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F. B. MUMFORD, *Director*

Terracing, an Important Step in Erosion Control

MARION CLARK AND J. C. WOOLEY

A terraced field at the Federal-State Soil Erosion Experiment Station, Bethany, Missouri. Grain is bound over the terraces without difficulty on this 7 per cent slope. Field was severely eroded prior to terracing. Gullies were plowed in and terraces were constructed across them in the fall of 1930. Picture by courtesy of the Soil Erosion Experiment Station.

COLUMBIA, MISSOURI

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The terrace proving best suited to agriculture in Missouri consists of a combination of a ridge of soil and a channel built sufficiently wide, on moderate slopes, to be crossed easily with farm implements. It is constructed by placing earth above the ground line in a ridge at right angles to the land slope, with most of the earth taken from a broad channel cut on the uphill edge of the ridge. Terraces are spaced on the slope so as to prevent excessive soil movement between them where a good supply of organic matter is kept in the soil. It must be built with sufficient height to prevent runoff water overtopping it, and given just enough grade in the channel to allow excess runoff water to flow from the field at a non-scouring velocity.

TYPES OF EROSION

Erosion may be divided into two types, sheet and gully erosion. Gully erosion is easily seen since it divides the fields and causes trouble in cultivating, but it is not the most serious form of erosion. Sheet erosion takes the topsoil so evenly that it may not be noticed until most of the top soil is gone. The greatest cost to farmers comes from sheet erosion because it takes a layer of the best soil from the whole field. Severe sheet erosion on cultivated fields leads to gully formation, although gullies may be found in good pasture land without the accompanying sheet erosion. Terraces may be used as a permanent control for hillside gullies but they are used chiefly to assist in the control of sheet erosion.

FORCE TO BE CONTROLLED

If one considers that an acre-inch of water weighs more than 113 tons, he will not doubt the power of runoff water and may visualize what is required to stop a load of this magnitude after it gets well under way. When runoff water from one small area is allowed to run straight down the slope, it joins with the runoff from other areas and soon attains great volume as well as high velocity. The ability of flowing water to move objects varies as the sixth power of its velocity, and tons upon tons of topsoil may be rolled or suspended and carried from a cultivated field, leaving eventually only a small amount of either soil or moisture on the field for plant growth. By terracing, the field slope is divided into several small watersheds. The short slopes thus formed, plus the use of a cropping plan, soil treatment, and cultural practices fitted to that field, will allow only a minimum of runoff water to attain a scouring velocity (either between terraces or in the terrace channels). By controlling the velocity practically all of the soil is kept on the field and more runoff water is absorbed as it moves slowly from the field.

Fig. 2.—Terraced field on 11% slope just after a hard rain. Note in the channels the tons of excess runoff water, which is moving too slowly to erode. Osage County.

TYPES OF TERRACES

Bench Terrace.—The bench terrace may be divided into two forms. One form is found on extremely steep slopes and consists of a series of vertical rock walls placed at right angles to the land slope. Soil is placed behind each wall and the top leveled, sometimes with a small berm next to the wall to hold the water, or the soil is given a slight grade to the base of the next higher wall. This type of terrace has been used in the older countries, where it has become necessary to save and utilize all of the productive soil and where tillable land is scarce.

Another form of bench terrace is the sodded bench terrace used in lawns for decorative purposes.

Nichols and Narrow Base Ridge Type Terrace.—The Nichols or channel type terrace is used quite extensively on agricultural land in the southern areas of the United States for the conservation of soil and moisture. Channels are cut in the soil to carry the excess runoff water instead of carrying it behind a wall or mound of earth. Also extensively used in the South for the same purposes, is the narrow-ridge type terrace.

Mangum Terrace.—The Mangum broad-base, ridge type terrace is used quite extensively on agricultural land in the west central area of the United States to conserve soil and moisture. It is also used for land reclamation and hillside gully control. Although practically every terrace used for agricultural purposes in this area is referred to as the Mangum terrace, there is a very great difference in size, shape, method of construction, spacing, grade, benefits derived and satisfaction resulting from the use of the different forms of this same type of terrace.

Type of Terrace Best Suited to Missouri.—The type of terrace which has given best results in Missouri is neither strictly a ridge nor a channel type terrace, but is a combination of the two. It consists of a ridge built above the original ground level and a channel, on the up-hill side of the ridge, cut below the original ground level. It may be considered one form of the regular Mangum terrace. From one-third to one-half the effective height is secured by use of the channel and the remainder is obtained by the construction of the broad, oval ridge on the down hill edge of the channel. Such a ridge prevents the formation of a deep, narrow ditch around the field. This combination forms a terrace which is easily cultivated and which avoids the removal of an excessive amount of topsoil in order to get material for the construction of the ridge.

THE NEED FOR TERRACES

If man had not damaged or destroyed the virgin sod and timber covering of sloping land, soil losses would have been kept at a minimum and terraces would not be needed. However, in order to build and maintain a civilization such as ours, much of our upland is cultivated to raise a variety of crops, and a great deal of our pasture land is grazed to or beyond capacity. In raising the different grain crops, the protective sod is destroyed and the land left open to the destructive forces of uncontrolled water and wind for varying periods of time. Great quantities of plant nutrients are removed from the soil each year through crops, yet some of the best soils authorities estimate that on the larger portion of rolling cultivated land in the United States, from twenty to thirty times as much plant nutrients, are lost by erosion as are taken from the soil by plants. It is safe to say that in Missouri without control on long and rather steep slopes, fifteen to twenty crops of corn could be grown with the plant nutrients now being washed away while growing only one unprotected crop.

The Present Status of Soil Loss in Missouri.—According to the Missouri Experiment Station Bulletin 349, published in 1935, approximately 72 per cent of the state of Missouri has lost one-fourth to three-fourths (an average of one-half) of its topsoil, and approximately 2,000,000 acres have lost from three-fourths to all of their topsoil. The latter area, approximately one-twentieth of the state, represents land for the most part abandoned, land which pays no taxes and provides a living for no one. Only a small number of Missouri farms have been cultivated as long as one hundred years; most of them have been actively farmed no more than seventy or eighty years. In other words, we have lost in the lifetime of two generations approximately half of our topsoil, which took thousands of years for nature to form.

An Understanding of the Function of Terraces is Necessary for Their Proper Use.—Failure to understand clearly the benefits of terraces, both immediate and future, has been responsible for many half-hearted attempts at terracing, with consequent disappointing results and costly failures. One must have some definite ideas of the benefits to be derived before he will be willing to spend the money or the time and labor to do the job right. This is one of the most important problems and it is before us constantly. At the same time, the individual must be aware of the limitations of terraces.

Terrace Limitations.—Without a good rotation of crops, including the proper soil treatments, organic matter and plant nutrients will become deficient in the soil, and in addition to suffering reduced crop yields, there will be excessive soil movement between the terraces. This soil movement causes the terrace channels to fill, thus making it necessary to clean them frequently. The channels are cleaned by placing the earth from the channel on the terrace ridge, where it will wash to the next terrace channel, arriving there only to be put on its way down the slope again by being cleaned from the channel as before. Sections in the South have suffered from such a practice. Under this procedure a terraced area may become abandoned to agriculture, perhaps not quite so rapidly, but as surely as without the terraces.

EXPERIMENTAL DATA

A study of summarized experimental data will be helpful in determining the value and proper place of terraces in a farming program. Such data were gathered in research work by the Missouri Agricultural Experiment Station and the U. S. Department of Agriculture cooperating. All of the soil and runoff water from small areas was actually caught, measured, and analyzed. On larger areas only a certain known portion of the runoff was measured and analyzed to calculate total losses. Brief summaries of important findings are given here.

Figure 3 shows clearly the great effect that roots and organic matter have on reducing the soil loss even on a much shorter than average field slope, and only about one-third greater in length than the recommended terrace spacing for the same slope. Note how the aver-

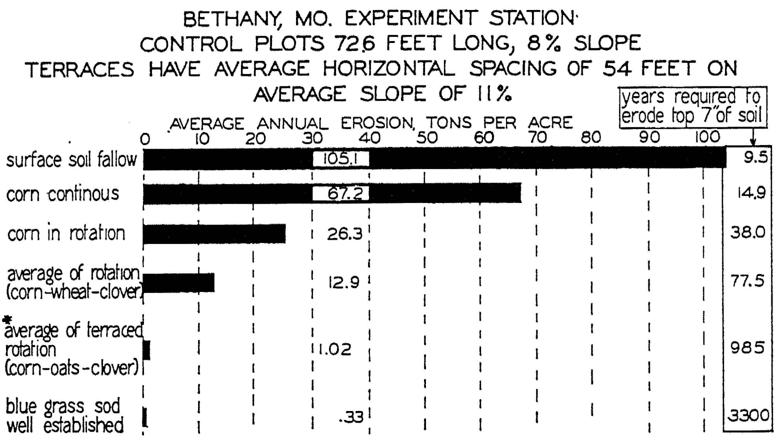

Fig. 3.—Graph showing comparative losses of soil under different cropping systems, with and without terraces. Based on a four-year summary of soil losses by crops, and a three-year summary of soil losses by crop rotation plus terraces. It should be borne in mind that all of the slopes except those on the terraced field are much shorter than normal field slopes, and that the soil losses here reported, therefore, are very conservative.

age soil loss from the three small terraced areas was cut to approximately one-thirteenth of the average loss of the rotation without terraces. Notice also that soil loss from a heavy stand of bluegrass sod well cared for is so small that more than 3000 years would be required to remove the top 7 inches of soil.

Figure 4 shows that a small natural field with a rotation of corn, oats, clover and timothy will lose its 7 inches of topsoil in the short period of 45 years. A second field, tilled on the contour, with ditches controlled by check dams and sod, and with fertilizer added, will lose its surface 7 inches of soil in 70 years. The third field, which is treated like the second, but has been terraced in addition to the other treatments will require 485 years to lose the top 7 inches.

It may be noted that the amount of soil lost from the terraced area, field D-2, shown in Fig. 4, is somewhat greater than that lost from the terraced area shown in Fig. 3. This is due to the fact that there was much soil lost from the terrace outlet on field D-2 before the sod in it became established. This loss might have been avoided had the outlet been established before the terraces were built.

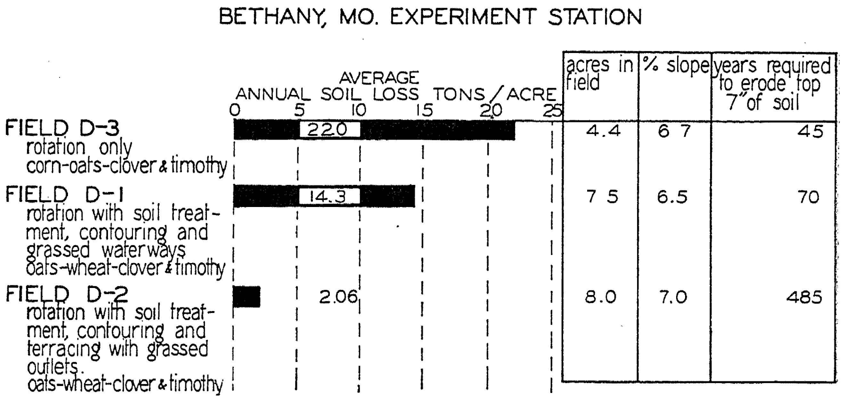

Fig. 4.—Graph showing comparative values of crop rotation, contouring with grassed waterways, and terracing on small watersheds. Note that a rotation, soil treatment, contour tillage, and terracing all combined fall short of a perfect job of controlling erosion.

It is evident therefore, that by combining terraces with a program of proper land use, good crop rotations, and soil management, including the application of reasonable amounts of manure and fertilizer, the level of soil fertility can be maintained or even increased. The result is an increased farm income for the present as well as for the future. We can look forward to a stabilized agriculture built on such a plan—stabilized (as far as natural resources and productivity is concerned) at a level which can allow the maintenance of a high standard of living for the American farmer.

Terraces Protect Land and Crops During Critical Periods.—Records from the Bethany Soil Erosion Station show that 89 to 98% of the total erosion taking place in a year on a field is caused by only a few of the higher intensity rains, often only one or two, and generally speaking, less than 10% of them. One experiment taken from the annual report of the Bethany Station brings this point out clearly and shows why terraces are needed on the cultivated fields used in the rotation even though it may be the wheat or oats year.

Here a corn crop, normally thought of as very inducive to soil erosion, has lost less soil in the six-month period than wheat, a crop thought to be rather conservative of soil. In addition to this, the wheat field was protected with grass waterways and check dams, and was cultivated on the contour. The reason is that a hard rain caught the wheat in a critical period; that is, before it reached a growth sufficient to protect the soil. All grain crops and even grass seedings have critical periods at a time when torrential rains can be expected. This is a practical problem that the farmer must meet to get really effective conservation.

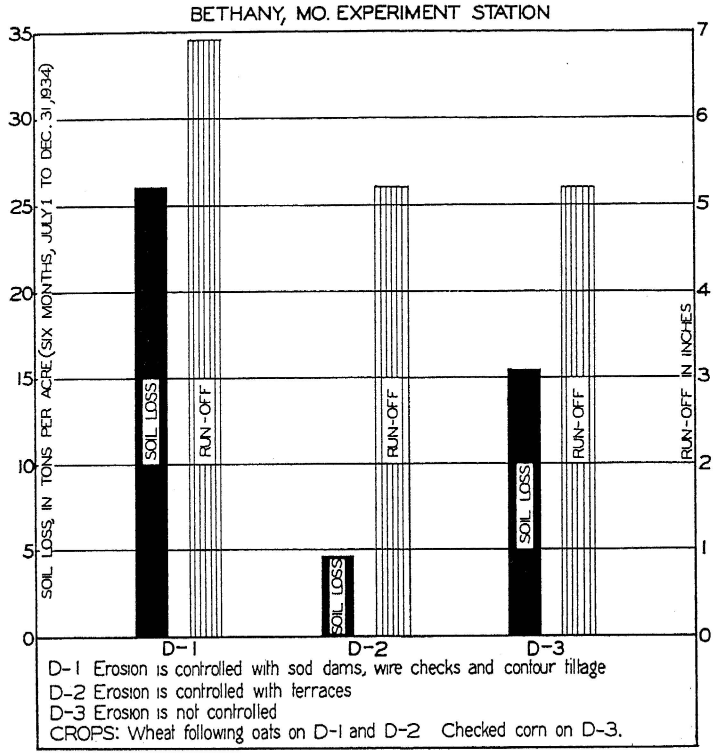

Fig. 5.—Effect of critical periods of crops on soil and water losses. Erosion is not controlled on field D-3 by terracing, contouring or by a good erosion resisting crop, but the crop of corn was not in a critical period when the hard rains came as was the wheat on the other two plots. The hard rain causing most damage to the wheat came October 19 before the wheat had grown sufficiently to protect the land or itself.

Moisture Conserved by Terraces.—Experimental results from a number of stations in states bordering Missouri show an appreciable reduction in total runoff of water from terraced areas. Notice that in Fig. 5 on the tight Shelby subsoil 2 inches more rainfall was conserved in the six-month period on the terraced wheat field than on the unterraced wheat field. Most data from the Bethany Station to date, however, indicate that moisture conserved on Missouri soils having tight subsoils is very small.

Effect of Length of Slopes on Soil Loss.—Realizing that small plots were not long enough to get accurately practical field conditions, a length of slope experiment was set up to get some data that would apply more nearly to practical field slopes.

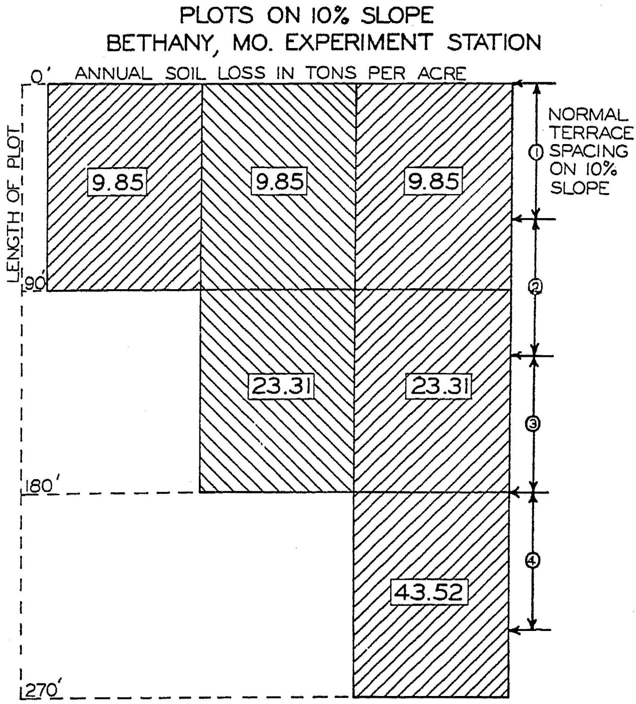

Fig. 6.—Effect of length of slope on soil losses. Plots have 10% slope. The upper edge of the chart represents the highest point on the slope. Note that the second 90 ft. section lost 2.36 times as much soil per acre as the first 90 ft. section, while the third 90 ft. section lost 4.42 times as much soil per acre as the first. Would the fourth 90 ft. section lose a proportionally larger amount per acre and so on down the slope?

The first 90-foot section lost 9.85 tons per acre, the second 90-foot section lost 2.36 times as much, and the third 90-foot section lost 4.43 times as much per acre as the first. The 270-foot slope is still much shorter than average field slopes, but this information gives an idea of what happens on the long slopes when the flow of runoff water is not controlled. Assuming that longer slopes would show proportionally increased losses, one can easily see why we have large gullies and why so much of our soil has washed away. It requires no stretch of the imagination to see where the major part of lime and fertilizer goes when it is applied to a long, cultivated slope that is unterraced. In addition to the fertilizers and seed applied, large quantities of plant nutrients, contained in the topsoil are also lost.

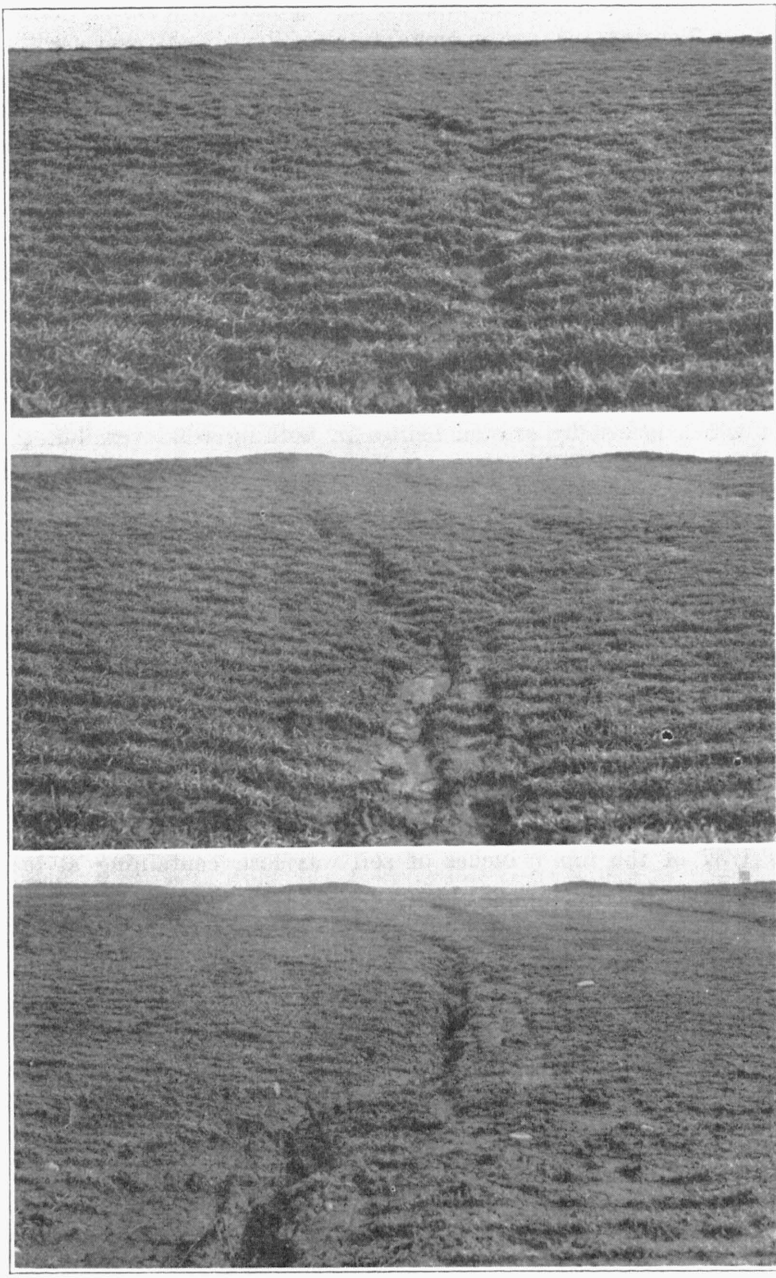

Fig. 7.—Wheat planted on the contour (without terraces). These pictures were taken at 90, 180 and 270 feet from the top of the plot. Note the progressive increase in erosion as the distance from the top of the plot is greater. Note also a poorer growth of wheat, and rock or gravel, indicating a severe loss of top soil on the lower part of the slope. These pictures by courtesy of the Bethany Experiment Station.

The Cost of Commercial Fertilizer to Replace Plant Nutrients Lost Through Erosion.—As previously stated soil washed from a rolling cultivated field, with little or no attempt at controlling erosion, takes many more pounds of mineral nutrients than the crop takes for growth. The amount of nutrients carried away varies greatly, depending upon the length and degree of the slope, the crop, the soil type, fertility level, organic matter present, etc. Soil containing 4000 pounds of nitrogen per acre in the surface 7 inches will on the average produce a yield of about 40 bushels of corn per acre. If one-half of this plant nutrient is lost, the yield will be cut to approximately one-half. In other words, the reduction in corn yields is proportional to the soil fertility losses. (See Missouri Experiment Station Bulletin 324, "Soil Fertility Losses Under Missouri Conditions.") That which is lost by erosion brings in nothing whatever, but that taken out in crops is largely compensated for by returns of residue, manure from livestock, etc.

Suppose, for example, one figures what it would cost to replace the plant nutrients washed from a corn field in a corn-oats-clover-timothy rotation in the one year that it is in corn. (Figures are based on results from a shorter than average slope on the Bethany Experiment Station which will give conservative losses, together with data taken from Missouri Experiment Station Bulletin 324 cited above). Twenty-seven tons of soil were lost per acre from the field during the year it was in corn. This land yields 35 to 40 bushels of corn per acre on the average; therefore, there will be approximately 4000 pounds of nitrogen to the acre 7 inches of top soil. During this one year 1/37 of the top 7 inches of soil was lost, containing at least $(\frac{4000}{37}=108)$ 108 pounds of nitrogen. Again referring to Missouri Experiment Station Bulletin 324, we see at 1933 price levels, it would cost $7.90 per acre to add 108 pounds of nitrogen in the form of commercial fertilizer, such as ammonium sulphate or sodium nitrate.

Figuring the soil loss from several terraced, rotated, and cultivated areas, we find the average annual soil loss from corn to be under 4 tons per acre. This field would then, under terraced conditions, and with the same rotations, have lost 4 tons per acre or $\frac{1}{250}$ of the top 7 inches of soil and only 16 pounds $(\frac{4000}{250}=16)$ of nitrogen, which would on the same basis cost $1.18 per acre. The net saving would then be ($7.90 — $1.18 = $6.72) $6.72 per acre on nitrogen alone, saying nothing of phosphorus and potash losses.

Experiments at the University of Georgia on Cecil Sandy loam of 5% slope show a loss of 56 tons per acre on bare land. The University of Georgia shows the cost of nitrate of soda, acid phosphate and muriate of potash fertilizers to replace plant foods in the 56 tons of soil washed from the acre to be $59.15, which is a cost of $1.05 for each ton of soil lost. While Georgia conditions do not apply directly to Missouri conditions, the experiment is cited to further emphasize the actual cost of erosion.

The above figures also explain why many outstanding farm leaders having experience with terraces express such views as these: "You can't afford *not* to terrace. If you put off terracing a cultivated field one year you lose more than it would cost to terrace it."

TERRACING COSTS

What is the cost of terracing? This is a question often asked.

In 1937 several custom machines were in operation in Missouri charging from $35.00 to $50.00 per mile of terrace constructed. The difference in cost was accounted for by the different sizes of terraces constructed, the types of soil and the degrees of erosion encountered. On severely eroded fields hourly charges were sometimes made and the terrace cost per mile was often double that of less severely eroded fields.

Many terraces were constructed with small terracing blades or fresno scrapers at a minimum or no cash outlay. The costs for all reported averaged $2.96 per acre. (These data included a labor cost figured on terraces constructed by use of farm power and borrowed or rented machinery). Occasionally a man reported that his terraces had cost him nothing because he used a scraper or borrowed a road grader and used his own power. In these cases a labor charge was figured against the terraces. The average cost of terracing reported is less than would be required to plow the field twice. A good philosophy might be to put more money in terracing fields and less in plowing them.

DEFINITE ANNUAL CASH RETURNS

If by terracing a field the crop yield is increased over the yield of the same field unterraced (this increase having been caused by maintaining fertility that would otherwise be washed away and by conserving moisture), there is a definite yearly cash return. This is as definite a cash return as the increased gain in pounds of flesh put on a steer per pound of feed fed, or the increase in crop yield due to the proper use of seed and fertilizer.

The following information is not scientific data, but is the unbiased practical observation of progressive farmers over the state and is believed valuable.

Without any question being asked on our part, twelve reports which gave definite estimated increases in yield directly attributable to the proper use of terraces, were received from over the state. The two highest estimates were dropped as being unusual and therefore probably not indicative of normal results to be expected. However, the truth of the reports was not questioned. Averaging the remaining ten reports with corn figured at 50¢ per bushel and other crops at current prices, the average increased income per acre for the year was $5.59 over other fields owned by those reporting, or by their immediate neighbors, treated similarly but not terraced.

It is common for farmers who have terraced one or two fields to state that the terraced field has made a marked improvement in production. It is also common to have reports of how terraced fields once severely eroded are now better than other fields which were not terraced because of less slope and less apparent washing.

TERRACE OUTLETS

The economical control of terrace outlets often presents a major problem. However, marked advance in the effectiveness and practical control of terrace outlets has been made in the past several years. The outlets may become a hazard to the terracing system unless a plan definitely thought out and strictly adhered to is developed with each terrace system undertaken. To successfully establish an outlet of either grass or permanent structures, involves a number of exacting details as follows:

1. When practical, prepare a grassed outlet before terracing. This can be done while the field is in a sod crop before it goes to a small grain or clean tilled crop.
2. Do not use road ditches for terrace outlets.
3. One should use an emergency outlet while preparing a grassed outlet if soil losses are so heavy that it seems undesirable to wait until a sod outlet is established before terracing.
4. If permanent structures are to be placed in the outlet it is not necessary to use an emergency outlet or to construct the outlet before the terraces are built.
5. A great deal of money and labor can be saved and more satisfaction derived by planning the location and construction of an outlet carefully.

6. For detailed suggestions on planning and construction of outlets see Extension Circular No. 355, "Terrace Outlets for Missouri."

A TERRACING PROGRAM FOR YOUR FARM

If an individual has had no experience with terraces, best results can usually be secured by building only two or three good terraces at the top of a slope the first year. Terraces can then be added every year the cropping plan will permit until the field is terraced. This does not take many years to get a field or even a farm terraced and at very little output of cash. It is true that additional soil will be lost from the tilled fields in the several years required to complete it. For this reason, where terraces are fully appreciated and outlet problems are solved, it is best to progress rapidly with a terracing program on fields to be cultivated.

When and Where to Construct Terraces.—If good outlets are available or can be made available by the use of a satisfactory emergency outlet, terraces should be constructed on rolling fields that are to be used in a rotation including a cultivated or small grain crop and having a slope length of two or three times the normal terrace spacing for that slope. For conservation of soil it is more important to have such fields terraced than to terrace a field that has just been seeded to hay or pasture grasses.

As far as the topography of the farm will allow, each field can be terraced as its time in the rotation arrives for a grain crop. When it is possible to progress more rapidly than this plan will allow, and when the individual is ready for the rapid progress, it is desirable to build the terraces and seed them down for one or two years, allowing the ridge to become firmly settled before being cultivated.

Terraces may be constructed any season of the year that ground conditions and crops will permit work in the field. If the ground is not too wet to plow, it is considered in good condition for terracing. Summer, fall and spring are considered good seasons to terrace. If the ground is not too hard and dry, the summer season is preferred because work can continue without long delays from rains. A field may be sown to oats or some early maturing crop, the crop removed and the field then terraced. Corn may be cut from small fields to allow terracing in the fall. Terraces are being successfully used on pasture land, but are here recommended only after rolling cultivated land on the farm is terraced.

Slopes.—Fields most ideal for terracing lay in a topography range of gently undulating to rolling; that is, from about 3% to about

8% slopes, although steeper slopes of from 8% to 12% can be terraced successfully.

On Gentle Slopes.—Terraces have proved valuable on long slopes as gentle as 1% or even less, where the subsoil is relatively impervious to the rapid penetration of surface water. In fact, as much as one-half the top soil has been found removed from long slopes having a fall of less than 1%. Poorly drained upland flats have been successfully terraced with the result that the terrace afforded drainage. With the proper farming practices, the terraces gradually form a uniform slope from the top of one terrace to the channel of the one below, which automatically gives the land a slight slope. In this case they serve to drain the flat spots and protect the more rolling areas of the same field from sheet washing.

On Steep Slopes.—Terraces are sometimes successfully used on slopes up to 30%. Their use on slopes above 10 to 12% is recommended only when the land can not be gotten into a good sod crop and kept sodded. If it is possible to use only land under this degree of slope for cultivation and place the steep slopes in grass or timber, this should be done. If the farm has no slopes of less degree and a small amount of grain must be raised, terraces are recommended in addition to all other methods of soil conservation applicable. The steep slope that must be placed into cultivation needs all the protection it can get. Often the back side of the terrace is not farmed on very steep slopes, but allowed to sod. This tends to develop a bench terrace in time by allowing the downward moving soil to pile up and level off, but the bench of good top soil is preferred to no top soil at all. Only on the very extreme slopes will this practice of maintenance, allowing the formation of bench terraces, be desirable.

Reclamation and Hillside Gully Control.—In general, terraces should be put on the best land first so as to save it. Too often a field is almost washed away before the owner decides to terrace it. The question then arises as to whether or not the land is worth the investment. It may be better to plant it to trees, or just let it go, as far as the present owner is concerned. If the owner does not intend to spend money on seed and fertilizer for the field, it may not be worth terracing. If one does intend to build up the field, he should consider terracing the land if for no other reason than to protect his investment. To leave it unterraced would be to allow much of the seed, lime, manure, and fertilizer to wash off, and as a result more money would be wasted than terracing would cost. The field will be built up and become productive much more rapidly after being terraced.

Terracing is one of the most complete, economical, and permanent methods of controlling numerous hillside gullies. The whole slope may often be given permanent protection by terracing including the control of the gullies and terrace outlet, for less than would be required to control the gullies alone by means of individual gully control dams.

PLANNING A TERRACE SYSTEM

Planning a terrace system for one field usually involves other fields and may involve the whole farm. To construct terraces on one field without due consideration for adjoining fields generally results in a patched-up system for the whole farm. The patched system calls for extra cash outlay and labor for outlets, more maintenance, and altogether a much less satisfactory job than would have been the result of planning the fields into a system. The system may include all fields falling together by natural divisions, or by water courses not heading on the property, by property lines, between timbered areas, and other logical divisions.

Preliminary Survey.—One seldom has sufficient knowledge of the surroundings to recommend a terracing system for a field until he has walked over that field and all of the adjoining fields that might be worked into the same system, observing at least these different points:

1. Is there drainage from other fields above? If so, how can it be intercepted in case the fields above cannot be terraced?
2. Where can the most satisfactory and most economical outlets be located? What plans will give a fewer number of good outlets, located at field boundaries where possible, and located so as not to cause excessive length of terraces?

Outlets are always a critical point in a terrace system and a possible source of trouble. If outlets can consist of a few good ones, the owner will take pride in them and will be more likely to care for them properly. Such cares as mowing and fertilizing are needed for grass outlets, while repairing damages made by rodents, dry weather cracks, and any other needed upkeep on structures are cares that increase in almost direct proportion to the number of separate outlet systems used. If structures are used, or if it is contemplated that they will ever be needed, one set of structures to handle runoff from two adjoining fields can be constructed at a great saving over the cost of two sets of structures to handle the two fields separately.

Intercepting Head Water With Dikes or Diversion Ditches.—It is sometimes necessary to use an interception ditch or dike to intercept water coming onto the field from land above before the field can be terraced. The dike should be located so as to intercept the runoff as soon after it enters the field as possible. Sometimes the water can be intercepted before it gets onto the field to be terraced. This will be true in many cases on south Missouri farms where water from timbered, rocky areas drains down onto gentler slopes of cultivated land belonging to the same farmer.

Oftentimes a short dike leading into an outlet can be used to protect the field from water above. The outlet along a field boundary then may serve as an interception for other water coming down the slope. Interceptions are given a grade of 6 inches per 100 feet to prevent excessive scouring and also to allow sufficient grade to carry the rush of water from unterraced slopes above. It is not usually difficult to obtain a sod in a channel graded 6 inches per 100 feet. If a steeper grade is used and water is carried at considerable depth some form of permanent check will probably be needed to keep the channel from forming a ditch. The effective width and depth for the diversion given 6 inches to 100 feet, or ½% slope, can be taken from the first line of the tables given in Missouri Extension Service Circular 355, "Terrace Outlets for Missouri." Information on the use of dams which may be needed in the control of interception ditches having a steeper grade may be found in the same circular.

The interception of head waters is not always easily accomplished and increases the cost of the terracing job; therefore, if it is possible terrace the field above, or encourage the neighbor to do so. If the field above has active gullies or is cultivated, special care should be used to construct the dike *larger* than is recommended in Circular 355. It should be inspected frequently and cleaned out when and where necessary to prevent its filling up and allowing water to flow over.

USE OF THE FARM LEVEL IN TERRACING

In order to insure successful operation of the terrace it will be necessary to use some form of a surveyor's level in staking out, supervising construction, and checking the terrace, but an inexpensive instrument is sufficient. A small farm level is recommended for common use.

The farm level is a relatively simple and sturdy instrument, yet its proper use and adjustment must be understood if sufficiently accurate results are to be secured to properly control the flow of run-off water.

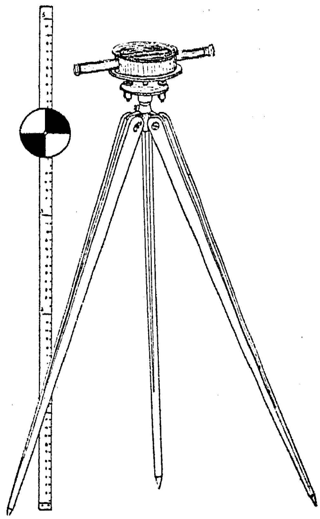

Fig. 8.—Farm level and rod used in laying out terraces.

Determining the Proper Location and Grade for Terraces.—*Finding the High Point.*—The first step in laying out the terrace system is to find the high point of the area which will drain into the first terrace. To do this the farm level is set up so that one looking through

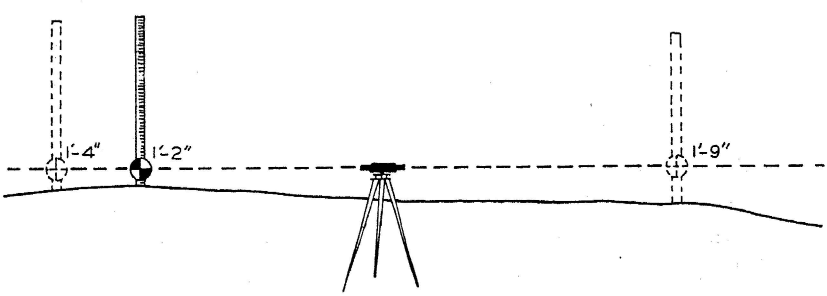

Fig. 9.—Finding the high point. The location of the rod giving the smallest reading is the highest point.

the leveled telescope will see over the high point, Figure 9. The smallest rod reading is the high point. This point should be marked. If a diversion ditch or dike is used to intercept head water, the high point in the staked line for the ditch or dike should be used as the high point of the drainage area for the first terrace.

Finding the Slope.—The next step is to find the degree of slope or the steepness of the land that will drain into the top terrace. The slope draining into the terrace near the outlet end may vary from the slope draining into the upper end or near the center of the terrace. For this reason, it is advisable to take two or three slope readings from different places and average them. Each reading is

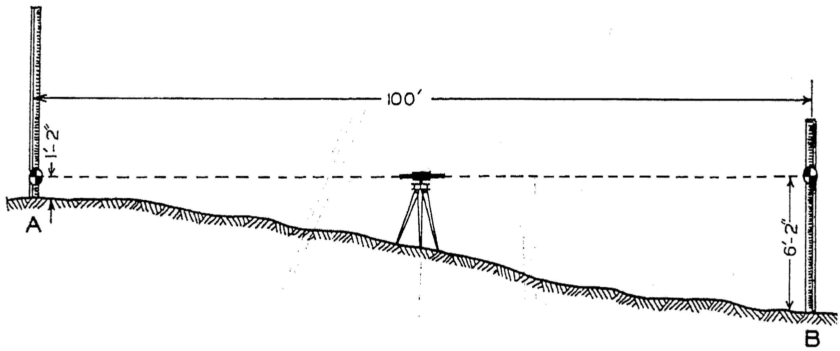

Fig. 10.—The average slope is determined by taking several slope readings as shown above and averaging them.

taken from the top of the drainage area straight down the slope (Fig. 10). Suppose the reading at the top of the slope in question is 1 ft., 2 in. (A Fig. 10), and a point 33 steps or 100 feet directly down the slope reads 6 ft. 2 in. (B Fig. 10), the slope would be 6 ft. 2 in. — 1 ft. 2 in. = 5 or a 5% slope. It is often convenient to step only 16 steps (50 ft.) down the slope to get the second reading. In this case double the fall found in the 50 feet to get the fall in 100 feet or the per cent slope. One should determine the number of steps normally taken in 50 or 100 feet and use this number because the length of steps of different individuals may vary greatly.

Suppose the two other slope readings reveal 6 per cent and 4 per cent slopes. The average slope draining into the first terrace will then be $\frac{5 + 6 + 4}{3} = 5$ or a 5% slope. The next step is to determine how far from the high point the first terrace should be located on the 5 per cent slope.

TABLE 1.—GUIDE FOR TERRACE SPACINGS.

Slope of Area Draining into Terraces	Vertical Interval between terraces		Surface Distance Between Terrace Centers
	For use on Rod Graduated in Ft. & 10ths	For Rod Graduated in Ft. & in.	
1%	1.3	1:4	130
2%	2.1	2:1	105
3%	2.8	2:10	93
4%	3.4	3:8	85
5%	4.0	4:0	80
6%	4.4	4:5	74
7%	4.8	4:10	70
8%	5.2	5:2	66
9%	5.6	5:7	63
10%	6.0	6:0	60
11%	6.2	6:2	57
12%	6.4	6:5	54
15%	8.0	8:0	54
20%	10.5	10:7	54

Variations from the table are to be discouraged, but when special soil conditions and a known future cropping plan warrant the change, spacings may be varied from the table as much as 20%.

Determining the Proper Vertical Interval for a Given Slope From the Table, and Locating the First Terrace.—Suppose, for example, we have found the average slope of the land draining into the first terrace to be 5%. We consult Table 1 above and find that for a 5% slope a 4 ft. vertical interval is recommended. The instrument remains in the same place and to the reading of 1 ft. 2 in. (Reading secured on high point) is added the recommended vertical interval of 4 ft. which sets the target at 5 ft. 2 in. on the rod.

The rod is then taken to what is believed to be one-half the distance to the end of the first terrace and moved up or down the hill as the instrument man signals, until the level signal is given. A stake is driven at this point. This is the center stake in the first terrace line. For one who is not familiar with terracing, it is advisable to run a level line from this stake and mark a point every 50 feet. This will locate a level terrace and give one a good idea as to what the graded terrace would look like, together with giving him a good check on the length and approximate linear center of the terrace. If needed, after running the level line, choose another stake as the center of the terrace.

Laying the Terrace Out to Grade.—Determine the fall for the lower one-half of the terrace by consulting Table 2. For example, suppose the first terrace will be 600 feet long. It will then be given a grade running from 1½ inches at the upper end for 300 feet to 2 inches per hundred for the next 300 feet. Therefore, the grade for the lower half of this terrace will be 2 inches per 100 feet or 1 inch per 50 feet. The target is then moved 1 inch for every stake. The terrace line is staked every 50 feet unless on extremely steep and

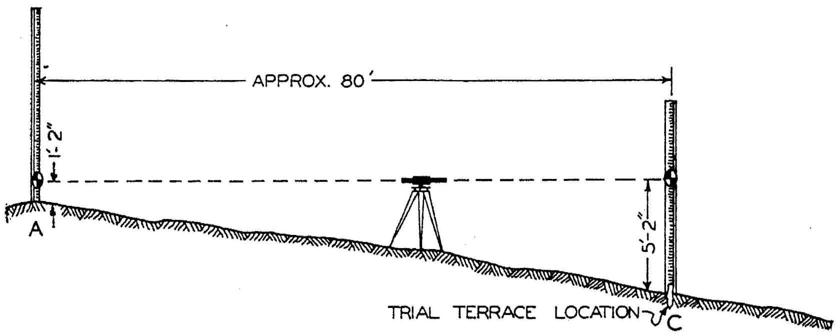

Fig. 11.—Locating the first line. An average of 5% slope calls for a 4 foot vertical spacing. Note the percent slope and vertical spacing are not the same. (Table 1.)

varying slopes or badly gullied fields where stakes are recommended every 25 feet.

TABLE 2.—GRADE IN TERRACE LINES PER STATION.
(Station 00 is at upper end of terrace)

Length of Terrace	Grade Recommended on Soil having medium to tight subsoils		Grade recommended on soil having very porous subsoil	
	Inches	Tenths	Inches	Tenths
00-100′	1½	.13	0	0
100-200′	1½	.13	0	0
200-300′	1½	.13	1	.09
300-400′	2	.17	1	.09
400-500′	2	.17	1½	.13
500-600′	2	.17	1½	.13
600-700′	2½	.20	1½	.13
700-800′	2½	.20	2	.17
800-900′	2½	.20	2	.17
900-1000′	3	.25	2	.17
1000-1100′	3	.25	3	.25
1100-1200′	3	.25	3	.25
1200-1300′	4	.33	3	.25
1300-1400′	4	.33	4	.33
1400-1500′	4	.33	4	.33
1500-1600′	4	.33	4	.33

On slopes over 14% the grade may be increased to 4½ inches per 100 feet if the terrace length exceeds 1200′ and ridge height is no more than 20 inches.

With the target set at 5 feet on the center stake, sixteen steps will be taken in the direction of the outlet and the target raised 1 inch. The stakes from the level line are pulled up and used to make the graded line. The target is raised another inch after the point is marked and another 50 feet stepped off. This is repeated until the outlet end is reached.

The rod is returned to the center stake again for a reading to check the total fall given the lower half, which will help to prevent any errors. From the center stake the grading of the upper half is begun. A distance of 16 steps (17 short steps) is paced off in the direction of the upper end of the terrace as before and the target is lowered on the rod this time $\frac{3}{4}$ inch, which places the target on the rod at 4 feet $11\frac{1}{4}$ inches. The target is brought to the line of sight as before and a stake driven. The target is lowered on the rod another $\frac{3}{4}$ inch and another 50 feet paced off, continuing in this manner to the upper end of the terrace.

Whether to raise or lower the target is sometimes a confusing point and should be checked often when a new man is carrying the rod. The target is *raised* on the rod when going with the desired direction of flow of the water and is *lowered* when going against the direction of flow of the water. A small pocket size notebook may be kept to record field notes and make sketches.

Checking the Final Location of The First Terrace.—The top terrace is the key terrace to the system. It must be properly located if the system is expected to function satisfactorily for long. The top terrace is also the most difficult one to locate on many fields.

A flat topped hill breaking off into a steeper slope will make it appear that the first terrace is located almost exactly on top of the hill where it will do no good, but if the water collected on the flat top can be kept from breaking over onto the steep grade excessive erosion can be prevented and the terrace channel will not be filled by the soil which is carried to the channel on long slopes. Fans or shoals sufficient to completely dam the terrace channel may be formed when the runoff between terraces is allowed to attain a scouring velocity. High velocities are attained by allowing water to run an excessive distance for that particular slope before being checked by the terrace. Fan or shoal deposits in the channel of the top terrace force water over the ridge and allow the water load of the first terrace to carry a shoal into the second terrace, breaking or overtopping it and adding the water load of the first two terraces to the third which will in all probability break. In this manner, all of the terraces down the slope may be filled and be overtopped or broken because the slope is too long above the first terrace, even though the total area drained into the first terrace may be only a fraction of an acre.

Considering Conditions to Make Sure that First Terrace is Properly Located.—The ground should be studied closely as one walks the full length of the first terrace. If the field is sodded, close scrutiny will be necessary to find former rivulets, or small depressions caused by excessive sheet wash. Small overfalling rivulets eating back toward the top of the hill can be easily seen and the point of their beginning is easily located. If the points of excessive soil movement are above the location for the first terrace, they will serve to carry shoals into the top terrace after it is constructed. A terrace does not benefit that land above it so far as sheet erosion is concerned. In fact, cutting the channel and leaving the newly constructed back slope will tend to aggravate any small washes already present. A terrace does protect land above it from large overfalling or head cutting gullies by taking the water from them. However, if excessive sheet or rivulet washing is seen above the first terrace line, the line should be moved up the hill farther. One should observe carefully to see that water from any other field is not causing the wash. By combining a study of the recommended vertical interval and the appearance of washes, the proper location for the first terrace can be accurately decided upon. If excessive wash fails to show for a considerable distance below the first terrace line, do not make the mistake of moving the terrace down hill. The washes can be smoothed over too easily by regular tillage tools if no hard rain happens to catch them before they become sodded. Then, too, very uniform sheet wash is not always easily detected until in advanced stages as soil borings will convince one. After checking these points and moving the terrace if needed, the second terrace is ready to be staked out.

Locating the Second Terrace.—The ridge of the first terrace is the divide at the top of the watershed draining into the second terrace. The center stake of the first terrace is used for the high point of the second terrace and several slope readings are taken down the slope at right angles to the first terrace line to determine the average slope. If approximately $\frac{2}{3}$ of this area is a 6% slope and $\frac{1}{3}$ of the area is a 8% slope, the proper average is 6.7% $(6 + 6 + 8 = 20 .\ \frac{20}{3} = 6.7)$. A 7% slope may be used in determining the vertical interval since it is almost a 7% average and irregularities in the land while determining the slope and spacing the terrace for the vertical interval will allow chances for more error than failing to interpolate to the tenth of 1%. Table 1 suggests 4 ft. 10 in. vertical interval. For example, after moving the instrument down hill and releveling, a backsight on the ground by the center stake of the first terrace reads 2 feet. Two feet plus the recommended vertical interval of 4 ft. 10 in. would put the target on the rod at 6 ft. 10 in., then moving down the slope with the rod at what is thought to be the center of the second terrace, the instrument man signals the rodman to the proper level. A stake is driven at this point. The second terrace is staked out in the same manner as the first one. After the terrace is staked a check is made to see that it has as nearly the proper spacing from the first terrace as can be obtained. By referring to Table 1, you will notice a column which gives the "horizontal spacing" or distance between terraces for different slopes. The degree of slope is pretty well known from the slope readings and by stepping from one terrace to the other in several places, a good check on the spacing is given.

The distance between any two terraces will vary at given points, but if it is found that the points of narrow spacing are a little too close while the points of wide spacing are a little too wide, the terrace location is probably as good as can be obtained with the variation in slope. However, if the points of narrow spacing are wider than recommended for that slope and the points where the terraces are farthest from each other are much wider than recommended, it is obvious that the second terrace should be moved up the slope to a new location. Do not hesitate to move a terrace when it needs to be moved. To make a preliminary location of a terrace, studying it and relocating it, if needed, is an indication that a good job of surveying for terraces is being done. Effort should not be spared to fit the terraces into the field to give maximum efficiency.

Dividing Flow of Water in Terraces.—When it is seen that a terrace will become too long (more than 1600 feet) to carry all of the water in one direction, the grade may be broken in the middle, or any other point along the terrace, and water carried in the other direction for 1600 feet or less, dividing the water equally between outlets if desired. When terraces are medium to long, it is particularly important to avoid grading the total terrace in the opposite direction to the one above it, because the opposite direction of grades will place the terraces too close together at one end or too far apart at the other.

The third terrace is located in reference to the second terrace using the center of the second terrace line for the high point. Consecutive terrace lines down the slope are surveyed out in like manner.

The use of the level trail line may be dispensed with after some experience is secured, because the graded line is staked out almost as easily and gives a better idea as to the final location of the terrace.

Temporary Obstructions in Fields.—Temporary obstructions such as straw stacks, hay stacks, post piles, etc., should be removed and not allowed to interfere with the terrace system. Leaving out one terrace, or doing what will be the equivalent by spacing it almost twice as far as it should be from the one above, in order to miss a temporary obstruction will cause serious damage to the system. The obstruction should be removed before the terraces are constructed.

A permanent structure such as a hay barn or corn crib in the middle of the field may be terraced around successfully by dividing the water at the barn and carrying it away in both directions. This need not destroy the proper spacing of the terraces. Occasionally a satisfactory outlet can not be arranged on both ends of the field. This may call for a short outlet on the up-terrace side of the obstruction. An interception dike just below the obstruction could be used to intercept the water from the short outlet and carry it to the main outlet. Terracing can then continue on the remainder of the field in the regular manner.

Design Factors in Spacing and Grading Terraces.—In addition to the successful terrace system being designed to carry the excess run-off, the terraces must be spaced so as to prevent excessive soil movement between them. This is a very important point and without design for this feature, only a series of diversion ditches or dikes is the result.

As has already been pointed out, the cropping system and amount of organic matter in the soil will have a marked effect on the normal movement of soil between terraces.

Under the best of conditions spacings may be increased 20% over those recommended in Table 1. However, the terrace system, being constructed of earth, if properly maintained will be a permanent part of that field. Because terraces are a permanent improvement they must be designed for a field to meet such uncertainties as extremes in weather conditions, rainfall, change of ownership, cropping plans, etc. The greatest test to the terraces is the hardest rain in several years coming when the soil is not in position to absorb moisture rapidly (frozen a few inches below the surface or completely saturated with water), with plant growth either not present or too small to assist in control. This is not an uncommon situation which the farmer must meet and recognize as one of his big problems in soil conservation. If the terraces are not designed and constructed for these conditions, failures occur at critical times when nothing else can prevent a great loss to that field and its owner. Aside from this important fact, the carefully designed and constructed system saves more soil, allows less movement of soil between terraces, and conserves more moisture during normal rains even though it is cropped with the best of recommended rotations and given the most fitting land use, than does the too liberally spaced and carelessly constructed system.

If all affecting variables could be determined for any one field over a long period of years, including the psychology that the individual would follow, the terracing system could be designed for these variables; that is, much more attention could be paid to soil types and individual crops or cropping systems, dispersibility, colloidal content, degree of erosion, etc., in the spacing and design of the terraces. The most common error, even on steep slopes, is to space the terraces too far apart. However, research data and practical experience indicate that terraces can be spaced too closely together on very steep land, resulting in a marked increase in the degree of slope between the terraces. This is one reason for a constant horizontal spacing recommended in Table 1 when the slope of the original land is over 12%.

Laying Out Terraces on a Badly Eroded Field.—Terraces should be conservatively spaced on badly eroded fields because of the tendency toward excessive movement of soil between the terraces. Spacings 10 to 20% closer than recommended in the table in this bulletin should be used, except on excessive slopes of 12% or greater. Soil treatment with an attempt to get a stand of grass or a cover crop as soon as possible should be used on badly eroded and depleted soils. This will assist in checking soil movement occurring between the terraces.

In badly gullied fields terraces may be laid off and the gullies worked in by sloping them where the terrace lines cross. Stakes will be removed to do this and should be set again to guide the terrace across the gullies. In extremely irregular areas, stakes should be used every 25 feet. A maximum grade of 6 inches per 100 feet is sometimes recommended for badly eroded fields. However, a grade of 6 inches per 100 feet will allow scouring, and a larger portion of seed or fertilizer may be carried from the field with the additional soil loss. Lack of organic matter and plant growth allows more scouring in terrace channels on severely eroded soil than on less eroded areas, also a higher percentage of runoff will occur on the steep grades. For these reasons use of the standard grade with a maximum of 4 in./100 ft. is recommended.

TERRACING MACHINERY

Terracing machinery used in Missouri consists of the small and large blade type machines, the rotor or whirlwind terracer, the elevating grader type machine, the Martin Ditcher type, the V drag, the terracing plow, and the Fresno scraper. The ordinary disk or moldboard breaking plow is also sometimes used.

The Blade Type Terracer.—The blade type terracer is the most common type used in Missouri. These machines range from the small 6 and 7-foot blades made especially for terracing, to the large 10 or 12-foot blades, including regular road graders. The small blades may be powered by a 4 to 6-horse team or a common farm tractor.

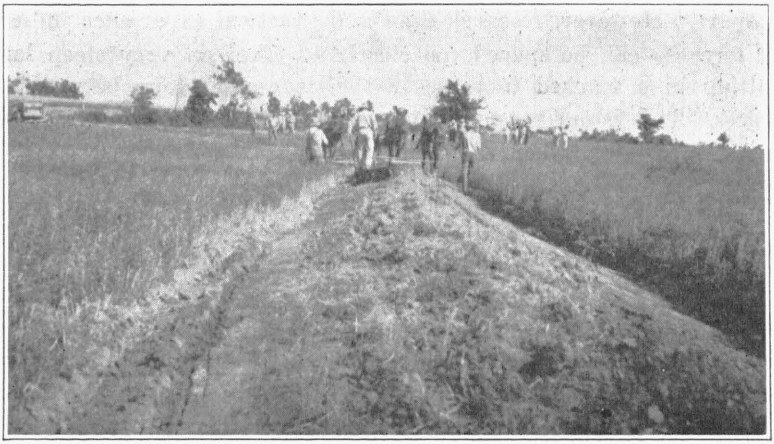

Fig. 12.—A terrace being constructed with a small blade pulled by a 4-mule team. Warren County.

Some advantages of the blade type of machine are: (1) It can be used in any section of the state regardless of rocks, etc. (2) It can be used to construct grass outlets. (3) It has many common uses around the farm. (4) The smaller machines have comparatively small first cost. (5) Maintenance on the machine is not excessive.

Probably the greatest disadvantage of this type machine is the comparatively inefficient method of moving earth, particularly with the smaller blades, and the time required to construct a truly good terrace. The tendency of the individual is to get tired and quit when a terrace is about one-half completed. However, a very good terrace can be built even with the smallest blade if time is taken to do so. If the soil is unusually dry and dusty it may sometimes be necessary to return after a rain and complete the terrace.

Whirlwind Type Terracer.—The whirlwind terracer developed by the agricultural engineering department of Iowa State College is now the most popular custom or contract terracer used in Missouri. This machine is, however, limited to soils that are free of excess rock or gravel and does not give good results on steep slopes. It is powered with a rubber-tired tractor of no smaller than the three-bottom plow size. The terracer is also on rubber, which provides a rapidly transportable unit. Under good conditions, it constructs a terrace rapidly and meets with general favor for contract work.

Fig. 13.—The Whirlwind Terracer. Picture by courtesy of the Soil Conservation Service.

Probably the chief disadvantages of the whirlwind type terracer to date are: (1) a tendency to construct a terrace with a narrow deep channel, usually the result of an effort to secure effective terrace height. The narrow channel is difficult to cross and is soon filled with earth, thereby materially reducing the effective height of the terrace, (2) excessive repair costs, (3) the loose condition of the terrace ridge and the time required for it to settle, and (4) its lack of adaptation to extremely dry soil.

The extremely loose ridge made by the whirlwind terracer is sometimes reported difficult to farm for a season or two and is often too loose to get a good stand of grass. Excellent terraces can be constructed with this machine by spending more time on them than is a common practice, or by finishing the channel with a small blade. The machine operates successfully on moist soil and will operate on soil too wet for ordinary farming operations. About 10 or 12 of these machines are owned and operated in Missouri at present.

The Elevator Type Terracer.—This machine was developed by the agricultural engineering department of the Missouri Agricultural Experiment Station. For construction of what is considered an ideal terrace cross section and for efficiency in moving earth, it leads all types of terracing machinery now used in Missouri. This is shown by results of various tests made by government and state officials on efficiency of terracing machinery. The machine can be used when-

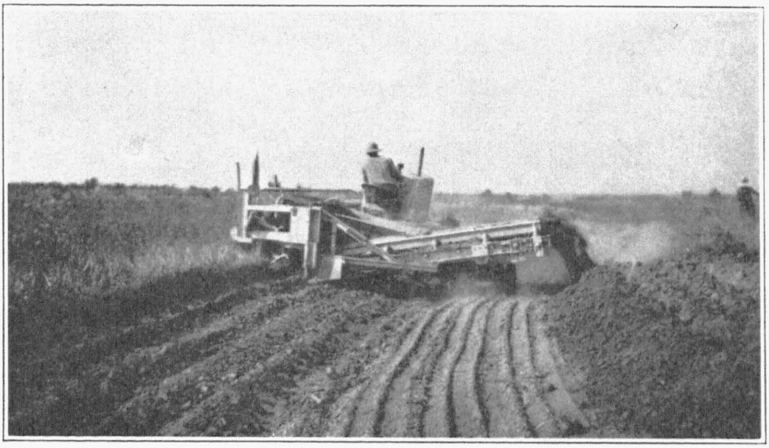

Fig. 14.—Elevating Grader Type Terracer in Operation. Clinton County.

ever the soil is dry enough to farm but works to best advantage in dry soil. It cannot be used successfully in soil having excessive amounts of large gravel or stone.

The machine is usually considered too expensive for private use and is therefore a contract or custom machine. Its chief disadvantage is a loss of time caused by the necessity for excessive repairs, and this has prevented it from gaining as much popularity among contractors as some of the other machines. This machine, like the whirlwind terracer, is a rather new development and has required some time to work out the weak points. A great improvement was shown in this respect the past year. Some three or four of these machines are owned by the Soil Conservation Service in Missouri. One machine is privately owned and operated on a contract basis.

The Small Ditcher, V Drag, and Terracing Plow.—All of these machines are being used in Missouri to construct terraces. Any of them can be used to construct rather satisfactory terraces if enough time is spent on the terrace. In the case of the plow particularly, it will be necessary to repeat construction several times, either after a rain or when the ground has had time to settle.

The danger from this method of construction is that a hard rain may come which will wash out sections of the small terrace before it is completed, thus wasting soil and labor and discouraging further effort. It is very seldom that good terraces are constructed with these machines, because the operator does not stay on the job until the terrace is completed. The main advantages are the low first cost of the machine, and the small cash outlay in the construction of the terraces.

STARTING CONSTRUCTION

Position of Stake Line in Relation to Finished Terrace.—The first point that must be decided in starting construction from a staked out terrace line is, should the high point on the terrace ridge, the center of the terrace channel, or a line half way between these points, be on the survey line? Different people construct the terrace in different positions with reference to the stake line. It is recommended here that a point half way between the low point in the channel and the high point on the ridge of the completed terrace coincide with the stake line. This does not allow the channel to vary from the surveyed grade to any appreciable degree, nor does it allow an extreme variation in elevation of the top of the terrace ridge caused by a varying degree of slope through which the terrace passes. A variation in either the channel or the top of the ridge has the same effect in reducing the effective height and capacity of the terrace. Often difficulty in securing a uniform terrace grade, particularly on medium to steep land, can be avoided by locating the lower edge of the channel and upper edge of the terrace ridge on the stake line. Objectionable ponds may also be avoided in terraces so constructed on land having medium to tight subsoils.

Following Surveyed Line in Starting Terrace Construction.—When marking off the terrace there seems to be a tendency for all inexperienced men to cut across the curves in the staked line in an effort to straighten the terrace. This has some advantages if it is not carried to the extreme, but at first these advantages appear more important than they are. Extreme attempts at straightening terraces are responsible for many poor jobs and even for many complete failures.

The staked line should be followed as accurately as the machinery can follow it and still not leave any short, sharp "kinks" in the line. Variations from the stake line of a few inches (vertical distance) may be made without giving poor results, provided this change is noted and construction is carried on accordingly.

In general, the correct procedure in walking ahead of the construction unit is to follow the stake line closely (large units cannot follow small kinks) missing isolated stakes enough to form a curve in places that would otherwise result in an extremely sharp bend. This is what is known as "softening" the curves. Farming operations on a terraced field, year after year, gradually soften the curves with no harmful effect, no special effort, nor any appreciable increase in labor.

Some of the disadvantages of cutting across and attempting to straighten terraces are:

1. Large cuts and fills are required to get the terrace to grade and to prevent serious breaks in the fill which result in unnecessary loss of soil and labor.
2. The expense of construction to make the project a success may be doubled, tripled, or quadrupled, depending upon the degree of departure from the staked line, type of soil, labor and power arrangements.
3. If cuts and fills are made to specifications, the backslope and backside of the fills are left similar to road cuts and fills, or to the back side of a pond dam. These banks are almost impossible to farm. Large ponds or wet areas are left that will require years to fill because of reduced soil movement in and between terraces. The larger ponds can not be crossed and require much more time to farm around than even a very sharp bend without the pond.
4. It leaves great variations in the size and cross section of the terrace where otherwise the terrace could be uniform in size and cross section. The uniform terrace also results in less disturbance of earth in the field and a more uniform tillable field area throughout.

Figure 15 illustrates the three different methods of walking out the terrace line. Method No. 1 is to be recommended. No. 2 may be used with small units and numerous gullies, but may be considered the extreme in following the exact line. No. 3 should not be used and is almost sure to give very disappointing results on any but the most gentle slopes (2% or less).

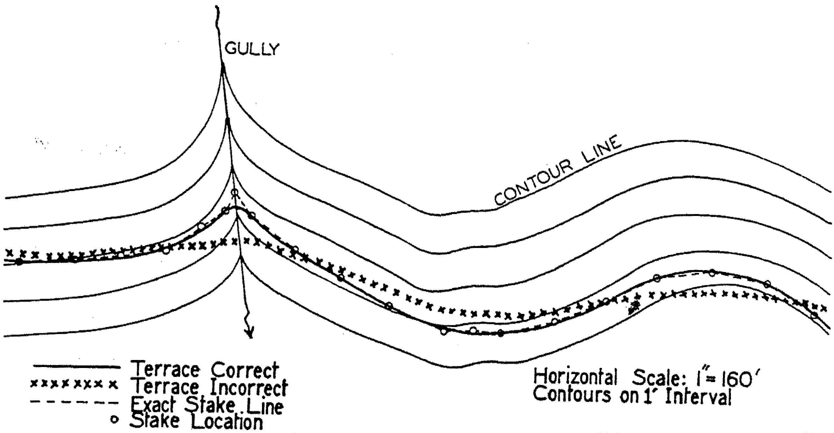

Fig. 15.—Sketch illustrating the three different methods of walking out the terrace line. The small circles indicate position of the stakes set on the grade, 50 feet apart. The solid line (No. 1) indicates the proper line of the terrace. The line of crosses (No. 2) indicates incorrect location of the terrace caused by attempts to straighten the terrace. The broken line (No. 3) shows what may be extremes in following every stake.

CONSTRUCTION OF THE TERRACE

In order to construct a terrace with the proper relation to the stake line, it is important that the first round be made properly. This will vary with different machines. Directions are given with the Whirlwind or the Elevator Terracer to any purchaser of these machines.

After learning the construction procedure of his machine the operator can easily start construction so as to place the completed terrace on any desired position with reference to the stake line.

Suggested Procedure With Blade.—When starting construction with the blade type of machine, the forward end of the blade may be lowered into the ground about 3 to 4 feet uphill from the stake line. Earth is thrown down hill on the first cut. On the second cut, completing the first round, earth is moved up grade and the blade is pulled so that the slice of earth rolled from the blade lacks approximately 10 feet (4 to 6 feet on steep slope) reaching the line of earth shed from the blade on the first cut. The second round is used to place the two excavated ridges together in the center of the strip of undistributed earth. The third round is used to cut loose a new slice of earth just outside the first cut. Other rounds are used to move this loose soil over to the center.

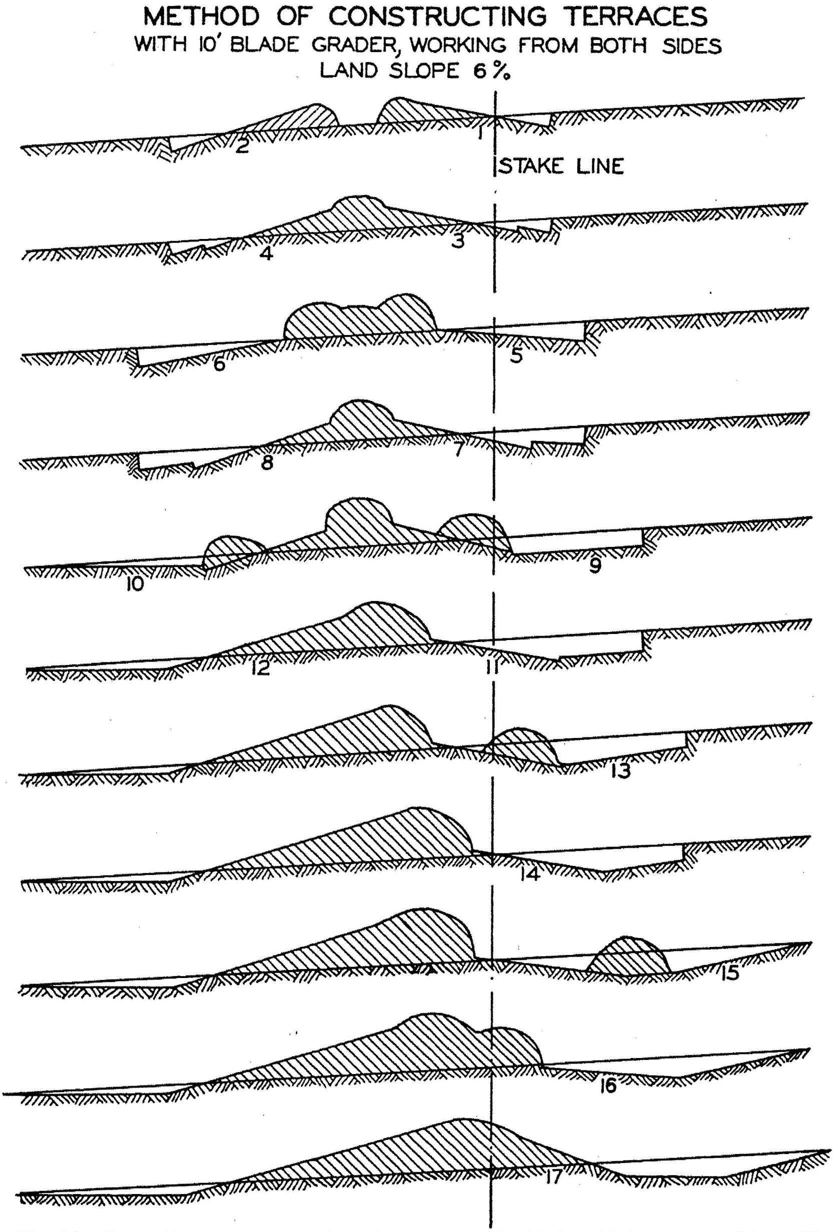

Fig. 16.—Suggestions on construction of terraces with 10 foot blade type machine. The same principle applies to other blade sizes, number of rounds are materially increased under unfavorable conditions and with small blades.

When terracing on average slopes, earth is moved from both sides of the terrace until about half of the terrace is constructed, then the back side is shaped up leaving no secondary channel to catch runoff from the back side of the ridge. From this point all further construction is done on the upper or channel side. This results in about $\frac{3}{4}$ of the terrace being constructed from the top side and $\frac{1}{4}$ from the lower. On excessively steep slopes all construction is done from the up-hill side except one or two rounds to shape the back slope of the terrace ridge. One important point to remember in either method of construction is to keep the loose earth moved over well into place. A common cause of trouble is cutting too much earth loose before attempting to move it over into the ridge. A back slope given to the upper side of the channel as gentle as those shown in Figure 17 is desirable. One should not wait until the last to back slope the upper side of the channel. This should be done as normal construction of the terrace proceeds.

A diagram illustrating the construction of a terrace with blade type equipment is given in Figure 16. It should be used only as a guide since ground conditions, power, and equipment vary greatly. Two to four times as many rounds as shown here may be required under adverse conditions for a large blade to construct a terrace to specifications. Under other conditions, terraces may be constructed in the number of rounds shown. The object, however, is to operate the machine effectively and secure a good terrace. The number of rounds should not be stressed, for attempts to keep the number of rounds to a minimum usually lead to poor and partially completed terraces.

Constructing Terraces to Specifications.—It is important to construct terraces to specifications shown in Figure 17 and also given in Table 3. They have a definite function which is to properly handle excess runoff water. (One inch runoff from an acre weighs 113 tons.) They must be checked for weak points before the runoff water from hard rains causes a break through such a point. A terrace is similar to a chain in that it requires only one weak place to break it. The terrace built uniformly, well packed, and to the specifications set forth (before effective height is reduced by farming) will carry the hardest rain to be expected in Missouri in twenty-five years.

Terraces built to specifications will look unnecessarily large when first constructed. Settling of as much as 15 to 25% will first reduce the size. Farming will farther lower the ridge and soil will drag or settle into the channel, materially reducing the effective height of the structure. Also irregularities, even in careful construction, will leave some points an inch or two high in the channel and that much low on the ridge, reducing the effective height by several inches. It is much safer to construct one or two terraces to specifications with fills complete than to spend the same amount of time on several terraces. The top terrace should be completed first and each successive terrace completed before the next terrace below is started.

CROSS-SECTION FOR FINISHED TERRACES

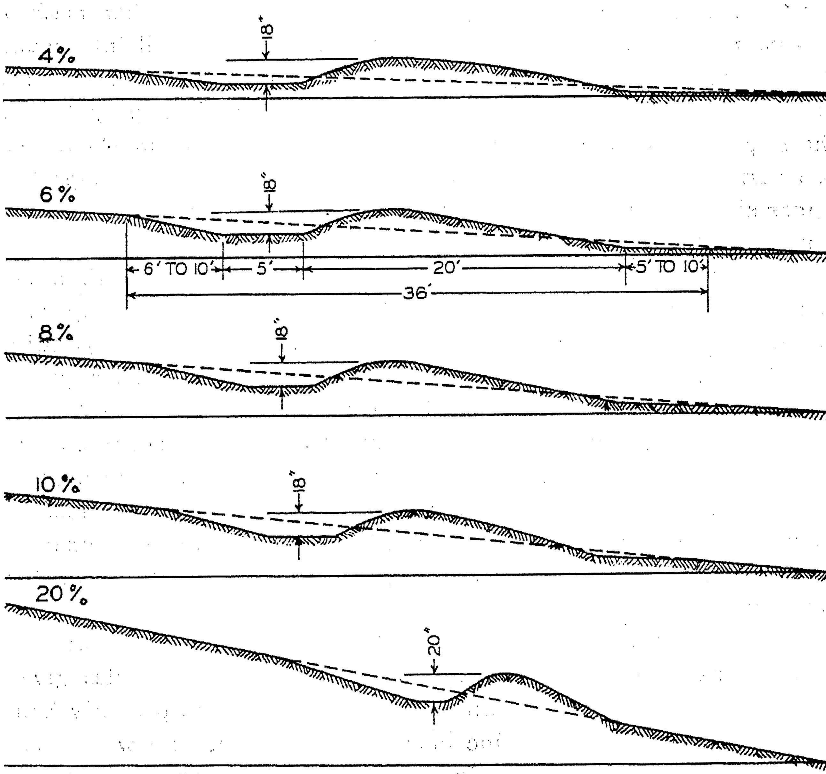

Fig. 17.—Terrace cross section for different slopes. Note the narrower terrace necessary on the steeper slopes.

It may be found necessary to construct terraces under some conditions to half or more effective height and wait for a gentle rain to settle them or soften the ground before they can be completed. Terraces constructed with large oval ridges and broad channels do not require maintenance or rebuilding every few years. A layer of good productive soil will soon accumulate in the channel if frequent rebuilding is not required.

TABLE 3.—GUIDE FOR TERRACE DIMENSIONS.

% Slope	Minimum Ridge Height* Inches	Ridge Width Feet	Bottom Width of Channel Feet	Acres Above Terrace/ 100′	Acres/ Mi. of Terrace Directly Protected	Surface Disturbed Ft. Width	Surface Disturbed Percent
1	18	24	6	.30	15.8	40	31
2	18	24	6	.24	12.7	37	35
3	18	22	5	.21	11.1	37	40
4	18	22	5	.19	10.0	36	43
5	18	20	5	.18	9.5	36	45
6	18	20	5	.17	9.0	36	49
7	18	18	4	.16	8.5	35	50
8	18	18	4	.15	7.9	35	53
9	18	16	4	.14	7.6	35	56
10	18	16	4	.14	7.2	32	53
11	18	12	3	.13	6.9	30	53
12	18	12	3	.12	6.3	38	52
15	20	10	2	.12	6.3	24	44
20	20	10	2	.12	6.3	24	44

All terraces are to be constructed to a uniform minimum unsettled height of 18 in. above the channel except terraces built on slopes above 14% which are to have a minimum unsettled height of 20 in. when the length of terrace exceeds 1200 ft. The ridge width may be reduced 20% in areas where soil is scarce, but ridge height should remain the same.

*Minimum ridge height above channel at point of measurement. Ridge is to be well packed.

Checking Terraces to Precision Needed for Practical Results.— It is important to check every terrace for grade and effective height as construction is completed. Extra work with the terracing machine or scraper can often be saved by checking the terrace for grade soon after construction is begun. The check for effective height does not seem to be well understood in general, and is seldom made, yet one can not be assured of the successful operation of the terrace without it. A check for other specifications is not as important and is more easily done. See Figure 17 for width and shape of ridge, channel, etc.

It is convenient to start checking at the upper end of the terrace. A reading may be taken in the channel, taking care to avoid setting the rod in any small pocket that will be of no consequence. A reading should then be taken on any low point in the ridge, either directly opposite the channel reading or up the terrace from it (against the direction of flow in the terrace). Subtract the reading on the ridge from the one taken in the channel to get the effective height (depth at which water will flow in the terrace before overtopping). This should be 18 inches at least after the point on the ridge is well packed by trampling. Move down the terrace channel to what is believed to be a high place in the channel and take the next reading. If no easily detected high places are present, readings may be taken every 150-200 feet. Since one is traveling in the direction of flow if the target is raised at each reading in the channel, the water will drain out. If the target must be lowered, the point is higher than the channel at a previous reading and the depth of water standing in the channel will be the difference in the two channel readings. The effective height check is important to the success of the project since it determines where additional work is required to prevent terrace breaks. For example see Fig. 18. A reading is taken on a raised place in the channel and the rod reads 4 feet 6 inches. A reading is

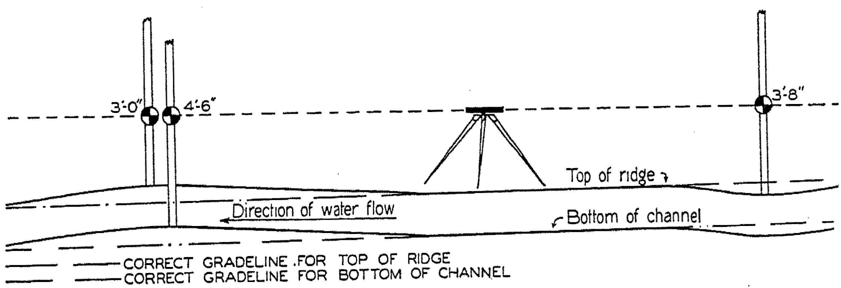

Fig. 18.—Checking for effective height of terrace. Note that even though the top of the terrace ridge is at least 18 in. above the terrace channel at any point along the terrace, it will carry a flow of water only 10 in. deep and therefore will have effective unsettled height of only 10 in.

taken on the ridge directly opposite and reads 3 feet which gives the height of ridge above the channel as 18 inches (4 ft. 6 in. — 3 ft. 0 in. = 1 ft. 6 in.). A ridge reading up the terrace (against the direction of water flow) gives 3 ft. 8 in. The effective height of the terrace is then no more than (4 ft. 6 in. — 3 ft. 8 in. = 10 in.) 10 inches even though the ridge is 18 inches or more above the channel directly opposite any given point. In this case the high point should be removed from the channel and placed in the low place on the ridge.

It is not necessary that the grade in the terrace channel check to the same grade the terrace is surveyed to. It is important, however, that the high places be removed for the reason pointed out above. The low places in the channel may be neglected in soil where water will soak in readily. On soils which pond badly, the low places should be dragged in or backfilled by the terracing machine and the high places cut out. There should be no place save a short distance where gullies are crossed, that water will stand over 2 inches deep. Such slight depressions soon work full of soil and eliminate the wet area. If the terrace checks level for a short distance, then has a slightly excessive grade for a distance and again levels off, further efforts to cut it to the grade laid out will probably not be worth

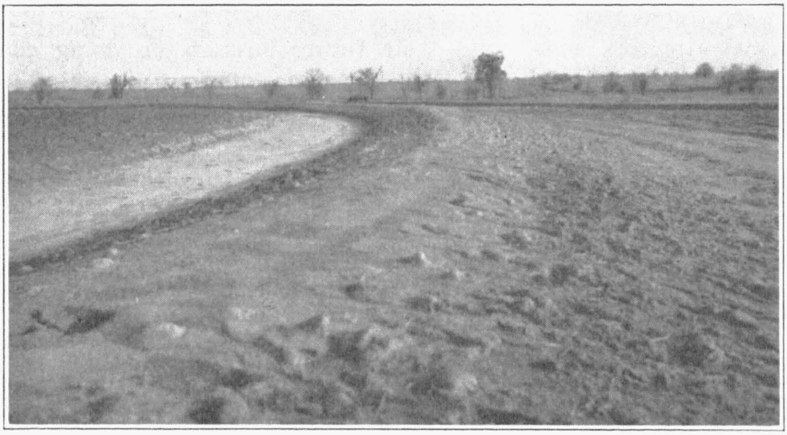

Fig. 19.—Broad channel and broad gentle ridge forms an ideal terrace. Newly constructed terrace in Boone County 1937. Approximately 6% slope.

the effort. After the channel is this well graded it will stabilize itself with good results. Where a ditch is crossed, the dam should be overfilled about 25% to allow for additional settling. Fills curved up stream in the gully save in amount of earth needed for the fill, reduce the size of pond above and make a gentle curve with the rest of the terrace.

CUSTOM OR CONTRACT TERRACING

The contract method of terracing is rapidly gaining popularity in central and northern Missouri. Considerable interest is also shown in some parts of south Missouri. Terracing work in Cooper county is keeping three custom machines busy. Several other counties kept one and sometimes two custom machines busy during the past year, in addition to small private machines. A range of from $35 to $50 per mile is the price charged for construction on fields not too badly eroded.

SOME OF THE DISADVANTAGES OF THE CONTRACT METHOD OF CONSTRUCTING TERRACES

1. Requires a ready cash expenditure by the farmer.
2. Terracing program may move so rapidly on the farm that most economical or satisfactory terrace outlet program may not be followed.

3. In new terracing communities farmers often do not get a chance to become accustomed to a few terraces before the whole field is terraced because the contractor usually objects to small and scattered jobs.
4. Contractors must build their future business on doing good work, but this does not always provide sufficient protection for the landowner. Sometimes a field is called complete and left before the terraces are to minimum specifications. If needed, an impartial party such as the county extension agent or one of the county's trained leaders may check the terraces for specifications and uniformity of construction.

SOME OF THE ADVANTAGES OF CONTRACT TERRACING

1. Fields are terraced rapidly and without keeping the landowner from his regular farming operations.
2. Work is done by experienced men and usually results in a much better job than if done by inexperienced individuals.
3. Terrace outlets may be constructed through contract by men with more experience.
4. By terracing the farm more rapidly soil losses from cultivated fields are checked, resulting in a saving through additional soil and plant nutrients conserved.
5. By the use of efficient dirt moving machinery, an experienced contractor can usually construct good terraces much cheaper than the farmer can do the same work when all of the farmer's expenses for the job are figured.

If terraces are constructed by contract the contractor should be held responsible for proper specifications in all of the terraces except where a gully is crossed. He is here responsible only when he contracts for the job of making the fills. Caring for the terrace outlet, completing the terrace construction by making the fills, finishing the extreme outlet end of the terraces and damming the upper ends are responsibilities the land owner usually assumes.

CULTURAL TREATMENT TO COMPLETE THE NEWLY CONSTRUCTED TERRACE

After construction and checking are completed, the terrace channel and the area where soil is removed just below the terrace ridge should be manured or fertilized and then plowed deeply. This will permit a reasonably good crop in these areas the first season after construction. Without this treatment, several years may be required for the area to reach equal productivity with the rest of the field. In dry years a better crop may be expected in the terrace channel than between terraces. The terrace ridge consistently produces the best crop in the field without treatment.

Terraces should be smoothed up and when possible seeded to grass or small grain to allow them to settle before being farmed to row crops. However, this should not prevent one from terracing a field that is to be farmed to a row crop the coming year. The soil saved will far overshadow the damage done to the new terraces. Cultivation with terraces helps widen and smooth the ridge making it somewhat more convenient to use hay tools over them.

MAINTENANCE OF TERRACES

Several years of experience at the Bethany Experiment Station indicates that if terraces are properly laid out, constructed and contour farmed to a 3 or 4-year rotation, there will be little or no cost of maintenance. The effective height is maintained or even increased by back furrowing on the terrace ridge when the field is plowed.

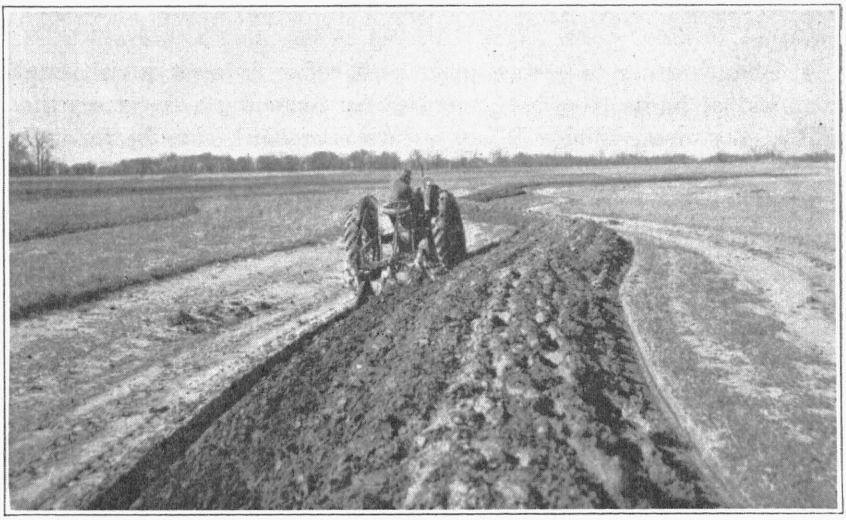

Fig. 20.—Terraces are back furrowed on the ridge to maintain effective height. The entire field is plowed on the contour. Plowing deep in the terrace channel. Picture by courtesy of the Soil Conservation Service.

This offsets any lowering of the ridge caused by contour tillage operations. See Extension Circular 365 for details on contour farming terraced land. One method recommended is to plant on the terrace ridge and parallel to it to the next terrace below, ending any point rows in the channel of the terrace below.

Some of the advantages of contouring, stated briefly, are: conserved moisture, reduced soil movement, and a saving of power by operating on the level. By a method of strict contouring of row crops, the terraces are not crossed except at the end of the field. This results in no regular maintenance being required.

Timely repair of terraces must be made when the need for the repair arises. Need for repairs may be caused by hauling a heavy load over soft terraces, burrowing by small animals, occasionally a dry weather crack washing out, overtopping caused by dams of snow or ice in the channel, etc. Only a few minutes may be required, but such repairs are necessary to avoid larger repairs. A terrace system, including the outlet, may be well and inexpensively maintained by keeping this thought foremost.

TERRACES FOR ORCHARD LAND

Terraces are often badly needed in a young orchard because of the cultivation practices carried on to promote favorable growth conditions for the trees. Terraces are used in orchards, also, to conserve moisture.

It is much easier to terrace an orchard before it is set out although some old orchards have been terraced by removing a few trees that fall in the terrace line. When a future orchard is to be terraced, it may be terraced in the usual manner and trees planted on the contour. One method is to plant a row of trees on or just below the terrace ridge and as many rows between as will be required. If the ground is not steep, but is irregular, short or point rows of trees may be required with this method of planting. If it is felt that this would be a serious objection, a gently rolling field may be planted in straight rows over the terraces as though no terraces were present. Increased maintenance of the terraces under these conditions can be expected.

Terraces placed on rather uniformly steep slopes will not vary greatly in horizontal distance from each other at any one point. Vertical spacing can be varied so that for the width of planting desired there would be one row on the terraces and one between. For instance, terraces could be given a 40-foot horizontal spacing on the uniformly steep slope and not vary greatly from this, allowing two rows of close growing trees to be planted 20 feet apart or one row of trees placed on 40-foot spacing.

Some orchardists prefer to have a terrace for each row of trees and have the trees planted on the terrace ridge. Other orchardists prefer a terrace to every row of trees, but desire to have the row of trees just between the terraces, allowing a level place in the terrace channel from which to operate their spray machinery.

If the width of two rows greatly exceeds the normal spacing of terraces on that particular slope, much better results will be secured by placing the terraces somewhat closer than recommended for field crops and close enough to allow one terrace to each row of trees.

Level Terraces.—A level terrace with ends closed is not recommended for general use as most soils in Missouri are too tight to allow rapid infiltration. Level terraces with open ends on extremely porous soil, such as, river bluff soils, give good results because the trees are not planted in the channel and drowning of crops in the channel is unimportant. However, a level terrace requires more effective height or a closer spacing than normal if the same safety factor is desired as on the graded one, even though the ends of the terrace are left open.

Graded Terraces.—A terrace with a slight grade is recommended for general use on tight soils. On this type of soil the main function of the terrace is to conserve soil and to a lesser extent to conserve moisture. Conserving soil conserves plant nutrients and also conserves more moisture even on soils having the most impervious of subsoils. Anything which reduces the soil loss will conserve moisture indirectly. A thick layer of topsoil will soak up and hold more moisture. It may be compared to a sponge, the thick sponge of a given square area will soak up more water than a thin one of the same square area.

Terracing to Irrigate.—Sometimes very rough land of a type suited for orcharding may be cleared of sprouts and timber, then terraced and planted to an orchard, resulting in successful growth of the orchard. An orchard at the Stark Nurseries, Louisiana, Missouri, is one such example. Terraces were built almost level and the trees planted on the terrace ridge. The level terrace held water until it soaked into the ground and the tree roots were close to benefit from the water saved. Although the slope is approximately 30 per cent and the bluff somewhat rocky, the trees did not fail to bear a good crop every year during the drouth. It was reported that other orchards in the vicinity which were on similar slopes, but were unterraced, had the experience of poor or no crops and severe tree loss.

Not enough work has been done on the irrigating practice of terracing orchard land in Missouri to warrant any specific recommendations to date.

TERRACING PASTURE LAND

Terraces are often found extremely beneficial when attempting to establish a pasture, particularly on badly eroded land. They are also valuable to conserve soil and moisture when used on pastures that are closely grazed. However, the main benefits to be derived from terraces on established pasture land, when grazing is controlled, is to prevent gullying and to conserve some moisture. As has been shown, sheet erosion is cut to a minimum on heavily sodded pastures.

Pasture land is terraced on some farms with smaller terraces than those regularly used for cultivated fields. When smaller terraces

Fig. 21.—This terrace outlet will serve to carry the water from the two adjoining fields which means that the only place runoff water will escape from either of these fields is through the protected outlet shown.

are used, a closer spacing ($\frac{1}{2}$ to $\frac{2}{3}$ regular spacing) is recommended. This is a much safer practice and much more efficient than placing terraces in a so-called permanent pasture at twice the recommended spacing as is sometimes done. Even the small closely spaced terraces can not be recommended for general pasture use. Permanent pastures are often farmed for two or more years to control weeds, diseases, insects, etc., and may be put into rotation for several years. Small terraces even though somewhat closer together are likely to practically disappear under cultivation, fail to carry hard rains, and be considered a failure. The standard type terrace is therefore recommended for general use in pasture land.

SUMMARY

1. Soil losses are heavy enough that even with the best of crop rotations, the valuable part of the farm is being washed away many times faster than it is being formed.

2. Terraces are recommended with a good crop rotation, soil treatment, and proper land use. When used in this way the combination of methods can be expected to prevent at least 92% of the soil losses on medium to long slopes as compared with good rotations and soil treatment without terraces. Terraces cut soil losses to a point where the soil fertility level can be maintained indefinitely by good practical methods of farming.

3. Several dollars' worth of plant nutrients per acre are washed from unterraced, cultivated fields each year. The annual loss of the cultivated field, if replaced by commercial fertilizers, will be more than the cost of terracing the field. This loss comes from the capital stock of the farm, reducing yields and net income of the farm. Terraces increase the immediate as well as the long time earning power of the farm.

4. Moisture is conserved by the use of terraces; directly by greater absorption, indirectly by retaining a thicker layer of top soil, and by not allowing the water to run off at a high velocity, thereby giving more time for penetration.

5. Terrace costs on not too severely eroded land are seldom greater than two plowings of the same land. To use the terracer more and the plow less, might be a good philosophy to use on upland Missouri soils.

6. Definite cash returns are received from terraces in increased crop yields each year.

7. Consider the whole farm or any field that might later be worked

into the same system when planning a terrace system for one field. Do not do an independent patch job on each field terraced on the farm.

8. Provide for practical and effective control of terrace outlets. Do not use roadside ditches. See Missouri Extension Circular 355, "Terrace Outlets for Missouri."

9. Be sure that no water from a field above drains on to the field to be terraced.

10. The first terrace is very important. Place it well toward the the top of the slope. If it is only a few rods long, it need not be big, but the flow of water should be broken. Terraces protect the land below, but not above, from sheet wash. Space the top terrace from a high point as recommended in Table 1 and modify it according to any apparent washes above.

11. Space and grade the terraces according to Tables 1 and 2.

12. Study illustrations and practice with the instruments until you have a mental vision of what is being done in the different steps of finding high point, percentage of slope, figuring vertical interval, locating terrace, and grading it.

13. Check your lines and do not hesitate to move terrace if better spacing is secured by so doing. Check spacing at different points by horizontal distance column, Table 1.

14. Unless you are sure of your grades check them before starting construction.

15. Check grades after and during construction. Check effective height of terrace and weak places.

16. Follow general stake line as closely as possible. Deviate only a few inches vertically if necessary to eliminate kink in line. Special study should be made of any greater deviations.

17. Make fills curving up grade where ditches are crossed and allow for settling of 20-25%.

18. Manure or fertilize terrace channel and plow deep to improve yield for first year where top soil has been removed.

19. Contour terraced fields to prevent tearing down terraces, and to assist in saving soil and moisture. This will result in increased yields. Regular maintenance may be prevented by proper contouring methods.

20. Make timely repairs of terraces and outlet.

21. There is a place for terraces in many Missouri orchards to save soil and moisture. Trees may be planted on contour especially on steep land and they may be placed either on or between terrace ridges.

22. Closely grazed or badly eroded pastures may be greatly benefited by terraces.

23. Terracing on pasture land is not ordinarily recommended until crop land is terraced.

24. Terraces pay highest dividends on investment when placed in good fields first and used with proper cropping plan and soil management for those fields.