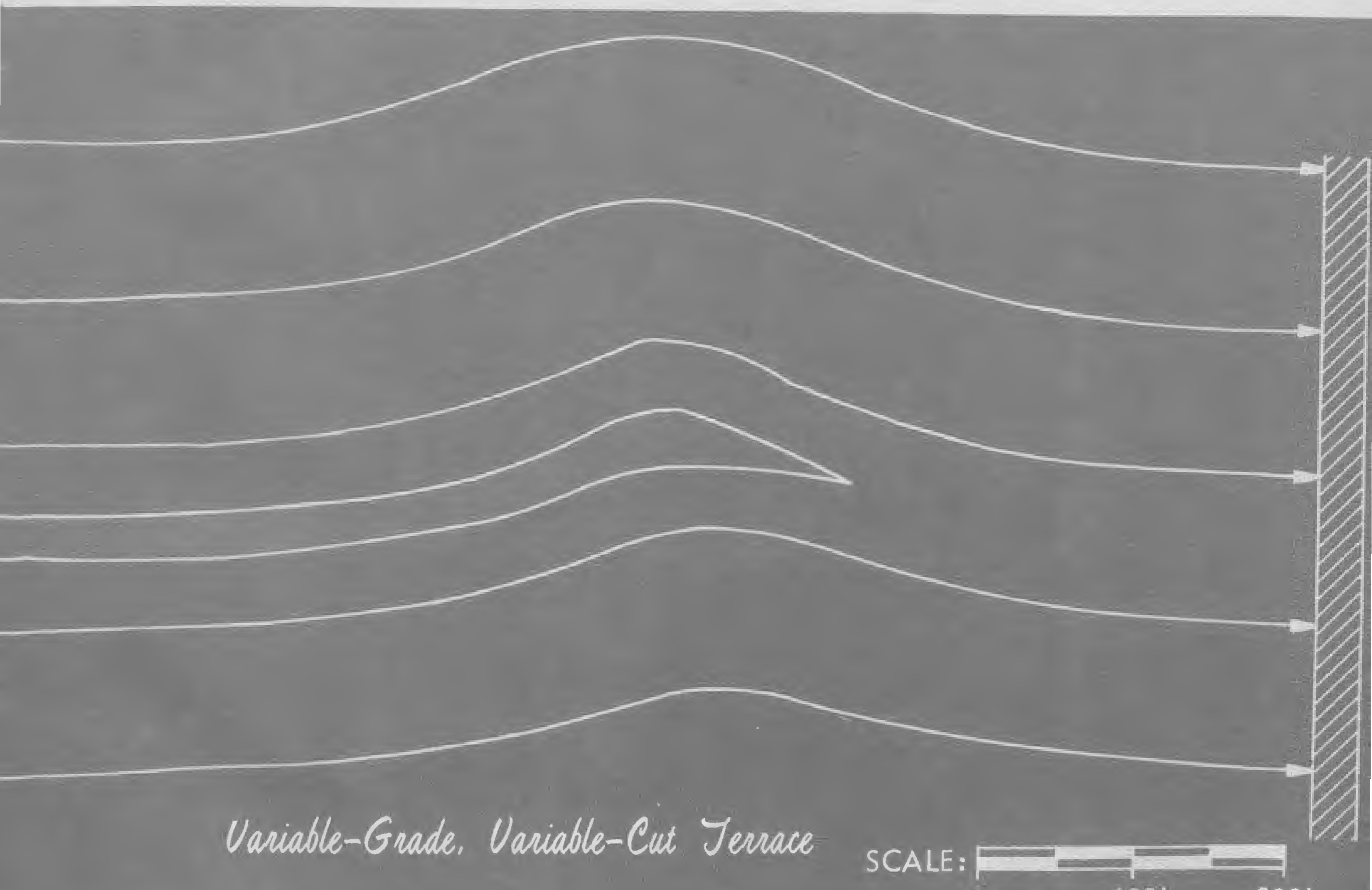
A New Method of TERRACING



Variable-Grade, Variable-Cut Terrace

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A Bulletin for Technicians

This bulletin has been prepared for technicians who are responsible for the layout of terrace systems, and who are familiar with the surveying procedures involved.

This revised edition explains new techniques in the design, layout, and construction of variable-grade, variable-cut terraces which will result in terraces with less curvature, more uniform spacing, and fewer point rows.

A New Method of

Part I: Planning

The objective should be to plan a complete terrace system rather than to just stake out individual terraces. Good planning on the part of the technician followed by a good job of construction will result in terraces with less curvature and with more uniform spacing. They will be easier to farm with modern machinery and the farming operations can be done faster and with less damage to the land and to the crop.

Good planning cannot be over-emphasized. Extra care in planning will result in a better layout with a minimum cost of construction.

Principles to Follow in Planning the Terrace System

In planning a terrace system consideration should be given not only to the terraces but also to terrace outlets, ponds, diversion channels, and stabilization structures. The following principles for planning the system are suggested.

1. Provide convenient access to all fields to facilitate movement of livestock and machinery from the farmstead to the fields, and from field to field, with a minimum of travel and a minimum of gates to open and close.
2. Whenever possible, locate terrace outlets so that terraces drain away from the farmstead. It will then be possible to go to and from the fields without crossing terraces or using the outlets as a roadway.

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TERRACING

by R. P. BEASLEY

(The Variable-Grade, Variable-Cut Terrace)

3. If possible locate terrace outlets so that the land to be terraced into the outlet has fairly uniform slopes. This will make it easier to lay out uniformly spaced terraces.
4. For most efficient use of machinery, make rows as long as possible and keep short or point rows to a minimum.
5. Terraces, outlets, diversion channels and other structures should be planned and constructed so as to interfere as little as possible with farming operations.
6. Plan for flexibility in the number and size of fields to meet changing needs of crop and livestock enterprises.
7. Plan for a reliable supply of water for livestock, and under some conditions, for household use also.
8. Plan so adjoining property will not be damaged by runoff from the terrace system.
9. Plan the system for maximum benefits and reasonable costs.

The location of an outlet requires a knowledge of agronomy to determine which location would support the best vegetation, a knowledge of engineering to be able to determine the correct size of outlet and the cost of construction, and a knowledge of farm management to be able to determine which location will result in the most efficient farm unit.

Once the terrace system is planned it is advisable to consider the sequence of construction. It is best to have the grass well established in the terrace outlets before the terraces are constructed. The stabilization structures should be constructed at the same time or before the outlets they are to protect are put into use.

Principles to Follow in Laying Out Variable-Grade, Variable-Cut Terraces

In the past it was common practice to stake out terraces to a constant grade throughout their length. In constructing these terraces a uniform depth of cut was made for the full length of the terrace. In this bulletin terraces constructed by this method will be called constant grade terraces. The dotted lines in Figure 1 represent the location of constant grade terraces on a field.

To reduce the curvature of terraces and make them more nearly parallel it is necessary to shift sections of terraces up or down slope. This can be accomplished by:

(a) Varying the depth of cut in the terrace channel.

(b) Varying the grade along the terrace.

(c) By a combination of (a) and (b).

In general, varying the depth of cut is more effective in moving short sections of a terrace up or down slope to reduce the sharpness of curvature. Varying the grade along the terrace is used to shift longer sections of a terrace up or down slope to make terraces more nearly parallel.

In Figure 1 the curvature of the top terrace may be reduced, as indicated by the solid line, by varying the depth of cut. The depth of cut must be greater in those sections (G) where the terrace is above the original location and less in those sections (L) where the terrace is below the original location in order to maintain grade in the terrace channel. The lower section of the second terrace up to point A can be made parallel to the top terrace by varying the depth of cut. In the upper section of this terrace, A-B, it will be necessary to vary both the grade and depth of cut. By increasing the grade the terrace can be moved to the location indicated by the dashed line, A-C. This section is still not exactly parallel to the top terrace and it still has one rather sharp curve. The curvature can be reduced and the terrace made parallel to the top terrace by varying the depth of cut. The final location is indicated by the solid line.

When it is necessary to vary the depth of cut, earth is moved from the sections of greater cut to those of lesser cut to maintain the terrace cross section. The allowable range in the depth of cut will vary with: (1) the type of soil, (2) the type of equipment used in constructing the terrace and (3) the amount that the individual is willing to spend. The depth of cut should seldom be more than 2.5 feet or less than 0 feet. In order to avoid exposing large areas of subsoil the width of the terrace cross section should be the same regardless of the depth of cut. Figure 2 illustrates the change in terrace cross section that occurs when the depth of cut is varied from 0 to 2.5 feet on 6 percent land slope. Note that the side slopes of the terrace channel are steeper where the deeper cut is made.

Comment

The extent to which the curvature of the terraces and the point row area between them can be reduced will vary with: (1) the topography, (2) the type of soil, (3) the type of equipment to be used in construction and (4) the amount of money to be spent on construction. The greatest improvement can be made on fields which have relatively uniform topography, moderate slopes, and a deep permeable soil. However, some improvement can be made on any field. The amount of improvement made will probably be influenced by the crops to be grown in the field. Most farmers would be willing to spend more to have uniformly spaced terraces with little curvature in a field to be intensely farmed to row crop than they would for a meadow or pasture field.

Whenever possible obtain uniform spacing between terraces by varying the grade of the terraces as there will be no extra cost involved in building the terrace. Whenever the depth of cut is varied the cost will be increased because of the additional earth movement.

Again, good planning cannot be over-emphasized. Additional time that may be required to do the best possible job of planning will be repaid many times by the reduction in cost of construction.

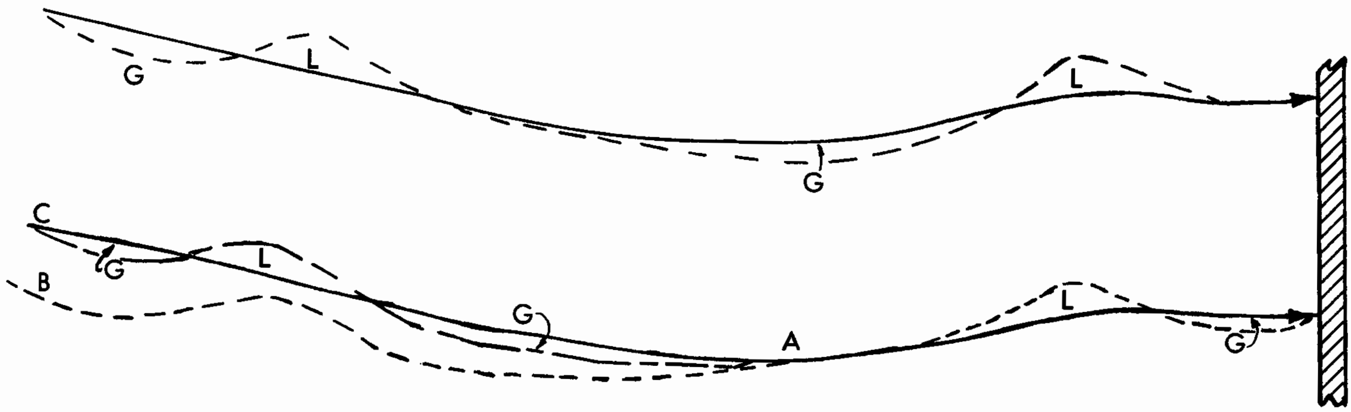


Fig. 1—Shifting terrace location by varying the depth of cut and the grade. The dotted lines designate location of constant grade terraces. The solid lines designate the location of the improved terraces. L designates less depth of cut. G designates greater depth of cut. Terrace shifted from AB to AC by increasing the grade.

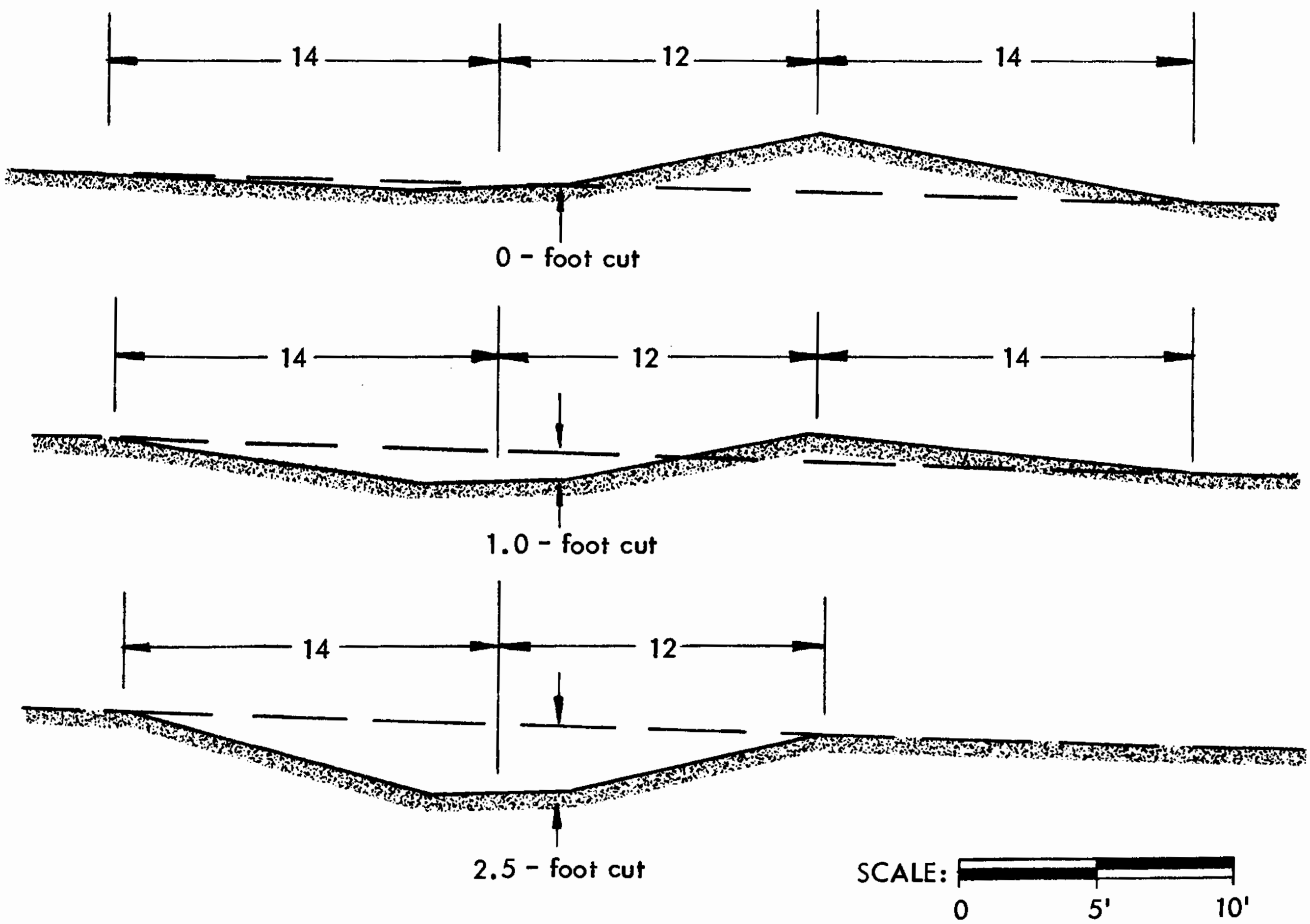


Fig. 2—Change in terrace cross section when the depth of cut is varied from 0 to 2.5 feet. Land slope 6 percent. Dashed lines represent original ground surface.

Part II: Design

HOW TO SPACE TERRACES: It is desirable to space terraces as far apart as possible. Wide spacing makes it easier to operate machinery in the field and reduces the cost of terracing. However, a number of factors limit the spacing between terraces: (1) erosion increases with length of slope; (2) if water concentrates between the terraces, small gullies may form and cause deposition in the channel of the terrace below; (3) runoff from the wide spacing may overload the channel of the terrace, causing over-topping and damage to the terrace involved and to the land below.

The principal factors affecting terrace spacing are the land slope, the soil type, and the intensity of rainfall to be expected. The terrace spacings recommended for Missouri conditions are given in Table 1. The terraces are spaced so that an even number of 40-inch crop rows may be planted between terraces. For other row widths, a different number of rows may be used or the surface distance between terraces varied slightly in order to plant an even number of crop rows between terraces.

TABLE 1 - TERRACE SPACINGS FOR MISSOURI

Average Land Slope, Per cent	Vertical Interval, Feet	Surface Distance Feet	Number of 40-inch Crop Rows*
1	1.6	160	48
2	2.4	120	36
3	3.2	107	32
4	3.7	93	28
5	4.7	93	28
6	4.8	80	24
7	5.1	73	22
8	5.8	73	22
9	6.6	73	22
10	6.7	67	20
11	7.4	67	20
12	8.0	67	20

*For other row widths a different number of rows may be used and the surface distance between terraces varied slightly in order to plant an even number of crop rows between terraces.

WHAT GRADE TO USE: The terrace grade must be great enough to prevent ponding but not so great as to cause erosion in the channel. Grades in this bulletin will be given in percent (feet drop in 100 feet of terrace). The grade may be varied in any section of a terrace between the minimum and maximum limits.

1. *Minimum Grade*—It is difficult to construct the terrace to a grade more accurate than plus or minus 0.10 percent, and tillage processes tend to build up barriers in the channel. Ponding in the terrace channel, damage to crops, and interference with farm operations will result if the terrace is constructed with too little grade on soils with low permeability. Suggested minimum grades are given in Table 2.

TABLE 2 - MINIMUM GRADES FOR TERRACES

Soil Permeability	Minimum Grade, Percent
Soils with low permeability	0.2
Soils with high permeability	0.0

2. *Maximum Grade*—If the terrace is constructed with too steep a grade, the velocity of flow will erode the channel, carry soil from the field and cause destructive deposition in the outlet. The maximum grade that can be used safely will vary with the erosiveness of the soil and the length of the terrace. Suggested maximum grades are given in Table 3.

TABLE 3 - MAXIMUM GRADES TO BE USED IN DIFFERENT SECTIONS OF A TERRACE

Distance from Upper End of Terrace, Feet	Maximum Grade, Percent
100	2.0
200	1.2
300	0.8
400	0.6
500	0.5
600	0.4
700	0.4
800	0.4
900	0.35
1000	0.35
1100	0.35
1200	0.35
1300	0.35
1400	0.3
1500	0.3
1600	0.3

The amount that a terrace can be shifted on the slope by varying the grade depends on the limits of grade in that section of the terrace. For example, if you were concerned with a section 200 feet from the upper end of the terrace, the maximum permissible grade would be 1.2 percent, the minimum grade 0.2 percent. In a 100-foot length of terrace, the terrace could be shifted 1.0 foot vertical distance on the slope by changing the grade between these limits.

However, if you were concerned with a section of a terrace 1000 feet from the upper end of the terrace the maximum permissible grade would be 0.35 percent, and the minimum grade 0.2 percent. In a 100 foot length of terrace, the terrace could only be shifted 0.15 foot vertical distance by changing the grade. Obviously, the greatest amount of terrace relocation by changing grade is limited to the upper ends of the terraces.

WHAT SIZE TERRACE: A terrace cross section should provide sufficient capacity to carry the runoff; it should have slopes that can be easily farmed with modern machines; and it should be economical to construct on the slope where it is to be located. The dimensions for terrace cross sections given in Table 4 and Figure 3 should be considered as minimum values for new terraces which are well compacted during construction. These minimum

TABLE 4 – DIMENSIONS FOR TERRACE CROSS SECTIONS

Land Slope Percent	Bottom* Width of Channel, Feet	Center of* Channel to Crest of Ridge, Feet	Center of** Channel to Upper Edge of Channel, Feet	Crest of** Ridge to Lower Edge of Ridge, Feet
0 - 2	6	14	14	14
3 - 4	6	14	14	14
5 - 6	5	12	14	14
7 - 8	5	12	14	14
9 - 10	4	8	14	14
11 - 12	4	8	14	14

*Under most conditions these dimensions should not be exceeded.

** These dimensions are such that four 40-inch crop rows may be planted on these slopes. They may be varied slightly if other widths of equipment are to be used but they should not be increased on the steeper slopes.

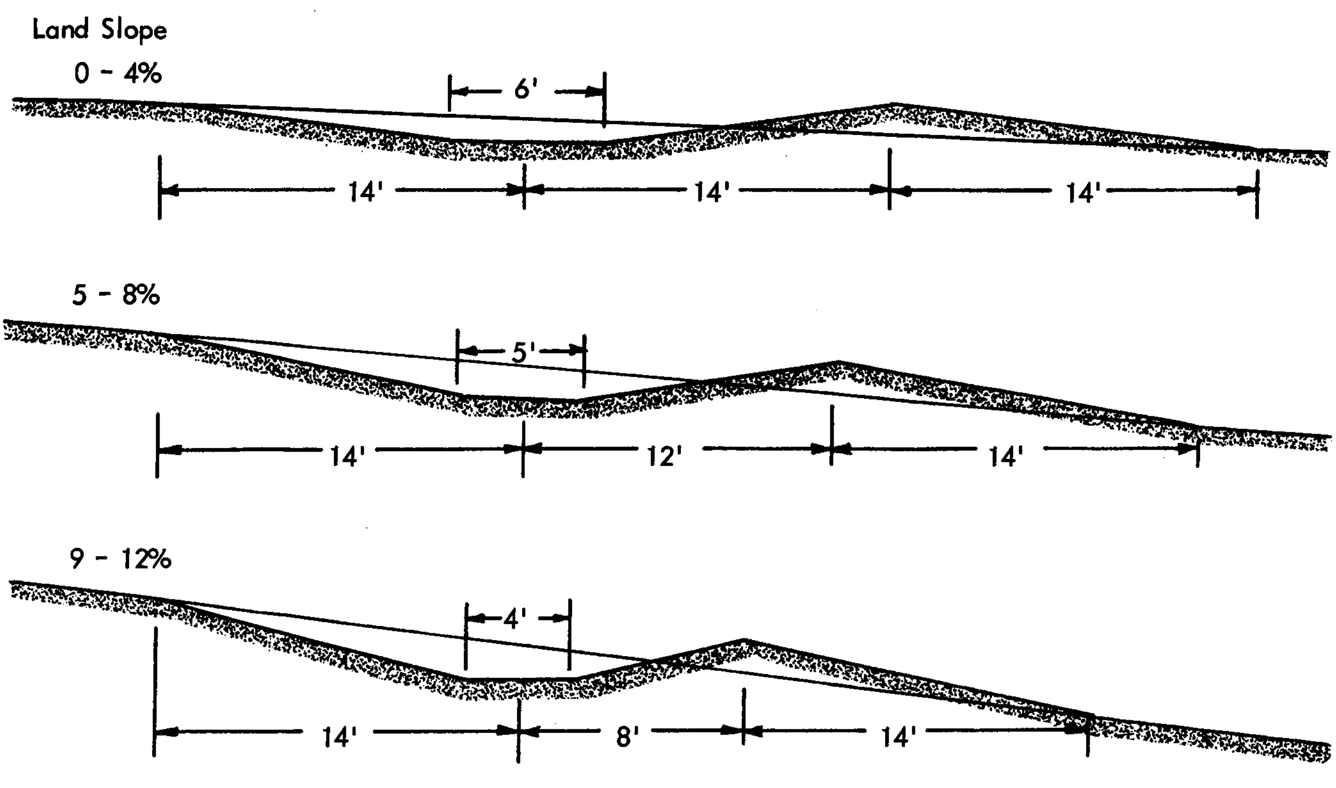


Fig. 3—Recommended Dimensions for Terrace Cross Sections. The ridge height varies depending upon the length of the terrace (See Table 5).

dimensions should be used for all terraces regardless of ridge height. The terrace may be constructed wider and the side slopes flatter to facilitate the operation of large farm machinery. Keep in mind that side slopes become less steep and the terrace height is reduced as the terraces are farmed.

As the length of a terrace increases a greater volume of water accumulates in the terrace channel. The terrace ridge height should be increased as the terrace length increases. The terrace ridge heights given in Table 5 should be considered as minimum values for new terraces which are well compacted during construction. If, due to the method of construction, or for any other reason, it is not feasible to vary the ridge height along the terrace, it may be constructed to the same height throughout its length. The height should be that indicated in Table 5 for the length of terrace involved.

TABLE 5 - MINIMUM TERRACE RIDGE HEIGHTS TO BE MAINTAINED

Distance from Upper End of Terrace, Feet	Terrace Ridge Height, Feet
0 - 400	1.00
400 - 800	1.25
800 - 1600	1.50

Since the height of a terrace ridge and the shape of a terrace cross section can be materially changed by the farming operations, it is important that the minimum height of ridge be maintained at all times if the terrace is to be effective. In the past it has been common practice to build the terrace ridge 18 inches high throughout the length of the terrace. Many farmers objected to this height of ridge and worked it down, in many cases to 12 inches or less, throughout the length of the terrace. The resulting terrace then lacked the necessary carrying capacity at the lower end where the greater volume of runoff occurred.

WHAT LENGTH TERRACE: Terraces with the cross sections given in Tables 4 and 5 will have sufficient capacity to carry the runoff that accumulates in 1600 feet of terrace. If terraces of greater length are required, that section in excess of 1600 feet should be designed as a diversion channel.

Part III: Layout

There are two methods of layout: (1) by using a key terrace and (2) by using a map.

LAYOUT BY USING A KEY TERRACE

If the topography is relatively uniform over the area to be terraced, the following procedure for the layout of variable-grade, variable-cut terraces may be used.

1. Stake out the top terrace on the slope using a grade of 0.3 percent for the full length of the terrace. The location of this terrace will probably be changed later.
2. Determine the average slope of the area that will drain into each of the remaining terraces. Select the spacing for each terrace. Mark the location of each terrace with a single stake. These stakes will usually be set near the middle of the field and if possible at a point where the land slope is about average.
3. Select the location of the key terrace. This terrace should be so located that other terraces can be made parallel to it with the least correction. On most fields this will probably be the second or third terrace down from the top of the slope. The location of the outlet and the topography of the field must be considered in selecting the key terrace. On long slopes with a large number of terraces, it may be necessary to divide the terraces into groups and select a key terrace for each group.
4. Stake out the key terrace using a 0.3 percent grade and setting stakes at 50-foot intervals.
5. Adjust stakes on the key terrace by moving them up or down slope a small amount where necessary to reduce the curvature of the terrace.
6. Stake other terraces parallel to the key terrace at the proper spacing for the average slope of the land between the terraces. This can be accomplished by two men using a tape or string of a given length. One man walks along the terrace line already staked, holds one end of the tape and checks to determine if the tape is perpendicular to his terrace. He is not necessarily at a stake on his terrace at the time the other man sets stakes at 50-foot intervals on the next terrace.
7. Check elevations along each terrace line. After each terrace is staked a rod reading should be taken on the ground beside each stake, before staking out succeeding terraces. A study of this profile will indicate if it will be feasible to have a terrace at this location and

what adjustments in grade and depth of cut will be required. As the layout progresses it may become apparent that for a part of the field a terrace other than the original key terrace should be used for the key. These adjustments can be made as the layout progresses. When the job is completed it may be found that the key may consist of parts of several terraces rather than a single terrace.

8. After all terraces are laid out, additional work will be required to determine the grade and depth of cut required in different sections of the terraces. This is discussed in Part IV—Computing Grades and Depths of Cut.

LAYOUT BY USING A MAP

On irregular slopes where many terraces are required it is difficult to select the proper key terrace or terraces that will give the best possible layout for the least cost of construction. In these cases it is advisable to first stake out all the terraces using a constant grade of 0.3 percent and to take measurements needed to prepare a map of the terraces. The map can then be used to plan the layout of the improved terraces.

The advantages of using the map in planning are that all of the terraces on the field can be seen at a glance and adjustments in terrace location can be made much faster than would be possible by restaking the terraces in the field. As experience is gained in the mapping procedure it will probably be found that a faster and better job of planning can be done on nearly all fields by using a map.

Procedure for Making the Map

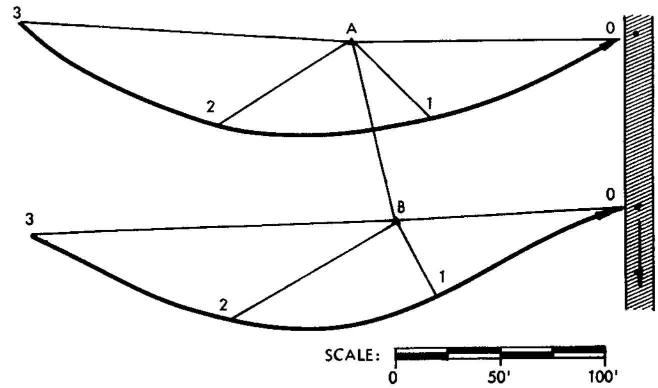
In making the map it is desirable to have a level equipped with stadia hairs and a horizontal circle graduated 0 to 360 degrees. Constant grade terraces are staked out on the field following the usual procedure with the following additions.

1. At the first level setup, A in Figure 4, set the horizontal circle to read 0 degrees on the first stake (0) on the top terrace. Read stadia hairs to obtain the distance to this point. Record data in the field notes. See Figure 4.

2. Set stakes along the terrace at 100-foot intervals, using a grade of 0.3 percent. Read the stadia hairs and the horizontal angle for each stake and record in field notes. Also take a rod reading in the outlet in line with the end of each terrace.

3. When it is necessary to move the level, read the stadia hairs and angle to the next level setup, point B in Figure 4. Move the level to point B, sight back to the previous setup, A, and set the horizontal circle to read 0 degrees. It may be necessary to tilt the level slightly to sight back on A.

4. Take a rod reading on the terrace above (1.2 on stake 0 of terrace 1 in Figure 4). Add the vertical interval to obtain the rod reading to use at the first stake on the next terrace. (In Figure 4, 1.2 + 4.4 = 5.6, the rod reading for Stake 0, Terrace 2). The land slope between terraces and the vertical interval used should be recorded in the field notes.



Field Notes for Mapping Terraces

Stake	Upper	Middle	Lower	Distance	Angle
		Level at A			
Terrace 1					
Outlet		5.0			
0	4.65	4.0	3.35	130	0°
1	3.96	3.7	3.44	52	46°5'
2	3.77	3.4	3.03	74	148°50'
3	3.89	3.1	2.31	158	184°30'
B	8.04	7.7	7.16	88	76°50'
		Level at B			
A					0°
0 on Terrace		1.2			
Terrace 2					
Outlet		6.4			
0	6.14	5.6	5.06	108	100°0'
1	5.50	5.3	5.10	40	166°30'
2	5.47	5.0	4.53	94	253°5'
3	5.57	4.7	3.83	174	281°30'

Fig. 4—Field Notes and Sketch Illustrating the Procedure for Mapping Terraces. Average slope between terraces 1 and 2 = 5.0 percent. Vertical interval = 4.4 feet.

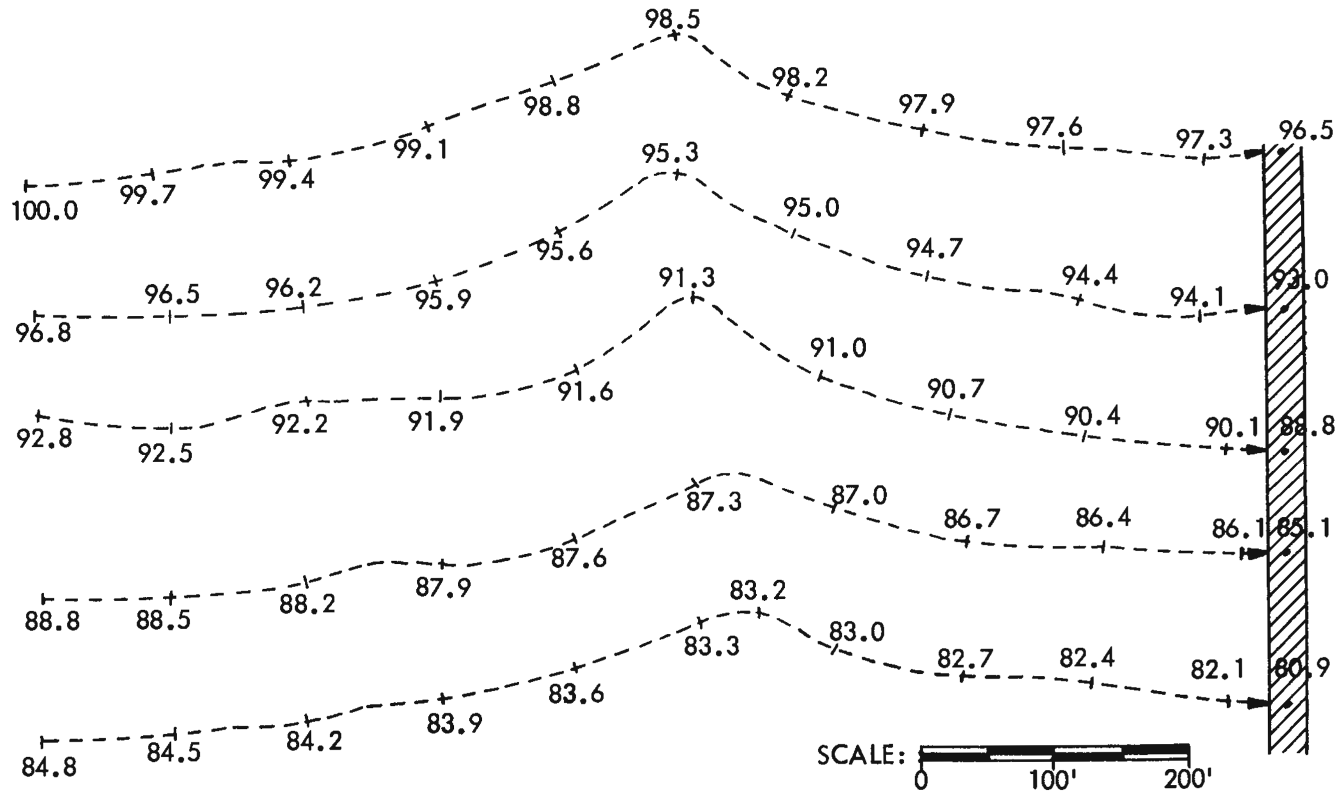


Fig. 5—Map of constant grade terraces to be used in planning.

5. When all terraces have been staked, draw a map of the terraces to an appropriate scale (usually 1 inch equals 50 feet or 1 inch equals 100 feet) by laying off angles and distances to scale. A completed map of 5 terraces, which have been staked out using a constant grade of 0.3 percent, is shown in Figure 5. Elevations can be noted on each terrace since the grade used in layout, 0.3 percent, and the vertical interval between the terraces is known.

Plan an Improved Terrace System on the Map

The map in Figure 5 will be used in a planning example. One possible layout for this field is shown in Figure 6.

The allowable variation in grade in different sections of a terrace and the maximum desirable depth of cut must be kept in mind while planning. In this example the maximum permissible grades used in different sections of the terrace will be those specified in Table 3. The minimum grade will be 0.2 percent.

In planning a terrace system on the map in Figure 5, first determine the slope of the land between the top three terraces and select the spacing to be used between them. The elevations at each 100-foot point along the terrace are shown on the map. The distance between terraces can be measured and the land slope computed.

Land slope between terraces 1 and 2 is 3 percent. A spacing of 107 feet should be used. See Table 1.

Land slope between terraces 2 and 3 is 4½ percent. A spacing of 93 feet should be used.

Next, determine if it will be possible to make terraces 1, 2, and 3 parallel. If either 1 or 2 is selected as the key terrace the upper 400 feet of terrace 3 will be below the terrace as mapped. This will require either a reduction in grade or a reduction in depth of cut over a considerable distance. Very little change in location could be accomplished by reducing the grade from 0.3 to 0.2 percent and reducing the cut would require earth to be hauled in for a considerable distance, so this is not feasible.

If the upper 400 feet of terrace 3 is selected as the key terrace it would first be relocated, as indicated by the solid line in Figure 6, to reduce the number of curves. Terraces 1 and 3 would then be made parallel to 3 at the proper distance upslope. The location of these terraces is shown in Figure 6. Note that the grade in the upper end of both terraces 1 and 2 will be greater than the grade in the original terraces. The greatest increase occurs in the upper 300 feet of terrace 1. It must be determined if this grade is greater than the maximum permissible grade for this section of the terrace. To do this the elevation at

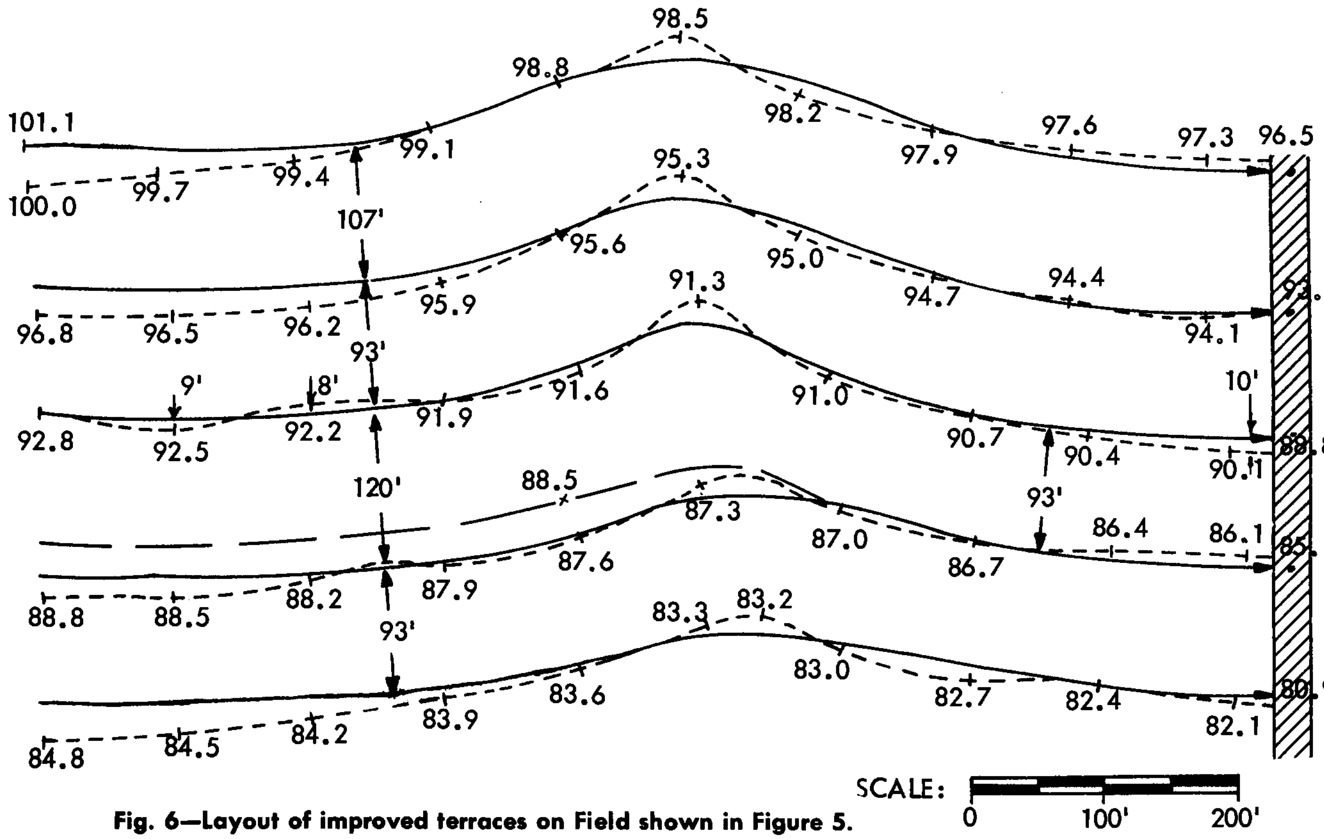


Fig. 6—Layout of improved terraces on Field shown in Figure 5.

the upper end of the terrace 1 must be computed.

The upper end of terrace 1 was moved upslope 30 feet. The land slope at this point is 3½ percent. The change in elevation then is 30 x .035 = 1.05. The elevation at the upper end of terrace 1 is 100.0 + 1.05 = 101.1 feet, to the nearest 0.1 foot.

In the upper 300 feet of terrace 1 the change in elevation is 101.1 - 99.1 = 2.0 feet. The grade in this section is then 0.67 percent which is less than the maximum permissible grade for this section of the terrace. See Table 3.

It is not necessary to determine the exact grade in all sections of the terraces. It is only necessary to determine if these grades are less than the maximum permissible grades. It is apparent, for example, that the grade in the upper 400 feet of terrace 2 will be less than the maximum, so this grade is not computed.

If the lower 300 feet of terrace 3 is used as the key, the lower ends of terrace 1 and 2 will be below the terraces as mapped. This will require an increase in grade or a reduction in depth of cut. The maximum permissible grade at the lower ends of these terraces is 0.35 percent, so very little relocation could be accomplished by changing the grade from 0.3 to 0.35 percent. Reducing the depth of cut will require earth to be hauled in which will add to the cost.

If the lower 300 feet of terrace 2 is used as a key the lower end of terrace 1 must be moved downslope slightly by increasing the grade and reducing the depth of cut. The lower end of terrace 3 must be moved upslope by reducing the grade and increasing the depth of cut. The total amount of earth movement, however, will be less than if either terrace 1 or terrace 3 had been used as the key.

Where the terraces cross the depression near the center of the field, Figure 6, it is probably advisable to reduce the sharpness of curvature to a certain extent by crossing the depression at a lower elevation. This will result in less depth of cut so earth must be hauled in to build the ridge to the required height. The type of equipment available for moving the earth and the amount that the individual is willing to spend will determine the extent to which these curves are reduced. In most cases it is not advisable to place fill to obtain the desired grade in the terrace channel.

The depth of cut required can also be determined approximately from the map. For example, the land slope where terrace 2 crosses the depression is 4 percent, terrace 2 is downslope 16 feet from the original location. The change in elevation is 16 x .04 = .64 feet. The depth of cut at the new location will then be 0.64 feet less than at the original.

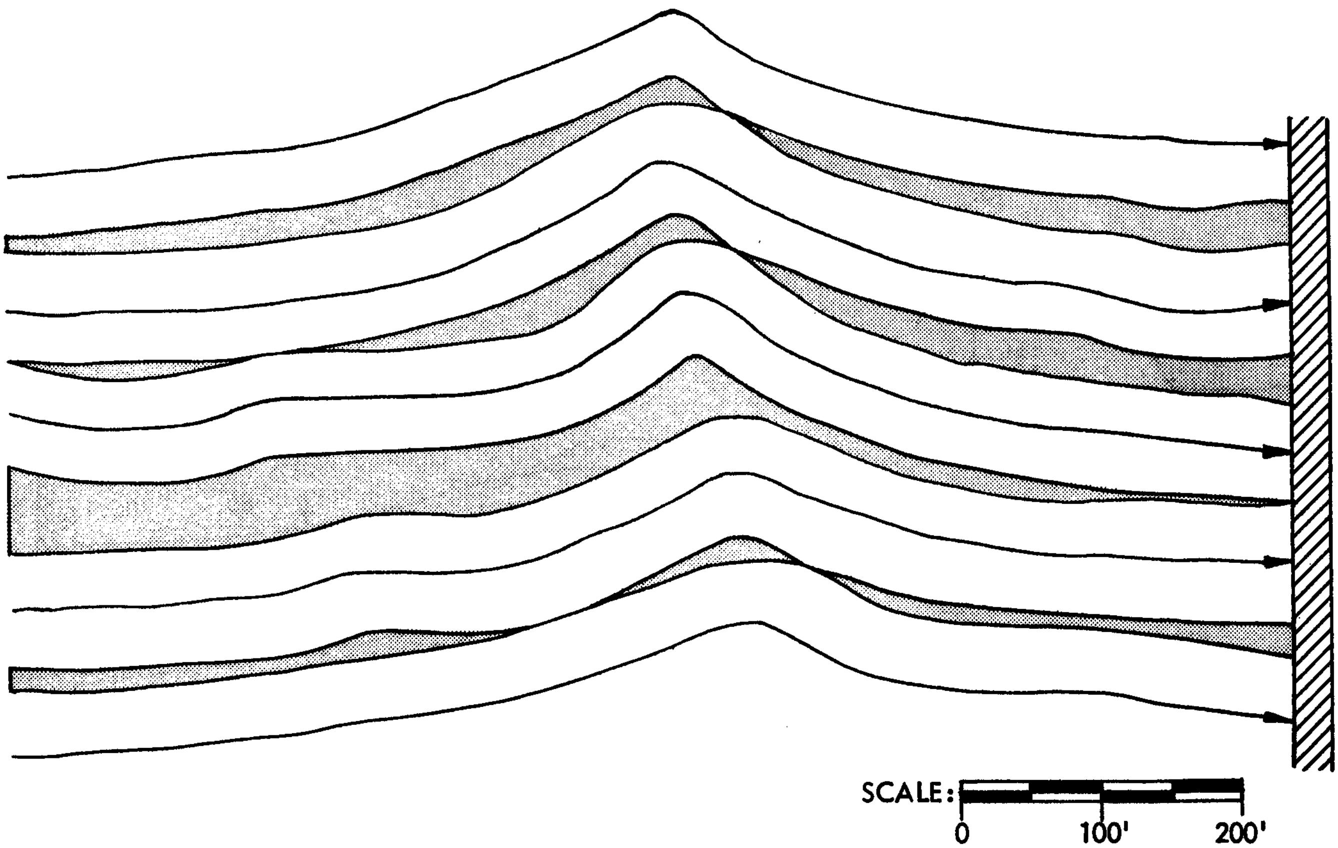


Fig. 7—Point row areas that would result from farming with constant grade terraces on the field shown in figure 5. The point row area represents 19 percent of the total area.

The land slope between terraces 3 and 4 is 3 percent near the left edge of the field and 5 percent near the right edge. If terrace 4 is drawn parallel to terrace 3 at the recommended spacing of 93 feet for a 4 percent slope, as indicated by the dashed line, it is noted that the elevation 400 feet from the upper end is 88.5 feet and at 600 feet the elevation is 87.0 feet, a 1.5 foot change in 200 feet, or a grade of 0.75 percent. This is in excess of the permissible grade of 0.4 percent so the terrace cannot be placed at this location.

If the terrace is located at a spacing of 120 feet for the upper 400 feet and 93 feet for the lower 300 feet and these sections joined by a smooth curve it is noted that the terrace can be built at this location with little change in grade or depth of cut. The spacing is such that there will be 36 crop rows between terraces on the left and 28 crop rows between terraces on the right. This is a difference of 8 crop rows which will require one turn in the field with four row equipment.

Terrace 5 can then be made parallel to terrace 4 at a spacing of 93 feet.

Figure 7 shows the point row areas that would result from farming with constant grade terraces on this field. The point row area represents 19 percent of the total area. It would be necessary to turn in the field at either one or both ends of the row in farming these areas which would increase the time required and result in more soil compaction. Also note that these point row areas are uneven in width. In planting these areas it would be necessary to plant across other rows or there would be areas that would be left unplanted. Difficulty would also be encountered in cultivating and harvesting these areas.

Figure 8 shows the point row areas that would result from farming with the improved terraces which have been planned for this field. Note the appreciable reduction in point row areas, and that the point row area remaining is uniform in width. The point row area represents 4 percent of the total area.

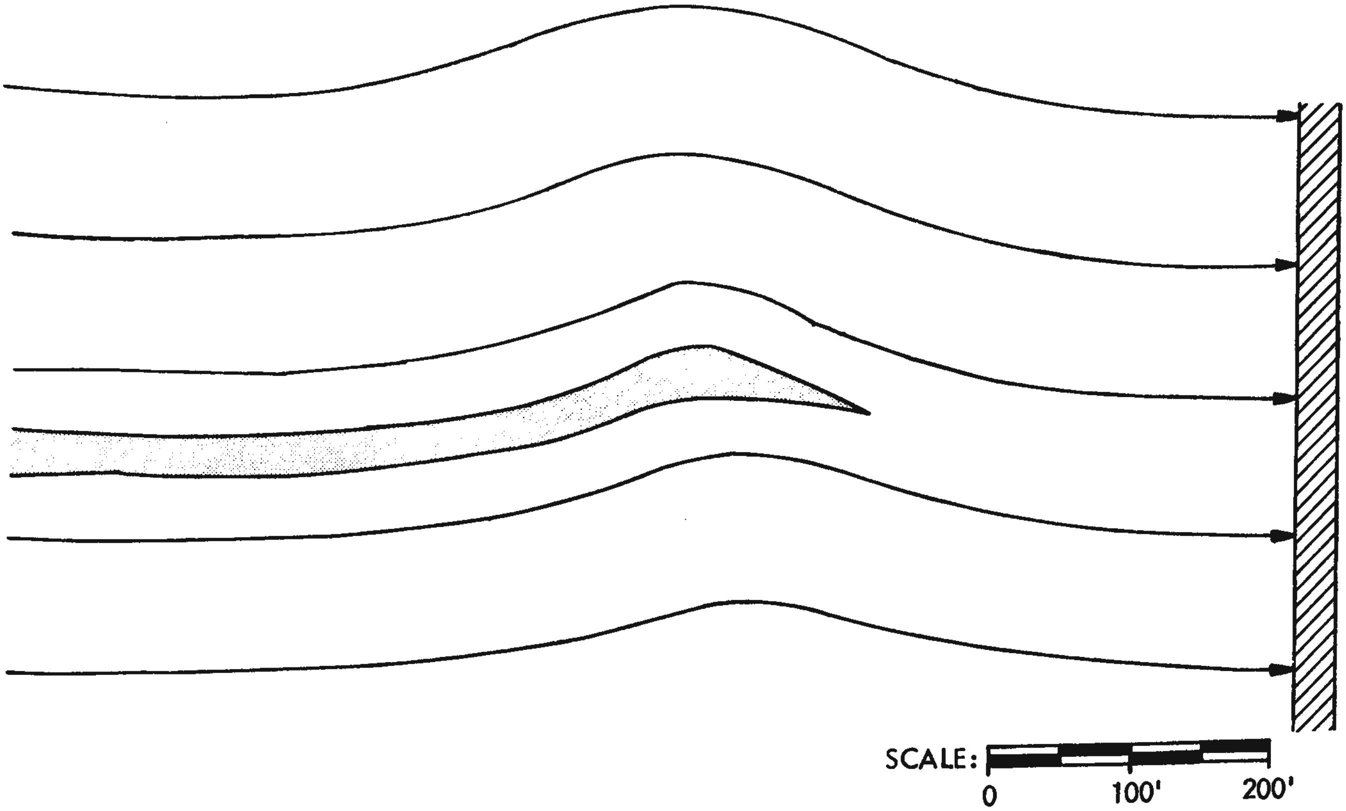


Fig. 8—Point row area that would result from farming with the improved terrace layout that was planned for the field shown in figure 5. The point row area represents 4 percent of the total area.

The objective in planning should be to eliminate as many point row areas as possible. Where they can not all be eliminated they should be made uniform and of such width that they can be planted conveniently with the equipment available.

Transfer Location of Terrace Lines from the Map to the Field

After the improved terraces have been located on the map these terraces must be staked out on the field by taking the necessary measurements from the map. On the field illustrated in Figure 6 terrace 3 would be staked first setting stakes at 50-foot intervals. At the upper end of this terrace the first stake on the improved terrace would coincide with the first stake on the terrace as mapped. The 100-foot stake would be upslope 9 feet from the terrace as mapped. The 200-foot stake would be downslope 8 feet from the terrace as mapped, and so on down the terrace. The stake at the outlet would be upslope 10 feet from the terrace as mapped. Minor shifting of these stakes should be made, if necessary, to assure smooth curves along the terrace line.

The other terraces would then be staked parallel to terrace 3 by using a tape or string, as previously discussed under *Layout by Using a Key Terrace,* step 6.

Part IV: Computing Grades and Depths of Cuts

Check Elevation at Each Stake Along Each Terrace

A rod reading should be taken on the ground beside each stake of the improved terraces and in the outlet in line with the end of the terrace. The rod readings should be recorded in a field book as "Ground Rod". See Figure 9, Column 2. Observe that these notes are of somewhat different form than conventional level notes and that the elevation of the ground surface is not computed. Note that when the level is moved a reading is taken on a stake from each setup (stake 6, Figure 9). The grade rod is obtained as described in the following sections, and the depth of cut is then computed.

Fig. 9—Survey Notes for an Improved Terrace.

Stake	Ground Rod	Grade Rod	Cut
0	5.3	6.0	0.7
1	5.7	6.4	0.7
2	6.0	6.7	0.7
3	6.3	7.1	0.8
4	7.0	7.7	0.7
5	7.2	7.8	0.6
6	7.2	7.9	0.7
TP			
6	5.2	5.9	
7	5.2	6.0	0.8
8	5.4	6.2	0.8
9	5.8	6.3	0.5
10	5.6	6.4	0.8
11	5.5	6.6	1.1
12	6.0	6.8	0.8
13	6.3	7.1	0.8
14	6.4	7.3	0.9
15	6.5	7.5	1.0
16	6.8	7.7	0.9
17	7.2	7.9	0.7
18	7.2	8.1	0.9
19	7.1	8.2	1.1
20	7.5	8.4	0.9
Outlet	8.5		

Plot a Profile of the Ground Surface Along Each Terrace

To determine the grade in each section of the terrace that will result in the least amount of work to be done in constructing the terrace the survey notes should be plotted and a profile of the ground surface drawn. See Figure 10. Note that rod readings are plotted rather than elevations and that rod readings are numbered down from the top of the profile sheet. If more than one level setup is made the profile is plotted as if all readings had been taken from one setup.

In the notes, Figure 9, observe that the second level setup was 2 feet lower in elevation than the previous setup. This can be determined by noting the rod reading on stake 6 from each setup. In plotting the profile, 2 feet is added to each rod reading taken from the second setup.

This profile represents the elevation of the ground surface along the terrace. Draw a line along the profile at such grade and elevation that the amount of earth above the line will be approximately equal to the amount below the line (line A in Figure 10). Where the profile is above this line a greater depth of cut will be required than where it is below the line. The grade of this line must fall within the allowable limits of grade for the different sections of the terrace as given in Table 3. The grade of different sections of this line is indicated in Figure 10.

Compute the Depth of Cut Required at Each Stake

A certain depth of cut is required so that the earth taken from the channel will be equal to the earth required in the ridge. This depth of cut will vary with the height of terrace and the land slope. The depth of cut required for the terraces with cross sections as given in Figure 3, are given in Table 6. The depth of cut where the terrace will have sufficient height if no earth is placed in the ridge, is also given in Table 6. These depths of cut are measured at the lower edge of the channel as indicated in Figure 2.

The terrace whose profile is plotted in Figure 10 is to be constructed on 6 percent land slope. The terrace

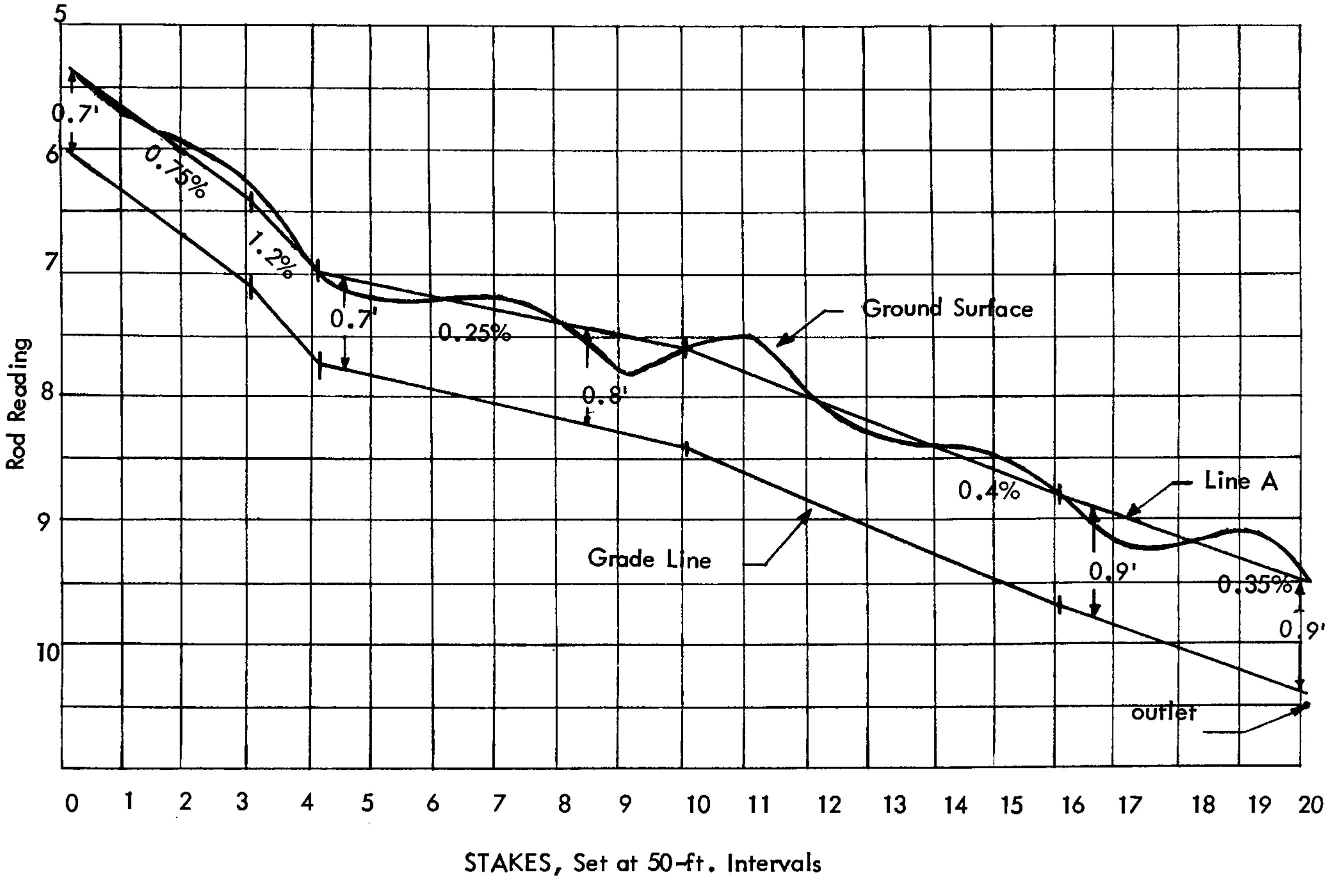


Fig. 10—Profile of ground surface and grade line of a terrace on a 6 percent slope. Plotted from level notes, Figure 9.

TABLE 6 - DEPTH OF CUT REQUIRED FOR TERRACES WITH DIFFERENT RIDGE HEIGHTS

Land Slope	Depth of Cut at Lower Edge of Channel for Balance of Cut and Fill, ft.			Depth of Cut Where Terrace Will Be All Channel, No Ridge Required, ft.		
	Terrace Ridge Height			Terrace Ridge Height		
	1.0	1.25	1.50	1.0	1.25	1.5
1	0.5	0.6	0.7	1.1	1.4	1.6
2	0.5	0.7	0.8	1.2	1.5	1.7
3	0.6	0.7	0.8	1.3	1.6	1.8
4	0.6	0.7	0.9	1.4	1.7	1.9
5	0.6	0.8	0.9	1.5	1.8	2.0
6	0.7	0.8	0.9	1.6	1.9	2.1
7	0.7	0.8	1.0	1.7	2.0	2.2
8	0.7	0.8	1.0	1.8	2.1	2.3
9	0.7	0.8	1.0	1.5	1.8	2.0
10	0.7	0.8	1.0	1.6	1.9	2.1
11	0.7	0.8	1.0	1.7	1.9	2.2
12	0.7	0.8	1.0	1.7	2.0	2.2

height in the upper 400 feet is to be 1.0 foot. From 400 to 800 feet, it is to be 1¼ feet and from 800 to 1000 feet, 1½ feet. In Table 6 note that the depths of cut required are 0.7 feet, 0.8 feet and 0.9 feet, respectively.

In Figure 10, draw a line on the profile parallel to line A and below it a distance equal to the depth of cut required to give a balance of earth from the channel for the ridge for each section of the terrace. This is designated *"grade line."* The depths of cut are noted in Figure 10. Note that the *grade line* is not exactly parallel to line A in those sections where it is necessary to change to a greater depth of cut.

The *grade line* represents the bottom of the completed terrace channel. The *"grade rod"* is the rod readings that would have been obtained had it been possible to place the rod at the elevation of the bottom of the completed terrace. These values may be taken directly from the profile; however, it is usually easier to compute them by taking the *grade rod* reading at the upper end of the terrace and adding the proper grade for each succeeding stake. Record these values to the nearest tenth of a foot in column 3 of the survey notes, Figure 9.

Compute the depth of cut at each stake by subtracting the ground rod from the grade rod and record in column 4 of the survey notes, Figure 9.

The grade rod reading at the stake at the outlet (8.4 at stake 20, Figure 9) should be approximately the same as the rod reading taken in the outlet opposite that stake (8.5, Figure 9). The terrace can be cut into the outlet either upslope or downslope from the point at which the rod reading was taken in the outlet if necessary to obtain the proper grade between the end of the terrace and the outlet.

Mark the Stakes for Construction

The depth of cut to be made at each stake should be marked on that stake.

Figure the Volume of Earth to be Moved in Constructing the Terrace (If desired)

The volume of earth to be excavated from the channel to build a terrace to the desired height can be determined from Table 7. In computing the volume of earth required for the ridge an additional 10 percent was used to allow for waste and shrinkage.

TABLE 7 - VOLUME OF EARTH TO BE TAKEN FROM THE CHANNEL OF A TERRACE TO GIVE SUFFICIENT EARTH FOR THE RIDGE

CUBIC FEET PER LINEAL FOOT OF TERRACE*

Land Slope	Terrace Height, Feet		
	1.0	1.25	1.50
1	7.6	8.7	9.8
2	8.7	9.8	10.9
3	9.7	10.8	11.9
4	10.6	11.7	12.8
5	11.2	12.4	13.5
6	11.5	12.9	14.2
7	11.7	13.2	14.7
8	11.8	13.3	14.8
9	11.7	13.2	14.7
10	11.6	13.0	14.4
11	11.3	12.7	13.9
12	11.0	12.1	13.2

*Includes 10 percent more volume than in actually present in the settled ridge. This is to allow for shrinkage and waste.

Figure the Excess or Deficiency of Earth for the Ridge with Varying Depths of Cut

The amount of earth that must be moved from sections of deeper cut and the additional amount that is required in the ridge in the sections of lesser cut can be computed from Tables 8, 9, and 10.

On a data sheet similar to Figure 11 record the depth of cut at each stake. Determine the excess or deficiency of earth in cubic yards for each 50-foot section from either Table 8, 9, or 10 depending on the height of the terrace required at that stake. Record on Figure 11. If earth is not taken to or brought from other terraces the total excess yardage should equal the total deficient yardage. However, in most cases it is advisable to have an excess of earth which can be used to fill gullies or other depressions between terraces.

In most cases it is more desirable to cut some deeper in the channel of the terrace to obtain earth to fill gullies than it is to fill the gullies with topsoil from the vicinity of the gully. In the example, Figure 11, there is an excess of 49 cu. yds.

The amount of excess or deficiency of earth can be adjusted by shifting the grade line to a higher or lower

TABLE 8 - EXCESS OR DEFICIENCY OF EARTH FOR THE TERRACE RIDGE WITH VARYING DEPTHS OF CUT.

(TERRACE RIDGE HEIGHT 1.0 FOOT)

CUBIC YARDS OF EARTH PER 50 FEET OF TERRACE*

Depth of Cut at Edge of Channel, feet	Slope of Land, percent											
	1	2	3	4	5	6	7	8	9	10	11	12
-0.4	-49	-51	-53	-54	-55	-56	-57	-57	-56	-55	-53	-48
-0.2	-39	-41	-43	-44	-45	-46	-47	-47	-47	-46	-43	-39
0.0	-27	-29	-31	-33	-34	-35	-35	-35	-35	-34	-33	-30
0.2	-16	-19	-20	-22	-23	-24	-25	-25	-25	-24	-23	-20
0.4	- 4	- 6	- 7	- 9	-11	-11	-13	-14	-14	-14	-13	-11
0.6	8	6	--	--	--	- 1	- 3	- 4	- 5	- 5	- 4	- 2
0.8	19	17	15	13	11	10	8	7	6	6	6	7
1.0	31	29	27	25	23	21	19	17	16	15	15	16
1.2	39	39	38	36	33	31	29	27	26	25	25	24
1.4	47	48	48	47	45	42	40	38	36	34	33	32
1.6	51	52	54	54	53	52	51	49	47	45	44	42
1.8	59	60	60	60	60	59	58	58	56	54	52	50
2.0	65	66	66	66	65	65	64	63	61	59	57	55
2.2	71	72	72	72	72	71	70	69	67	65	62	59
2.4	77	78	79	79	79	78	77	75	73	70	68	64
2.6	84	85	85	85	84	83	82	81	79	77	73	69
2.8	90	91	91	91	90	89	88	86	84	81	78	74
3.0	96	97	97	97	97	95	94	92	89	86	82	79

TABLE 9 - (TERRACE RIDGE HEIGHT 1.25 FEET)

-0.4	-58	-59	-60	-61	-62	-63	-63	-63	-63	-61	-59	-53
-0.2	-46	-48	-50	-51	-52	-52	-53	-53	-52	-51	-48	-44
0.0	-33	-36	-38	-40	-41	-41	-42	-42	-42	-41	-38	-35
0.2	-22	-24	-26	-27	-29	-30	-31	-31	-31	-31	-29	-26
0.4	-11	-13	-14	-16	-17	-19	-20	-21	-21	-20	-19	-16
0.6	1	- 1	- 2	- 4	- 6	- 8	- 9	-10	-10	-10	- 9	- 7
0.8	12	10	8	6	--	--	--	--	--	--	--	--
1.0	24	23	21	19	17	15	13	11	10	10	10	10
1.2	34	33	31	30	27	25	23	21	20	19	19	19
1.4	45	44	43	41	39	36	34	32	31	29	28	28
1.6	51	52	53	53	51	48	45	43	40	38	37	37
1.8	59	60	60	59	58	57	55	53	51	49	47	46
2.0	65	66	66	66	65	64	64	63	61	59	57	54
2.2	71	72	72	72	72	71	70	69	67	65	62	59
2.4	77	78	79	79	79	79	77	75	73	70	68	64
2.6	84	85	85	85	84	83	82	81	79	77	73	69
2.8	90	91	91	91	90	89	88	86	84	81	78	74
3.0	96	97	97	97	97	95	94	92	89	86	82	79

*Includes 10 percent more volume than is actually present in the settled ridge. This is to allow for shrinkage and waste.

TABLE 10 - EXCESS OR DEFICIENCY OF EARTH FOR THE TERRACE RIDGE WITH VARYING DEPTH OF CUT. (TERRACE RIDGE HEIGHT 1.5 FEET)

CUBIC YARDS OF EARTH PER 50 FEET OF TERRACE*

Depth of Cut at Edge of Channel, feet	Slope of Land, percent											
	1	2	3	4	5	6	7	8	9	10	11	12
-0.4	-63	-65	-67	-68	-69	-69	-69	-69	-69	-67	-65	-59
-0.2	-49	-53	-56	-58	-59	-60	-61	-60	-60	-59	-56	-50
0.0	-38	-41	-44	-46	-48	-49	-50	-50	-49	-48	-46	-41
0.2	-29	-31	-33	-34	-36	-37	-38	-39	-38	-38	-36	-31
0.4	-16	-18	-20	-23	-24	-26	-27	-28	-28	-27	-26	-22
0.6	- 5	- 6	- 9	-12	-14	-15	-16	-17	-18	-17	-16	-13
0.8	7	--	--	- 1	- 3	- 5	- 6	- 7	- 7	- 7	- 6	- 4
1.0	18	16	14	11	8	6	--	--	--	--	--	--
1.2	30	28	25	22	19	17	16	14	13	13	13	14
1.4	40	38	36	33	31	28	26	25	23	22	22	22
1.6	49	48	47	44	42	39	37	35	33	32	31	31
1.8	58	58	57	56	54	51	49	46	44	42	41	41
2.0	65	66	66	66	64	62	59	57	54	52	51	49
2.2	71	72	72	72	71	70	69	67	65	63	60	58
2.4	77	78	79	79	79	78	77	75	73	70	68	64
2.6	84	85	85	85	84	83	82	81	79	77	73	69
2.8	90	91	91	91	90	89	88	86	84	81	78	74
3.0	96	97	97	97	97	95	94	92	89	86	82	79

*Includes 10 percent more volume than is actually present in the settled ridge. This is to allow for shrinkage and waste.

Fig. 11—Data Sheet For The Contractor. For a terrace on a 6 percent slope.

Stake	Cut, ft.	Excess cu. yd.	Deficiency cu. yd.	Height Terrace feet	Depth of Cut, Feet. For Balance Cut & Fill	Depth of Cut, Feet. No Earth In Ridge
0	0.7	--	--	1.00	0.7	1.6
1	0.7	--	--	1.00	0.7	1.6
2	0.7	--	--	1.00	0.7	1.6
3	0.8	10	--	1.00	0.7	1.6
4	0.7	--	--	1.00	0.7	1.6
5	0.6	--	1	1.00	0.7	1.6
6	0.7	--	--	1.00	0.7	1.6
7	0.8	10	--	1.00	0.7	1.6
8	0.8	--	--	1.25	0.8	1.9
9	0.5	--	14	1.25	0.8	1.9
10	0.8	--	--	1.25	0.8	1.9
11	1.1	20	--	1.25	0.8	1.9
12	0.8	--	--	1.25	0.8	1.9
13	0.8	--	--	1.25	0.8	1.9
14	0.9	8	--	1.25	0.8	1.9
15	1.0	15	--	1.25	0.8	1.9
16	0.9	--	--	1.50	0.9	2.1
17	0.7	--	10	1.50	0.9	2.1
18	0.9	--	--	1.50	0.9	2.1
19	1.1	11	--	1.50	0.9	2.1
20	0.9	--	--	1.50	0.9	2.1
		74	25			

74 - 25 = 49 cu. yds. excess

elevation thus reducing or increasing the depth of cut as required. The change in depth of cut can be made for the entire terrace or only for certain sections as required.

Also indicate on the data sheet, Figure 11, the height of terrace to be constructed, the depth of cut for a balance of earth in the channel and ridge, and the depth of cut where no earth will be required in the ridge.

The contractor, or the one who is to build the terraces, should be given a sheet with the information given in Figure 11. He will find this quite valuable, particularly if he is just beginning to construct this type of terrace.

Part V: Construction

In the construction of this type terrace it may be necessary to vary the depth of cut in different sections of the terrace. The excess soil in the areas of deeper cut must be transported to the areas of shallower cut. Equipment that is best suited to transporting earth some distance is desirable. Bulldozers can be used satisfactorily if the length of haul is relatively short. On longer hauls scrapers or scoops, pulled by rubber-tired tractors, would be more desirable because of their greater speed in transport. Probably the most efficient combination of equipment for most jobs would be a scraper or scoop pulled by a rubber tired tractor to move the earth an appreciable distance and a dozer to move the earth from the channel into the ridge.

The first step in terrace construction is to plow furrows marking the over-all width of the terrace. The terrace should be the same width for its entire length. Figure 12 (a) illustrates the location of these furrows for a terrace on a 6 percent land slope. These furrows will be helpful to the contractor in maintaining the proper terrace width and cross section throughout the length of the terrace.

The practice of scalping topsoil from the field between terraces to obtain earth for the terrace ridge in areas of limited cut is not desirable. All earth for the terrace ridge should be taken from the area below the furrow marking the upper edge of the channel. The following procedure is suggested for constructing terraces with a scoop and dozer combination.

1. Use the scoop to move the excess earth from the channel in areas of deeper cut and place it in the ridge in the areas of shallower cut. For example, 11 yards is to be moved from near stake 19 in Figure 11 and 10 yards is needed in the ridge near stake 17. Excess earth can also be used to fill gullies and smooth the area between terraces. The cut should be made as close to the stake as possible without knocking it over. Figure 12 (b) represents the cut to be made at stake 19; note that the cut was made 1 foot from the stake line. The earth is placed on a line representing the center of the ridge, 8½ feet from the stake line, in the vicinity of stake 17. See Figure 12 (c). A scoop with a 6-foot width of cut is being used.
2. Use the dozer to move the remaining earth from the channel into the ridge for the full length of the terrace. The depth of cut should be as close as possible to that marked on the stake. Figure 12 (d) represents the cut at stake 18. Care must be taken so that the stakes are not knocked down. The cross hatched section in Figure 12 (d) represents the small mound of earth left on which the stake is setting.
3. Go lengthwise in the terrace channel with the scoop and make the exact depth of cut required at each stake. This depth can be checked by using a carpenters level and a rule as illustrated in Figure 12 (e), or by using a hand level as discussed later.
4. The final step is to smooth up the terrace side slopes being sure to obtain the proper widths in all sections of the terrace. Note that for this particular terrace, on a 6 percent slope, a 5-foot channel width was specified. Since a scoop 6 feet wide was used it will be necessary in this last step to dress the side slopes down so that a 5-foot channel width is obtained. See Figure 12 (f).

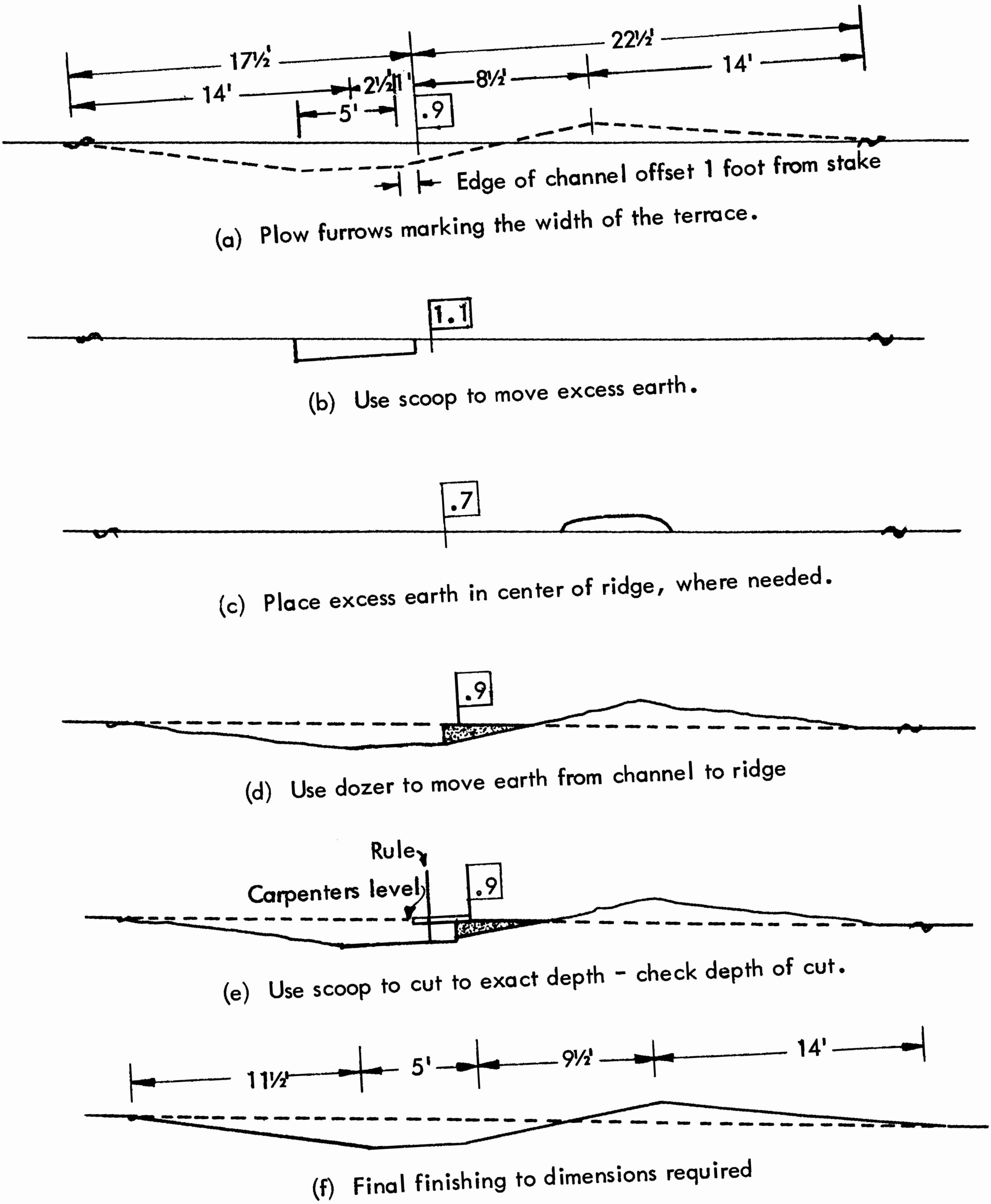


Figure 12—Constructing terraces with a scoop and dozer combination

Fig. 13—Checking to determine if the terrace channel has been excavated to the proper depth.

Fig. 14—Checking the height of a terrace ridge.

Building Terraces With a Dozer

If a dozer is the only equipment to be used the following procedure is suggested:

1. Move the excess earth from the channel in areas of deeper cut and place it in the terrace channel opposite the areas where earth will be needed in the ridge.
2. Move the remaining earth from the channel into the ridge for the full length of the terrace. Make the proper depth of cut at each stake.
3. Travel lengthwise in the channel with the dozer making the exact depth of cut.
4. Smooth the terrace side slopes and narrow channel down to the proper width.

Building Terraces With a Scoop

Scrapers or scoops work very well for building a terrace. They have the ability to transport earth some distance quite efficiently. Where it is not necessary to transport the earth they, of course, load and dump the earth in the shortest distance possible. A small scoop pulled by a farm tractor is shown in Figures 13 and 14.

Checking Depth of Cut by Use of Hub Stakes

A more exact method of checking the depth of cut is by use of hub stakes. Set hub stakes about 30 feet upslope from the channel stakes when the terrace is staked out. Take rod readings at the hub stakes when levels are being run for the channel stakes. The difference in elevation between the hub stake and the bottom of the completed terrace channel can then be computed by subtracting the hub rod reading from the grade rod reading given in Figure 9. In checking the depth of cut a man stands in the terrace channel and sights with a hand level to a rod set at the hub stake. See Figure 13. The difference in elevation between the hub stake and the terrace channel subtracted from his eye height will give the reading he will get on the rod if the channel is cut to the proper depth.

As an example assume the rod reading at the hub stake opposite stake 0 in Figure 9 was 3.3 feet.

Grade rod = 6.0, Hub rod = 3.3 feet.

Difference in elevation between the hub stake and the terrace channel is 6.0 - 3.3 = 2.7 feet.

Height to eye of man checking = 5.5 feet.

Reading on rod when channel is cut to proper depth is 5.5 - 2.7 = 2.8 feet.

Checking The Height of the Terrace Ridge

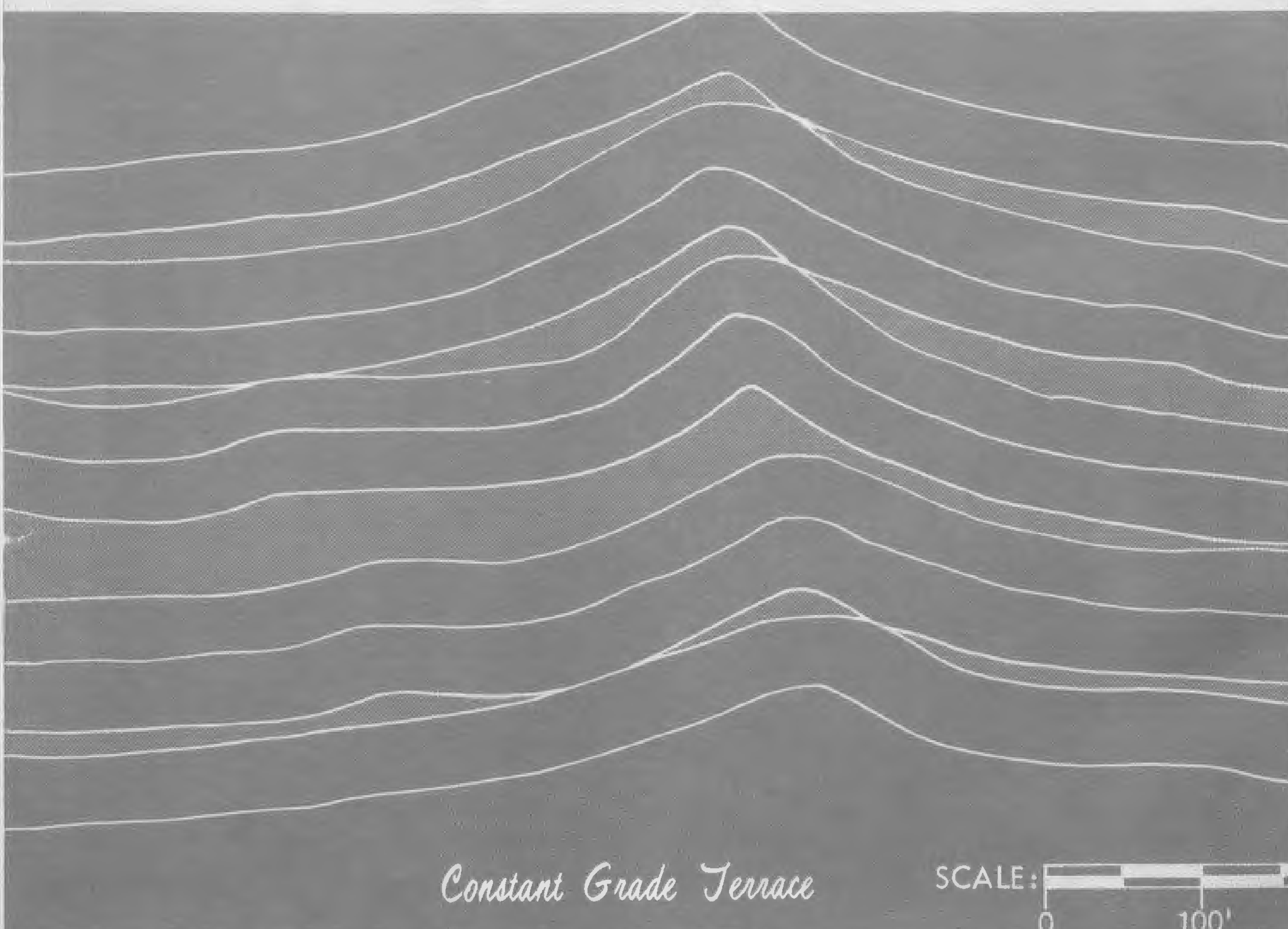
The height of the terrace ridge can be checked by setting the rod on the top of the ridge with the target set at a reading equal to the eye height of the man checking minus the ridge height desired. See Figure 14.

Part VI: Summary

The extent that a terrace system can be improved by this proposed method of terracing will vary depending upon the irregularity of the topography, the type of soil, the type of equipment to be used in building the terraces, and the amount of money to be spent on construction. On some fields all the terraces can be made parallel. On others only sections of terraces can be made parallel. In all fields, however, it will be possible to improve the layout by reducing the curvature of the terraces and by making sections of the terraces parallel, thereby reducing the size and number of irregular point row areas between them.

This proposed method of layout requires more thought and time than the layout of constant grade terraces. Construction of the terraces requires a change in technique and in some cases may cost more. But the added convenience and the saving of time in farming these terraces will offset any increase in time or cost of layout and construction.

A thorough knowledge of the principles and techniques involved is needed by the technician to plan and lay out the best possible terrace system by this method.


Constant Grade Terrace
SCALE:
0
100'