

IMPLEMENTATION OF FIELD LAYOUT FOR MECHANIZATION AND SURFACE WATER CONTROL

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Abstract

Escalating costs and the uncertain availability of labour have provided motivation for greater mechanization of field operations. It is difficult for machines to cope with irregular terrain, varying row widths and the presence of short lines, and hence it has become necessary to revise methods for laying out sugarcane fields. The principles involved, the necessary design criteria and the techniques for their implementation have been established in an attempt to solve the problem of mechanizing cane production on the steep and often rugged terrain found in the South African sugar industry.

Introduction

The traditional methods of sugarcane production in South Africa are increasingly being threatened by the rising cost of labour, and by a reluctance of employees to perform heavy manual tasks with diligence when less onerous work in commerce and mining offers an attractive alternative. The obvious solution would appear to be mechanization, but cane producers in this country are faced with difficulties in mechanizing which are almost unique. Sugarcane is grown on steep terrain, on soils which are not always ideal, and under high intensities of rainfall. Some operations can be mechanized, but except on relatively flat land harvesting must still be done manually. Planning for full scale mechanization therefore involves making special arrangements which will permit mechanized harvesting.

Criteria for mechanization and conservation

In view of the rugged nature of much of the terrain on which cane is grown, the needs of mechanization must be married to those for effective conservation of soil and water. Taken together these call for a revision of standards for planning field layouts. The basic criteria are:

- (1) Maximum utilization of soil and water resources for continued cane production.
- (2) Optimum operational efficiency for field operations.
- (3) An efficient road network.
- (4) A minimum of conflict in meeting the sometimes diverse requirements for mechanization and conservation.

Ideally for mechanization:

- (a) Land slopes should not exceed 21% or 12°.
- (b) Land slopes should be uniform.
- (c) Crop rows should be long, straight, parallel and uninterrupted.
- (d) There should be no obstructions such as ditches, banks or uneven ground surfaces to interfere with machine operation.
- (e) Roads and waterways which cross crop rows should not obstruct mechanical operations.

To ensure sound conservation, it is necessary to limit the velocity and volume of surface water below permissible maxima, dependent on land slope and soil erodibility. These requirements can usually be achieved best by:

- (i) Short crop rows if these run down the slope.
- (ii) Close spacing of conservation terraces.

- (iii) Gentle gradients for conservation terraces.
- (iv) Limiting the depth of flow in conservation terraces and waterways.

Taking both of these sets of criteria into account, an approach to layout planning which caters for the needs of both mechanization and conservation must be developed. This comprises:

- (1) Grouping areas of reasonably similar topography together so that there is as little variation in design as possible.
- (2) Levelling and planing fields to eliminate minor high spots and depressions.
- (3) Installing underground pipe drains to eliminate wet areas which might cause operational problems for machines.
- (4) Straightening or making smooth curves for in-field terraces, but taking care that the permissible gradient limits for parallel terraces on hillslopes are not exceeded.
- (5) Using correction strips where gradient changes would otherwise exceed the allowable limits, and in this way concentrating short lines into small and clearly defined areas.
- (6) Using pipe outlets from terraces to replace or supplement vegetated waterways.

Redesigning field layout

It has been found to be impractical to design a layout in the field. Alternatives can best be examined on a drawing board. The basic requirement is a contour map of the area to be planned. The flatter the area the smaller must be the contour interval. Thus the minimum requirement for a drainage design on a flat area would be 0,5 m contour intervals. In contrast, on steeper land 5 m to 10 m contour intervals should be adequate for design purposes.

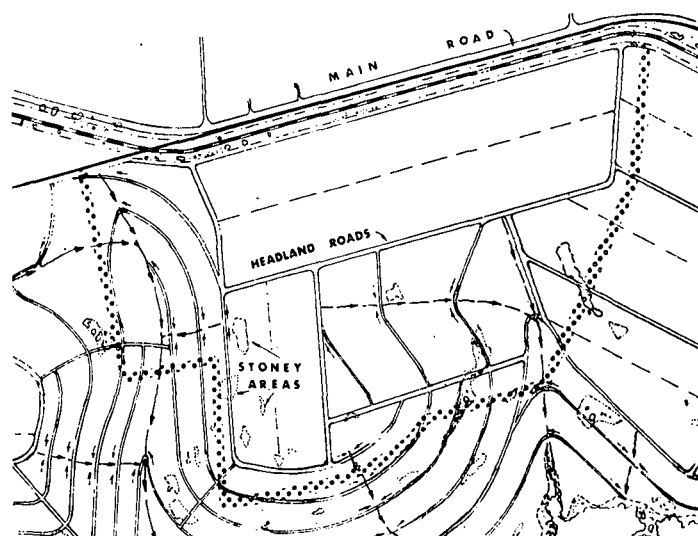


FIGURE 1 Development of a contour map to show different topographic units, flat ridges and parallel terraces.

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- (a) Group together such topographical units as flat ridges, valley floors and uniform hillslopes whilst excluding the steep, uneven areas.
- (b) Outline the relatively flat ridges by marking in headland roads, starting with areas where crop rows can be drawn in a straight line or parallel to curved crestlines.



FIGURE 2 A flat ridge showing straight parallel crop rows.

- (c) Where parallel structures are feasible, select a grade suitable for the hillslope areas concerned and plot gradient lines across the slopes.

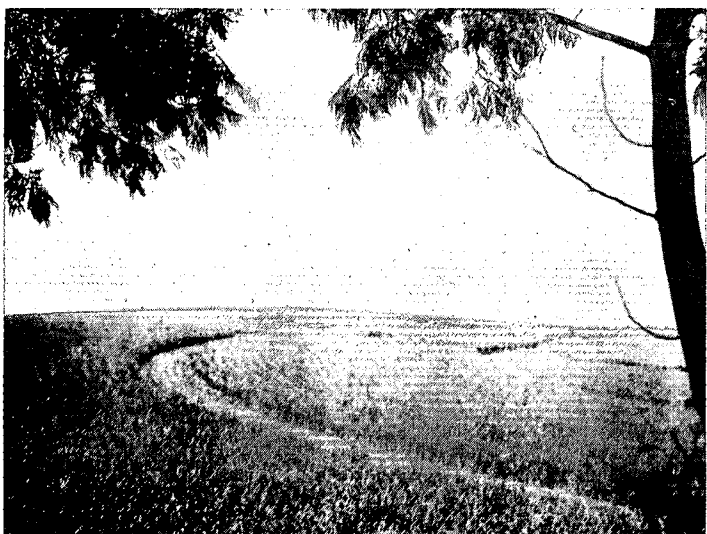


FIGURE 3 Parallel hillslope terraces.

- (d) Select one or more key lines and draw parallel terrace lines at the intervals required for land of the type being planned. Straighten these key lines across any depressions that can be used for waterways or pipe outlets from terraces, and smooth out curves. Insert correction strips where grades exceed the permissible gradient limits.
- (e) Demarcate wet areas and design appropriate drainage layouts.
- (f) Design surface and underground water disposal channels using either vegetated or paved waterways or pipe outlets from terraces.
- (g) Ensure that adequate in-field and boundary roads are provided. All roads must have adequate and efficient means of disposing of runoff water.
- (h) In irrigated areas the designed layout must also accommodate the irrigation system selected. Surface irrigation

layouts normally incorporate basic conservation measures but distribution canals and ditches obstruct mechanized operations. Overhead irrigation systems are easier to incorporate in a plan because lines need not necessarily follow the same lines as crop rows. Portable pipes, draglines and sprinklers may be removed where mechanical operations are due to take place.

Some basic criteria

- (1) *Slope categories*
 - (a) 0-8%. Crop rows may run along the longest length of slope, even running downslope if necessary, because the catchment areas within this category are usually so small that critical water velocities are unlikely to be exceeded.
 - (b) 8-10%. Broadbased terraces should be constructed across any crop rows that run downslope, but rows can still be aligned as in (a) above.
 - (c) 10-12,5%. Crop rows must run across the slope, parallel to the terraces. On these slopes construct broadbased terraces. It has been found in practice that it is difficult to construct broadbased terraces on slopes exceeding 12,5%.
 - (d) 12,5-21%. Crop rows should be drawn as in (c) above, but bench terraces should be constructed.
 - (e) 21-32%. Crop rows should again be drawn as in (c) above. Use bench terraces. On these slopes it is difficult to plan parallel terraces and mechanization can be achieved only with very specialised equipment. Waterway crossings must be protected with culverts or by using rock-pack or masonry-lined structures.



FIGURE 4 Rock-packed road crossing to waterway, with a tractor-drawn mower in the background, trimming the grassed section of the waterway.

- (f) More than 32%. Too steep for mechanization.

(2) Terrace gradients

These may range between 1 : 250 and 1 : 50. Ideally they should accelerate from crestline to waterway. Alternatively a uniform gradient may be used but the gradient should never be flattened or reversed. Maximum water velocities in grassed and mown channels should be:

- (a) erodible soils — 1,5 m/sec
- (b) moderately erodible soils — 2,0 m/sec
- (c) soils resistant to erosion — 2,5 m/sec

(3) Terrace spacings

These are given in Table 1 for various slopes, soil types and management factors.

TABLE 1
Terrace spacing, in metres, according to slope, soil and management factors

Land slopes	8-10%			12,5%			15%			20%			32%		
	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
Burnt	37	43	50	36,5	41,5	46,5	36	40	45	35	39	42	30	35	40
Trashed	44	50	60	42,5	49	57	40	48	54	37,5	47	50	35	42	46
Strip crop and trashed	55	65	75	52,5	62,5	70	50	60	65	45	55	60	40	50	55

Note: Soil Factors: 1 = Highly erodible
3 = Moderately erodible
5 = Resistant to erosion.

(4) *Waterway sizes*

The minimum width is 3 m, increasing by 0,4 m per ha of catchment area.

The maximum width is 10 m (or 10 m on either side of a natural stream or river).

The maximum depth of a grassed waterway 3 m wide is 0,40 m. The maximum depth of a grassed waterway from 6 m to 10 m wide is 0,75 m. The side slopes should not be steeper than 1 : 4.

(5) *Terrace sizes*

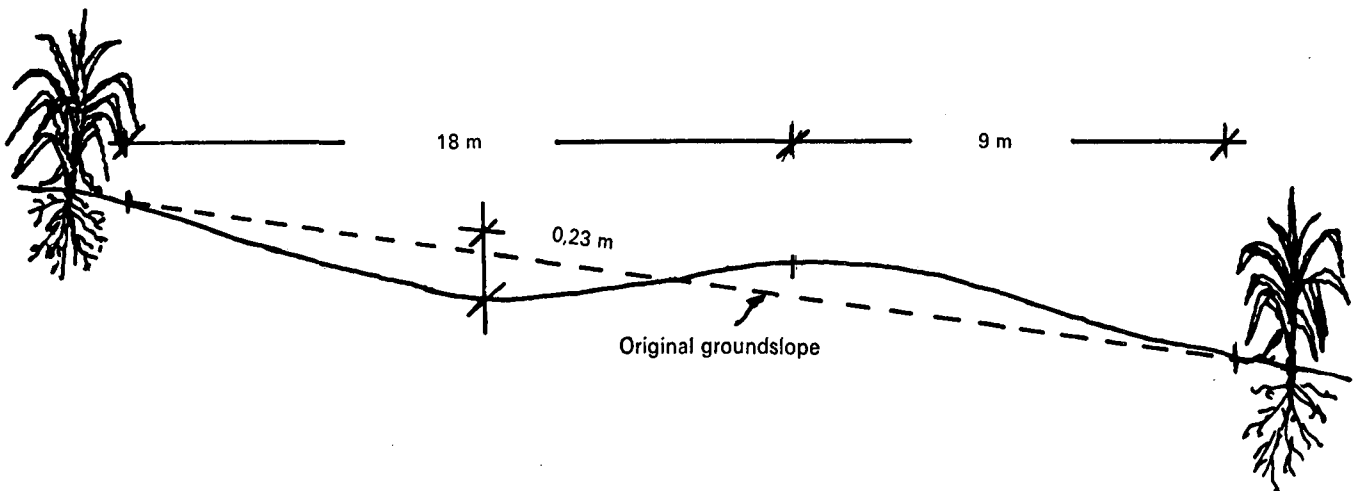


FIGURE 5 Broadbased terrace on 8% slope, designed to permit traversing by agricultural implements.

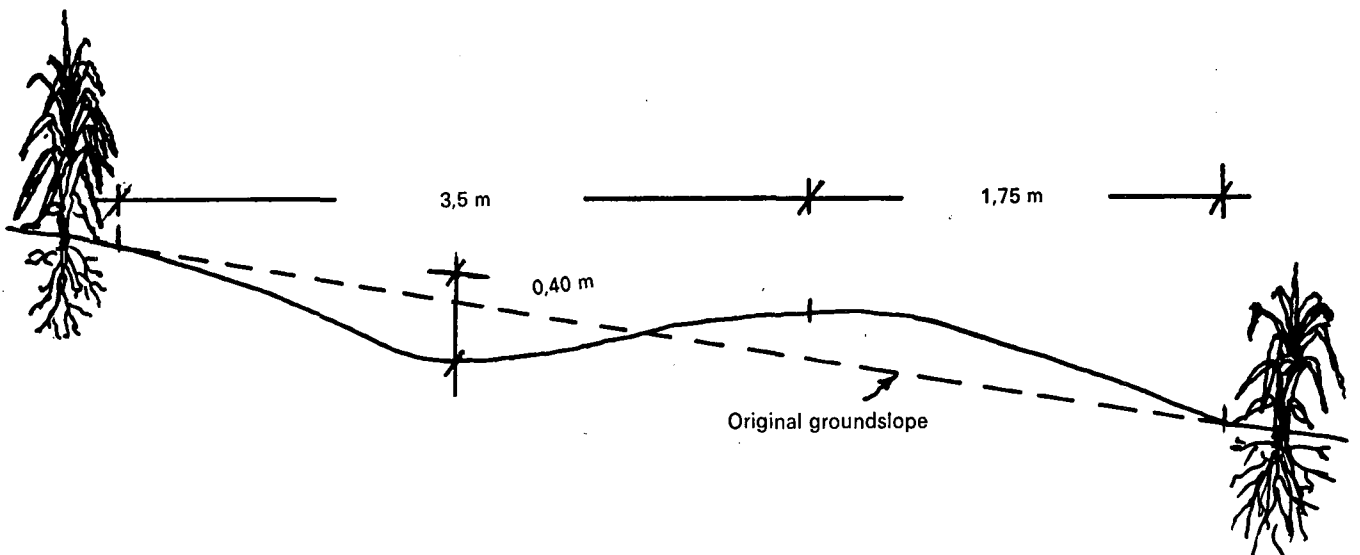


FIGURE 6 Broadbased terrace on 12,5% slope, cane rows to run parallel with this type of terrace.

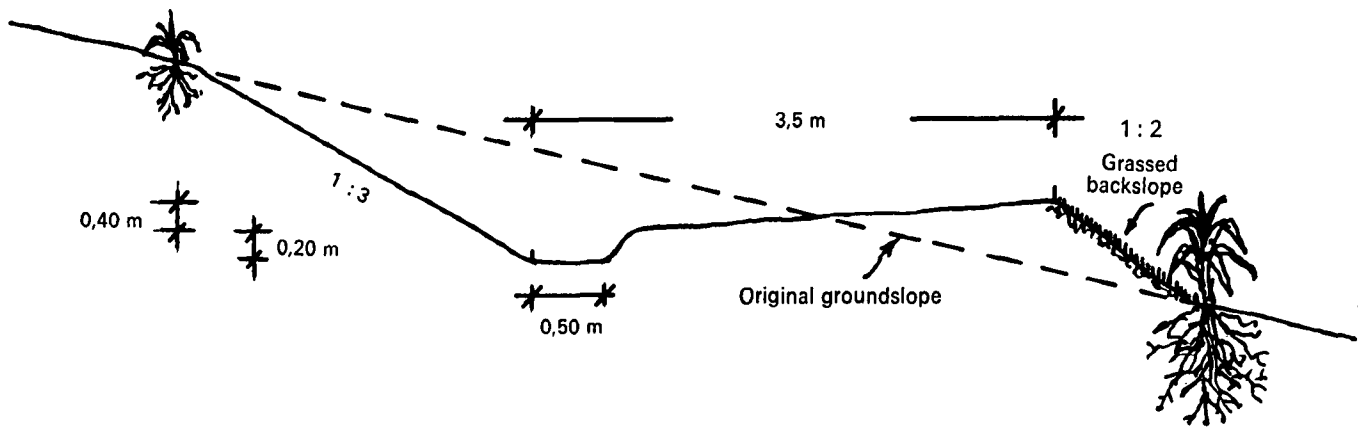


FIGURE 7 Bench terrace on 21% slope with grassed back slope.

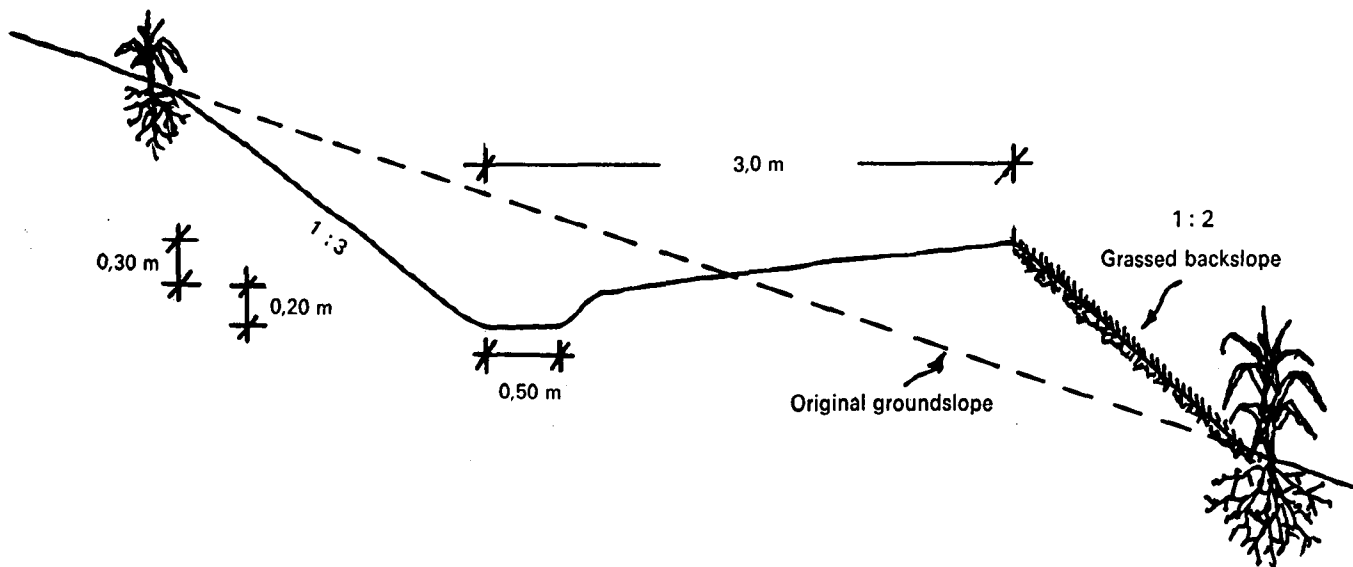


FIGURE 8 Bench terrace on 32% slope with grassed back slope.

(6) Row length

The optimum uninterrupted row length is 400 m, approximately, but this could vary according to the capacities of the mechanical planters, fertilizer distributors or trailer bins to be used.

(7) Row spacing

Rows should be between 1,4 m and 1,5 m apart depending on the type of machines to be used.

(8) In-field haulage and loading zones

(a) Critical tractor-trailer haulage gradients are:

- (i) Hauling up hill, the grade should not exceed 1 : 12
- (ii) Hauling down hill, the grade should not exceed 1 : 7

(b) The distance from field to loading zone should not exceed 1 km.

(9) Headlands and headland roads

The optimum width is 7 m.

Implementation procedures

- (1) Bulldoze and level all antheaps and localised humps, and fill in all minor depressions or washaways as far as soil depth will allow. Level all existing roads and breaks. This operation, although expensive will save many hours of landplaning later.
- (2) Plough and harrow the land according to the normal land preparation procedures.

- (3) After the final harrowing, landplane the soil surface until it is smooth. This is a vital operation which will generally make laying out and mechanical operations considerably easier. Do not work in one direction only, but directly across the slope, diagonally and even up and down if slopes are not too steep. Do at least three or four passes depending on the unevenness of the land. A land plane is best used by operating in a figure 8 pattern. During this operation make sure that all remaining rocks, stones, tree stumps and tree roots are removed from the field.
- (4) Using the layout plan, locate and peg crest and drainage lines.
- (5) Delineate those areas with slopes less than 10% by constructing headland roads. These areas will be shown on the plan and will be on either side of the crestline and parallel to it. Where the crestline becomes steeper than 10%, peg and construct cambered crest roads where these are required for in-field access. Do not camber the headland roads unless they follow a gradient parallel to a key terrace lower down the slope. In the latter event they fulfil the functions of both a headland road and an in-field terrace. Peg and construct the terraces required in areas having slopes between 8 and 10%.
- (6) Using a level peg the top key terrace at the gradient given in the plan. Straighten it where this is practical and even out curves. If the landplaning operation has been done well very little straightening or evening out should be necessary.
- (7) Peg, above and below the key terrace, those terraces which run parallel to it. It is imperative that this operation should

be done accurately. Even an error equivalent to half a row width over 1 000 m is too great. Use a surveying compass or a theodolite. Distances between terraces must be measured at right angles to the key terrace and the selected terrace interval should be a multiple of the selected row width.

An alternative technique which works in practice, is to furrow out from the key terrace the correct number of inter-terrace rows and then construct the next terrace. This, however, presupposes that the row widths can be maintained very accurately along their entire length. The technique suffers from a distinct disadvantage if the furrows are allowed to dry out before planting and covering takes place, and it cannot be used if planting is to be done by machine.

- (8) Use a level to check the grade of each terrace drawn parallel to the key terrace to ensure that it is within the permissible limits.
- (9) Repeat until the whole hillslope is complete. If more than one key terrace is required, correction strips automatically will occur between each set of parallel terraces. Correction strips may also have to be used between ridge and hillslope areas, or between hillslope and valley bottom areas.
- (10) Construct waterways according to the plan. Experience has shown that it is easier, when making waterways with mechanical equipment, to construct the whole waterway to the maximum width required, and then to plant the crop into it to provide the narrowed width required towards the top of the slope. Revette the waterway with canetop barriers at 3 to 5 m intervals, depending on the steepness of the slope, and plant grass in the intervening spaces.

Use either *Cynodon dactylon* (ngwengwe) or *Stenotaphrum secundatum* (coastal couch grass) for permanent cover, overseeded with *Eragrostis curvula* (Love grass) and *E. teff* for a quick-growing protective cover. Topdress with a suitable fertiliser. Where extensive land levelling and land planing have to be done, it is impractical to follow the ideal practice of establishing waterways after cutting the last crop but one before re-establishment.

- (11) Ensure at all times that there is adequate drainage of all roads because uncontrolled runoff onto and from roads is a major cause of erosion damage.



FIGURE 9 View of newly constructed waterway, showing cane top revettes.



FIGURE 10 Close-up of a revette in a newly constructed waterway, consisting of bundles of cane tops pegged into the ground with their butts pointing up-slope.



FIGURE 11 Terrace road showing the backslope into the hillside and the waterbearing channel.

- (12) It is well worth strip-cropping hillslopes. This technique enables one to use a wider terrace spacing, as can be seen from Table 1. It is also an efficient conservation and fire protection technique. With strip cropping all in-field terraces are used as roads.

Conclusion

The techniques outlined in this paper have been used to design layouts for Windy Hill Wattle Co., Umzimkulu Sugar Co.'s Paddock Section and T.S.B.'s Kaalrug Estate. Practical experience has been gained from implementing layouts at Windy Hill and at Umzimkulu. The tractor operations carried out at Umzimkulu are listed in Appendix I.

There are three key features for the successful implementation of this type of land use plan.

- (1) Thorough and adequate land levelling and planing.
- (2) Adequate drainage of wet areas.
- (3) Precise location of roads and in-field terraces and the creation of exactly parallel rows.

The Paddock layout has stood the test of 87 mm of rain in an afternoon within three months of planting, without any visible in-field erosion.

Acknowledgements

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APPENDIX I
Umzimkulu Sugar Company, Paddock Section
Tractor utilisation for the layout of Fields 306, 307 and 308.
Area 36 hectares

Operation	Mechanical unit	Meter hours
Land preparation . . .	County 4 with 3-furrow disc . . .	224
	D 5 with Rome harrow (3 passes) . . .	115
Levelling . . .	County 4 with Eversman TM 10 land plane (3 passes)	170
Harrowing . . .	MF 135 with light harrow	41
Waterway, road and terrace construction	Ford 5000 with 3-furrow disc plough, dam scoop and disc terracer . . .	87

These data have been used with the kind permission of Mr L. Murray of the Umzimkulu Sugar Company.