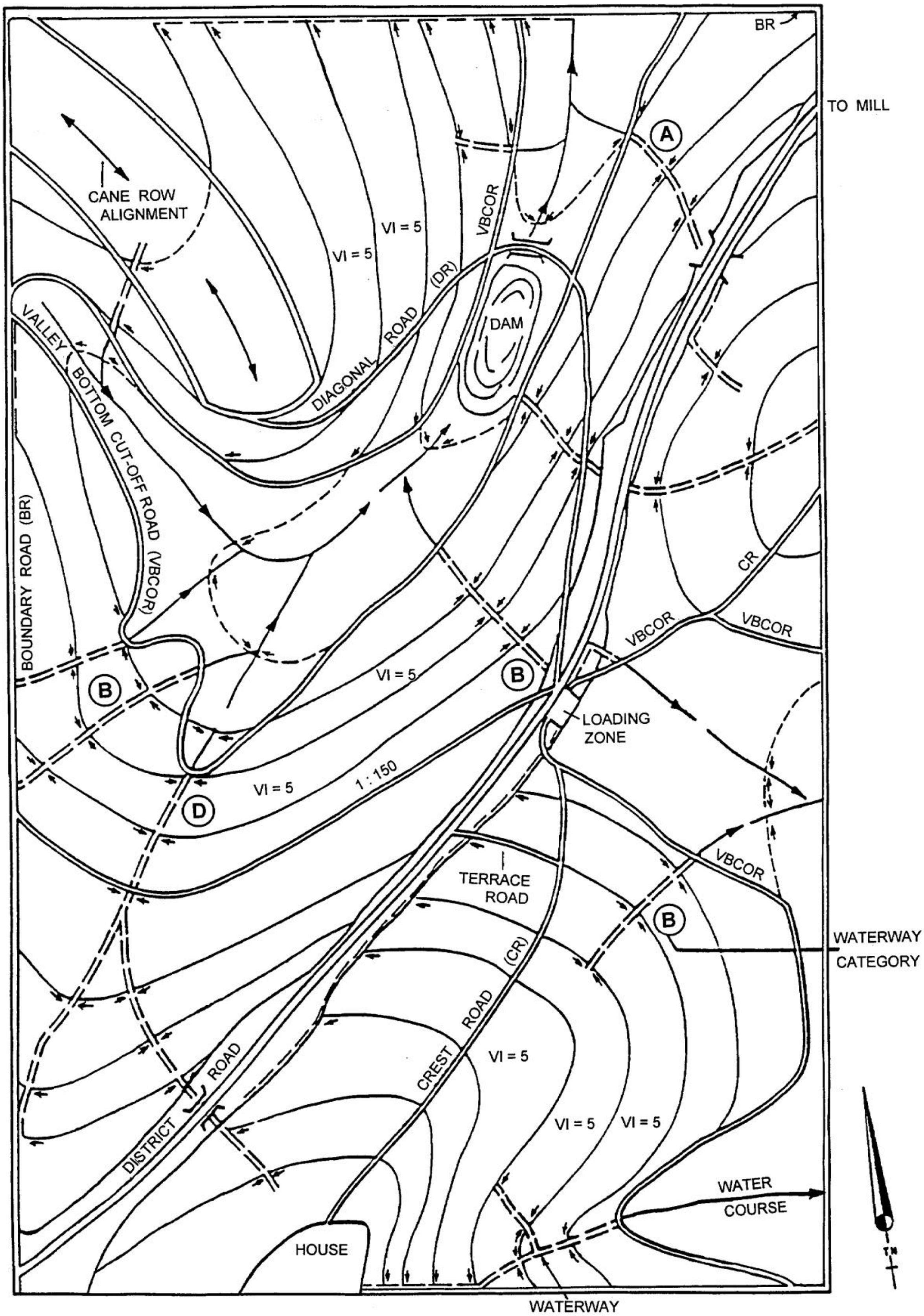
APPENDIX 3

SOIL PARENT MATERIAL (scale 1:6 000)



APPENDIX 4

LAND USE PLAN (scale 1:6 000)



APPENDIX 5 : TARGETS

HILLTOPS

97 hectares of 337 ha = 29% of total area
at 20 months cutting average, with 7 crops.

$\frac{7 \times 20}{12}$ = 11,7 years + 4 month fallow = 12 year cycle

Annual cut (7 crops in 12 years) = $\frac{7}{12}$ = 58,3%

or 58% of 97 ha = 56 hectares cut annually.
Annual replant crop cycle from above = 12 years.

$\therefore$ Replant should be $\frac{97}{12}$ = 8 hectares replanted annually.

HILLSIDES

180 hectares of 337 ha = 53% of total area
at 16 months cutting average, with 7 crops.

$\frac{7 \times 16}{12}$ = 9,3 years + 4 months fallow = 10 year cycle

Annual cut (7 crops in 10 years) = $\frac{7}{10}$ = 70%

or 70% of 180 ha = 126 hectares cut annually.
Annual replant crop cycle from above = 10 years.

$\therefore$ each year $\frac{180}{10}$ = 18 hectares replanted annually.

VALLEY BOTTOMS

60 hectares of 337 ha = 18% of total area
at 12 months cutting average, possibly 8 crops.

8 crops at 12 months = 8 years + 6 months fallow and drainage work
= 8,5 year cycle.

Annual cut = (8 crops in 8,5 years) = $\frac{8}{8,5}$ = 94%

or 94% of 60 ha = 56 hectares cut annually.
Annual replant crop cycle from above = 8,5 years.

$\therefore$ each year $\frac{60}{8,5}$ = 7 hectares replanted annually.

TARGETS

HILLTOPS & HILLSIDES

.... hectares of .... ha = ...% of total area

at .... months cutting average, with .... crops.

____x____ = ... years + ... months fallow

= .... year cycle.

Annual cut (.......... crops in .... years)

= _____ = ...%

or ....% of .... ha = ... ha cut annually.

Annual replant crop cycle from above = ... years,

∴ each year _____ = ... hectares replanted annually.

VALLEY BOTTOMS

.... hectares of .... ha = ...% of total area

at .... months cutting average, with .... crops.

____x____ = ... years + ... months fallow

= .... year cycle.

Annual cut (.......... crops in .... years)

= _____ = ...%

or ....% of .... ha = ... ha cut annually.

Annual replant crop cycle from above = ... years,

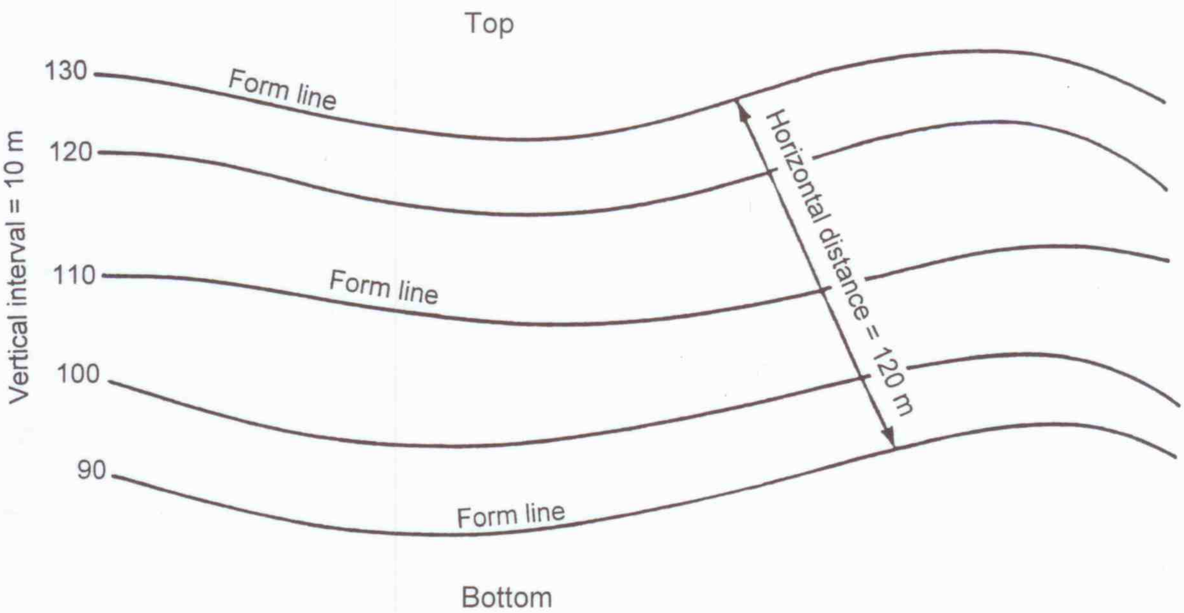
∴ each year _____ = ... hectares replanted annually.

APPENDIX 6:

HOW TO READ CONTOURS

MEASURING THE SLOPE

The average slope is measured in % by finding a set of uniform lines.



The horizontal distance is measured from the top form line to the bottom form line (HI).

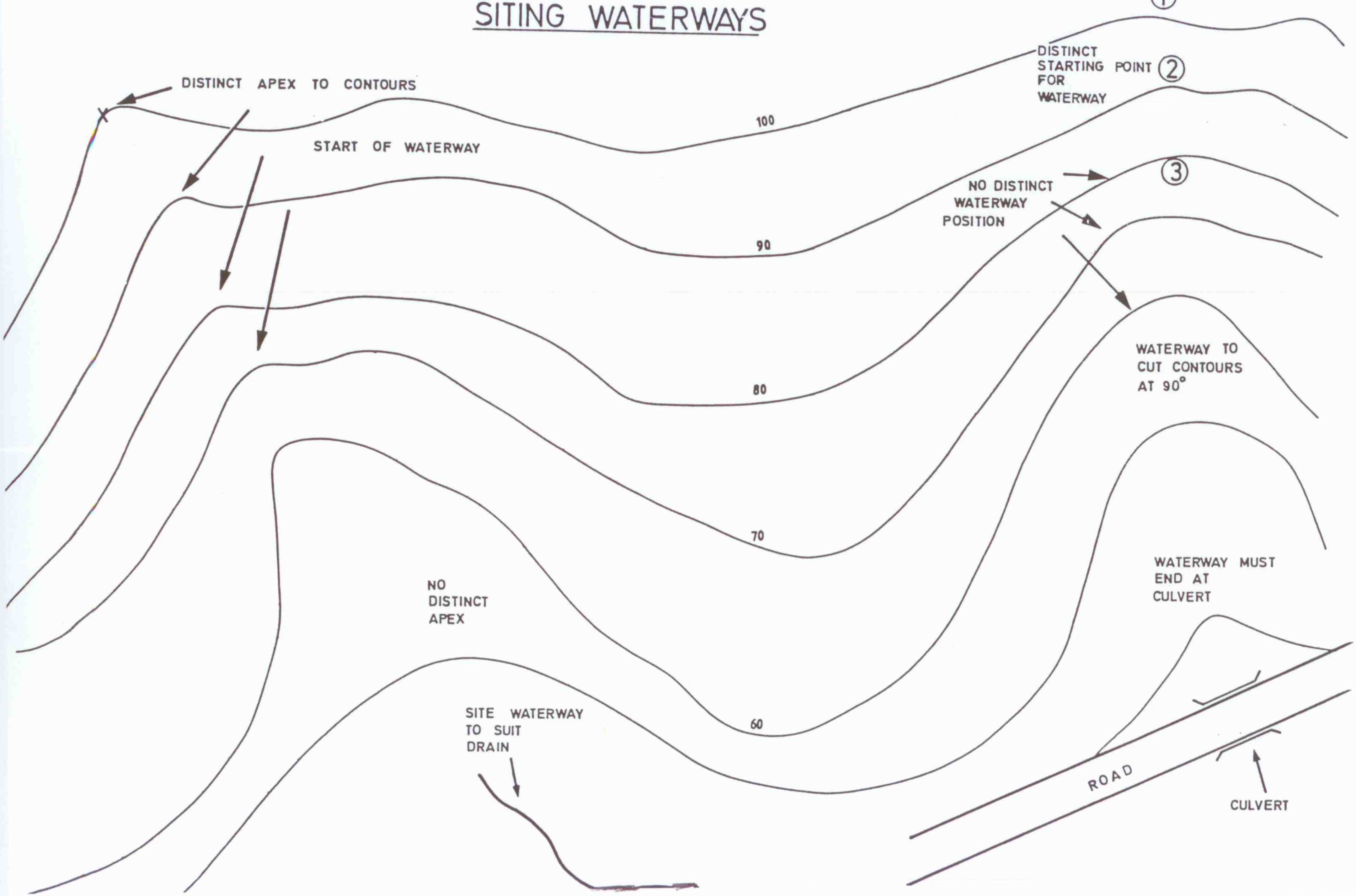
The vertical interval (VI) is calculated by subtracting the height of the bottom form line from the height of the top form line.

% slope is calculated by the formula:

$$\frac{VI}{HI} \times 100$$

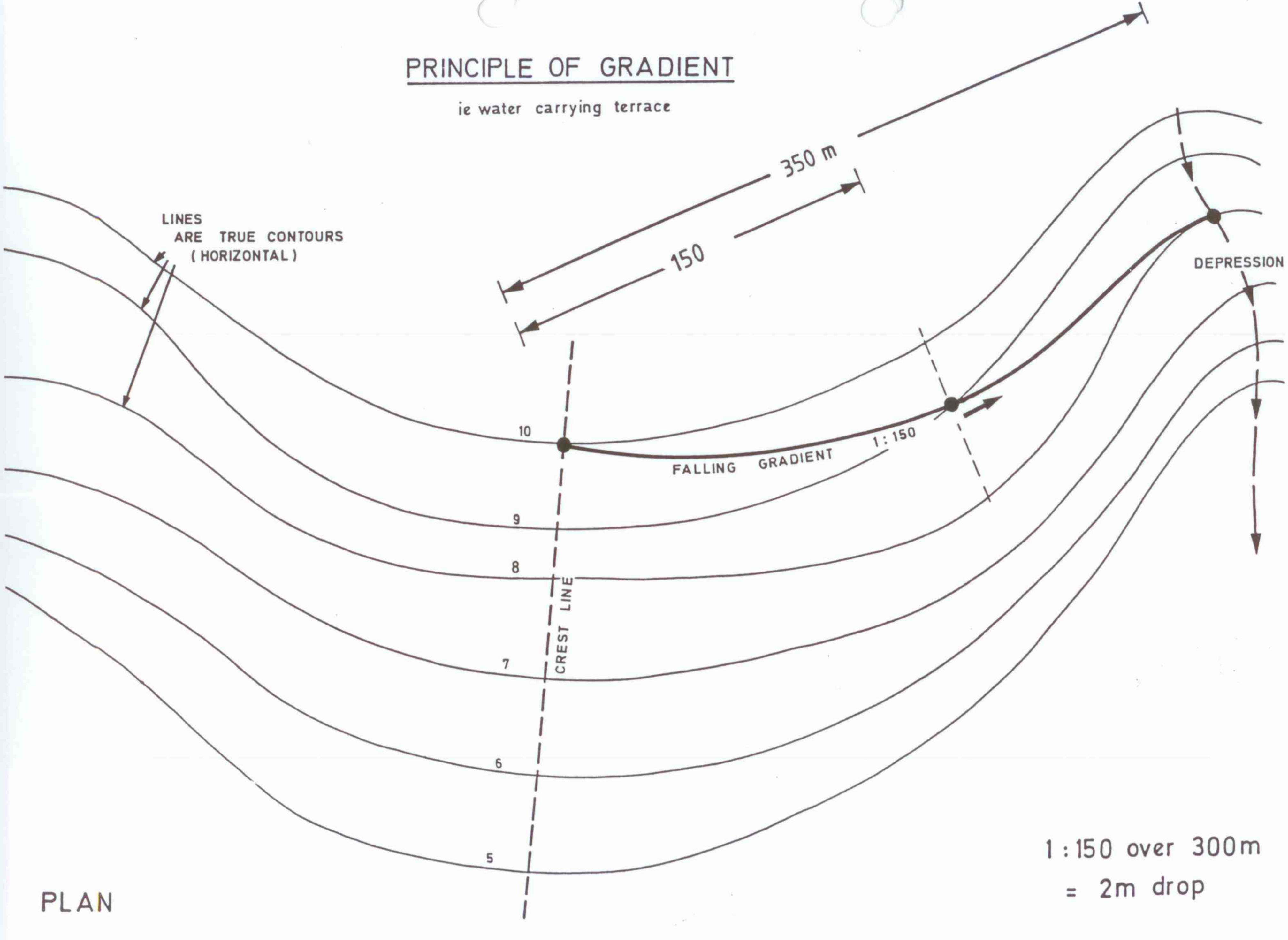
Eg: $$\frac{40}{120} \times 100 = 33\ \%$$

SITING WATERWAYS

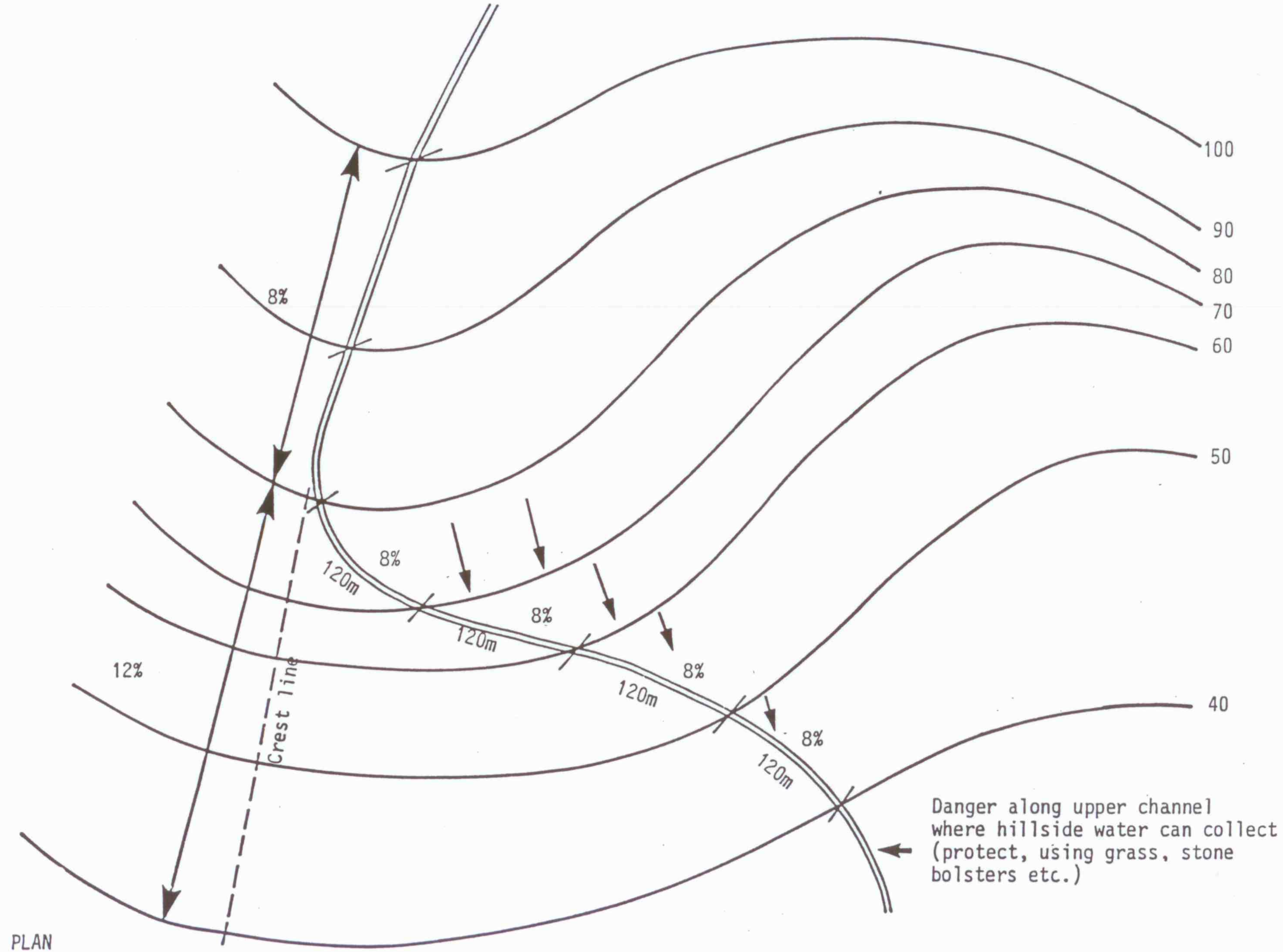


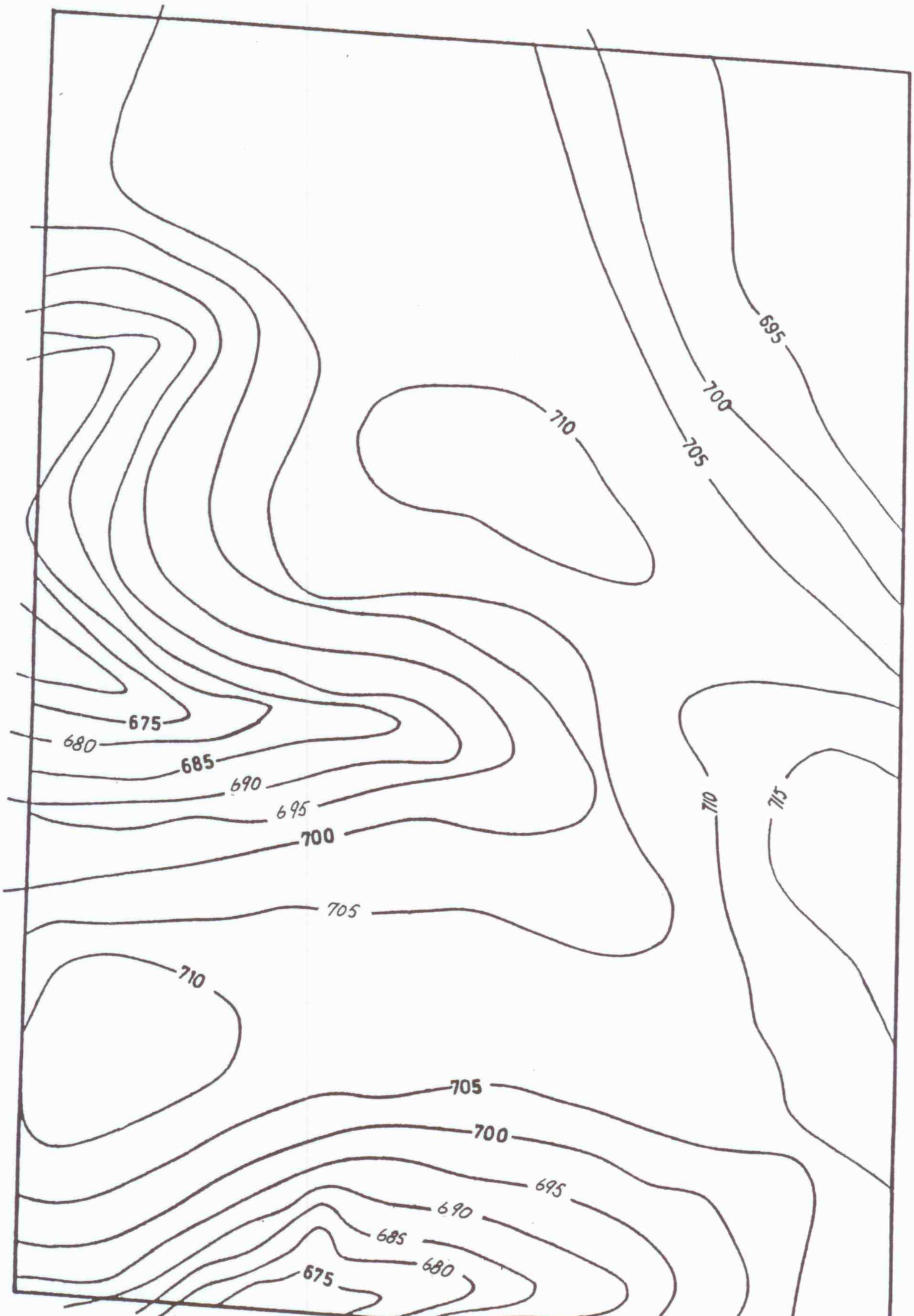
PRINCIPLE OF GRADIENT

ie water carrying terrace



PRINCIPLE OF DIAGONAL ROAD

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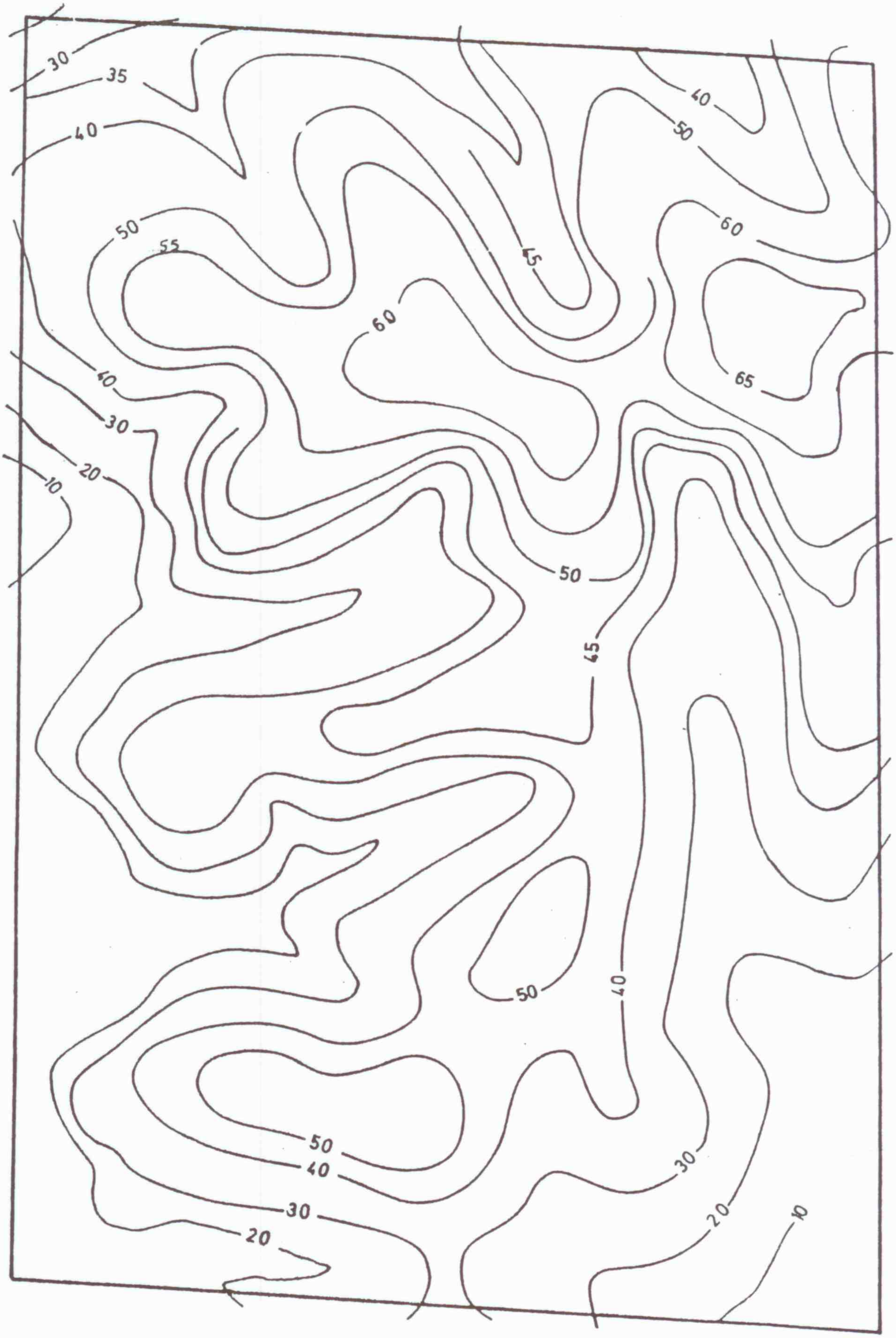
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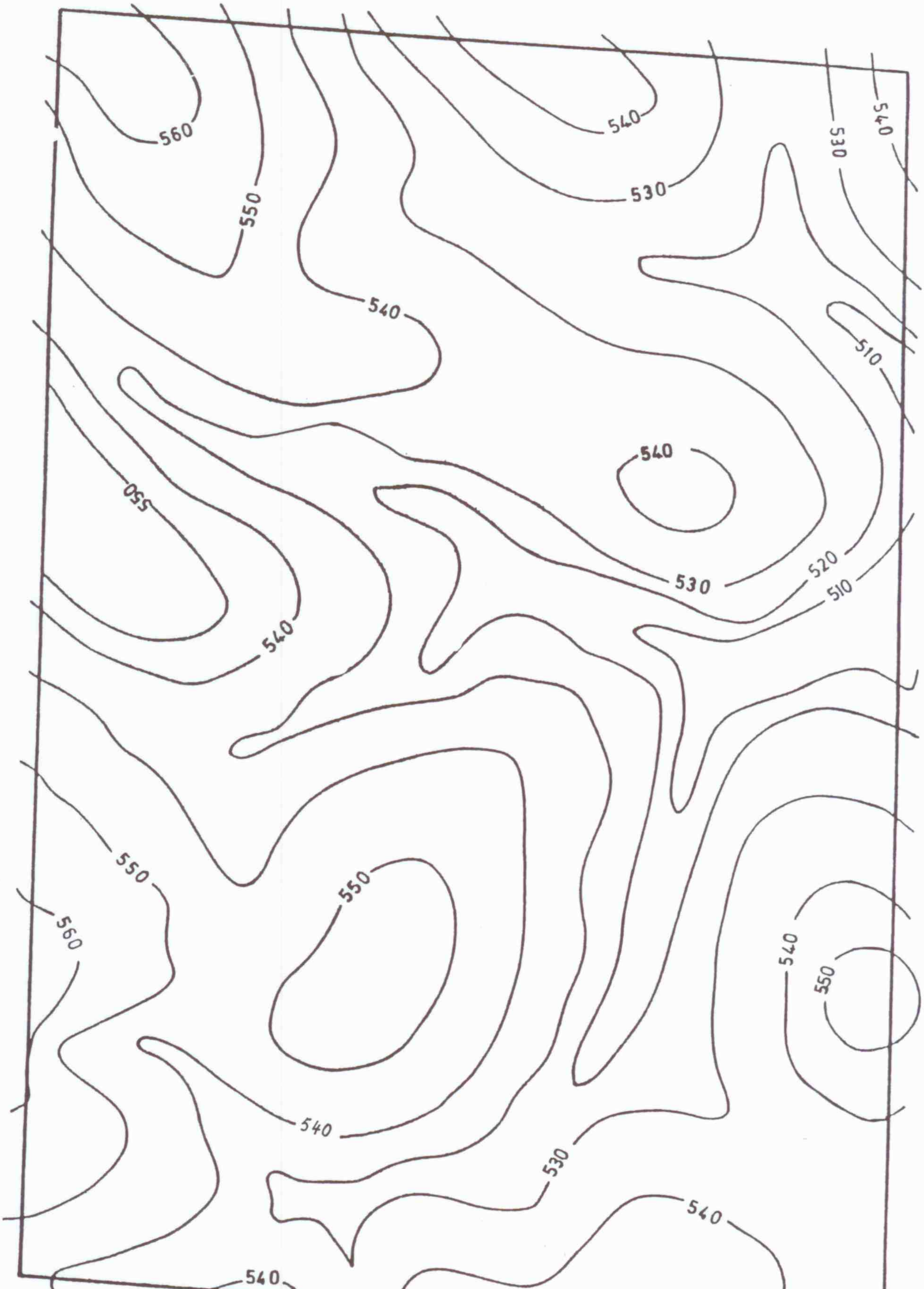
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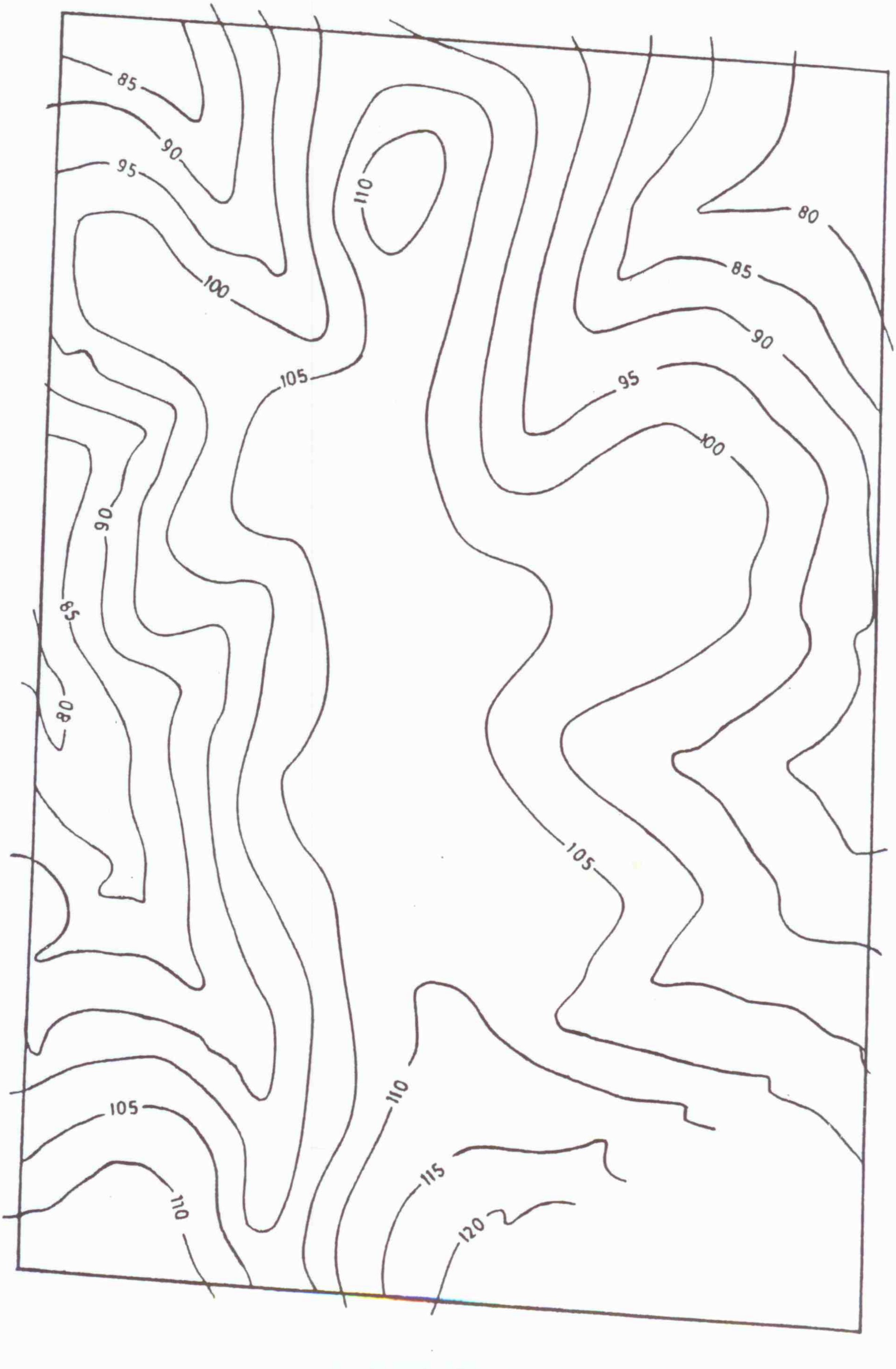
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