LAND GRADING METHODS

General

Land grading for drainage consists of shaping the land surface by cutting, filling, and smoothing to a continuous grade as shown in Figure 14-22.1. A continuous grade is necessary to assure uniform flow of runoff water over the land surface or along crop rows without ponding. Shaping land into a plane surface to provide uniform slopes in both a lateral and longitudinal direction normally is not essential but may be advantageous in situations where: (1) grading of the site can be handled more efficiently; (2) economical and efficient operation of special planting and harvesting machinery is necessary for high value crops; (3) change in crop row direction is desired; and (4) surface irrigation is used.

Detailed surveys, planning, and layout are necessary for land grading jobs. Emphasis in planning is given to filling depressions with soil available from immediately adjoining ridges and mounds. Where the material required for filling low places is excessive, or sufficient soil is not available, random field ditches can be established and surfaces warped toward them. In areas with little or no land slope, surface grades can be increased by grading between parallel field ditches, with the cuts made from the edge of one ditch and the fill placed with increasing depth toward the edge of the next upper ditch. Surface ridging similar to bedding can be established also by shaping and smoothing land surfaces and ditch spoil between a system of closely spaced and graded field ditches. The artifical ridge is created midway between ditches. Approximately parabolic convex surfaces are developed by shaping from the ditch shoulders to the ridge. Necessary crown heights and fill are obtained by an adjustment in spacing between ditches, flattening ditch side slopes, and use of ditch spoil. Ditch spacing and crown heights should be obtained from the state drainage guide. Row lengths will vary according to soil permeability and grade. Row grades on nonplastic, permeable, and erodible soils should seldon exceed 1/2 percent, although on plastic and slowly permeable soils, grades may run as steep as 2 percent. Recommended grades and row lengths also should be obtained from the state drainage guide.

Land grading for drainage is an intensive practice, the cost of which may be reduced by separating fields or portions of fields into areas having about the same slope and soil characteristics. These areas then provide a basis for selecting a proper field arrangement, which takes into account: (1) planned land use; (2) length of row or distance of water travel overland; (3) auxiliary drainage measures such as outlets and diversions; (4) access roads; (5) supplemental borrow; and (6) waste areas, if needed.

To illustrate methods and procedures, a representative problem for the Northeast is shown in Figure 14-22.2 through Figure 14-22.6. The problem assumes a 13-acre hay and pasture field (ACIG) consisting of slowly permeable clay loam soil which generally is wet and produces only

low-yielding and poor-quality hay and pasture. Drainage improvement requires protection from upland flooding and seepage by means of a diversion (CEI), a lateral (BDFH) at the break in slope, and a disposal channel consisting of a waterway (KL) and a main (JK). The sloping field section (BCIH) has a good down field grade of over 3 percent and a cross slope grade between 1 and 2 percent which will provide good furrow drainage without erosion when plowed. The flat section (ABHG) has several wet depressions. Grading and smoothing are necessary to develop a free draining surface toward the outlet.

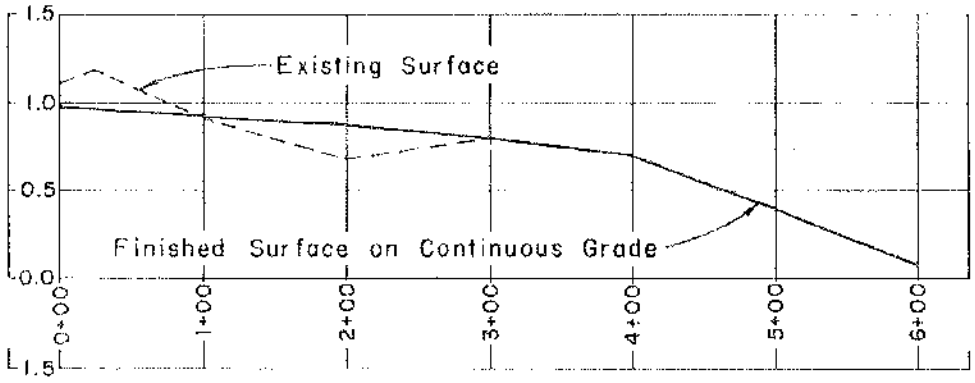


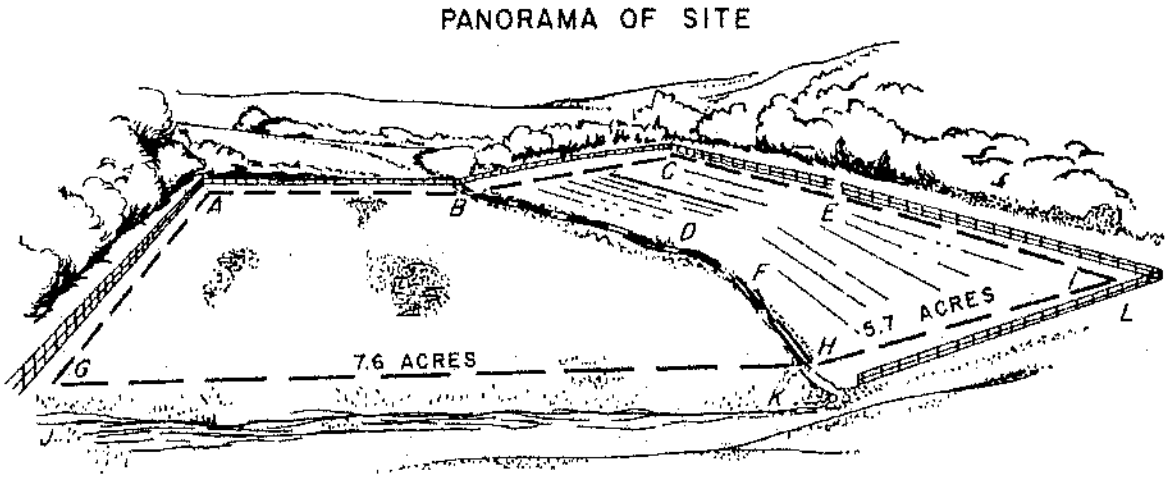
Figure 14-22.1 Surface graded for drainage

Surveys

Topographic surveys must be made to provide a basis for planning the surface grading and auxiliary drainage system. The intensity of surveys may range from a few scattered shots on land surfaces having a pronounced slope to a precise grid-type survey on slightly sloping to flat surfaces (1 percent or less). Bench marks and points of known horizontal position need to be located and mapped so that both vertical and horizontal control can be reestablished on the ground. Figure 14-22.2 illustrates a plat of essential survey data for improvement of the total field area (ACIG).

In addition to topographic data, an adequate number of soil borings should be made to determine depth of topsoil so that depth of grading can be controlled, when necessary, to prevent exposing harmful amounts of subsoil.

After the job has been planned, further staking of the sloping field area (BCIH) may not be necessary. However, grid stakes must be set for grading the flat field area (ABHG). Since stakes cannot be maintained for long in farm fields, staking and final design for surface grading



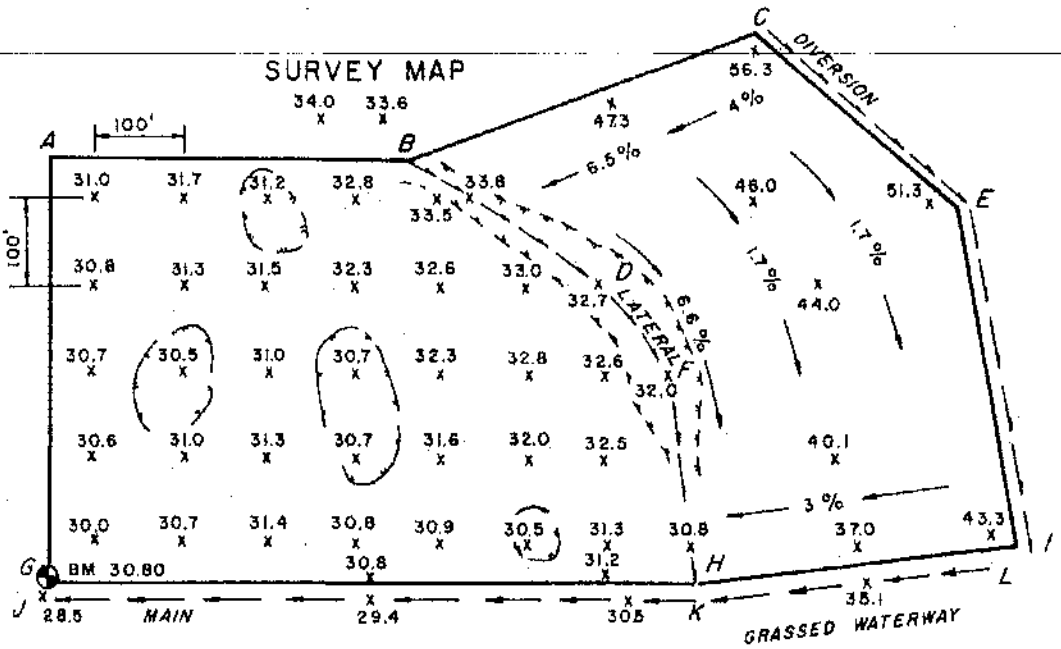
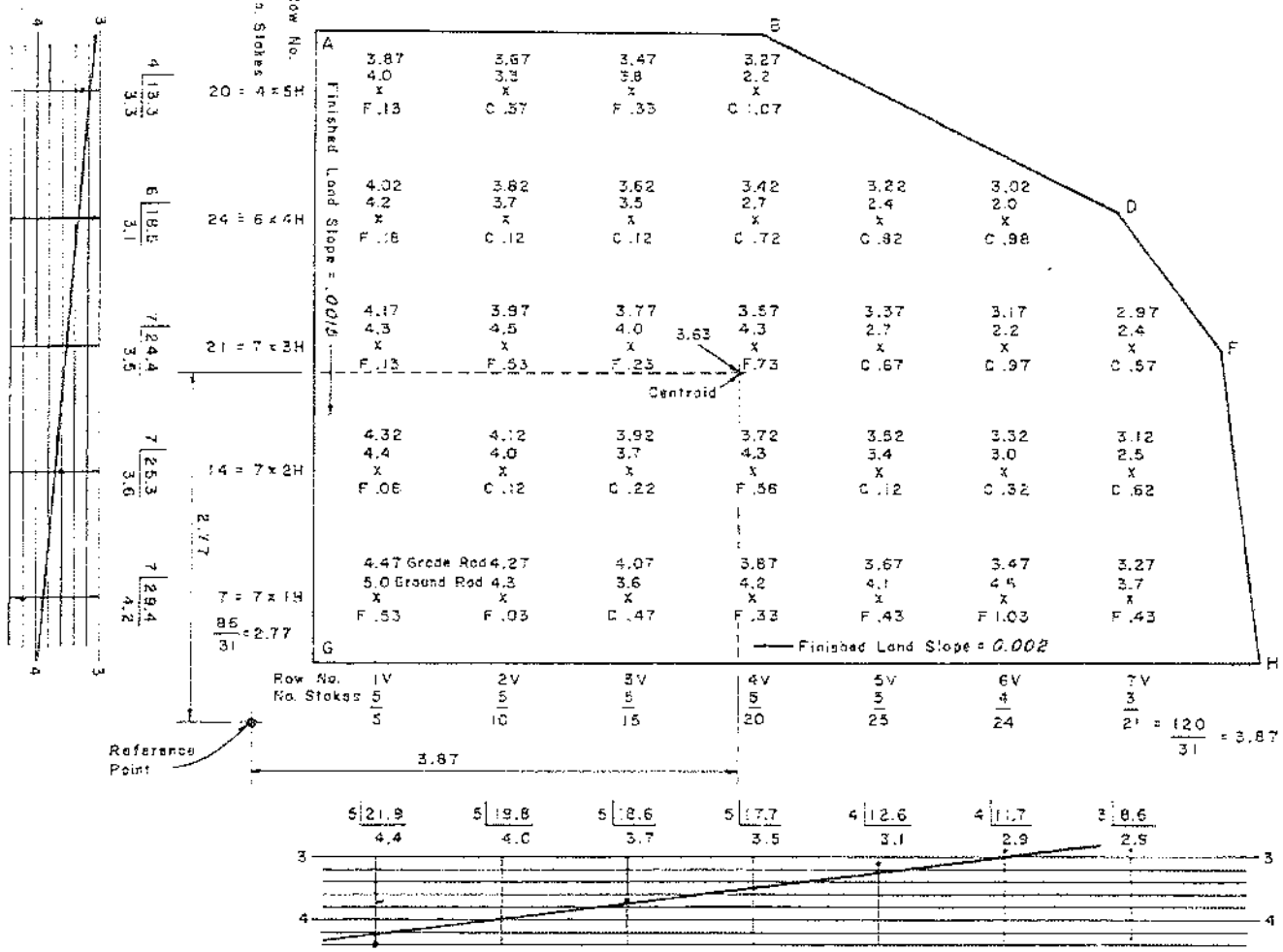


Figure 14-22.2 Land grading and smoothing

Total Fill 5.70
Shrinkage Adjustment ... 1.55 / 7.25
Total Cut 8.28
Variation per Stake ..... 1.03 / 31.0 = 0.03
Cubic Yards Cut ..... 100 x 100 x 8.28 / 27.0 = 3067.0 Cu. Yds.

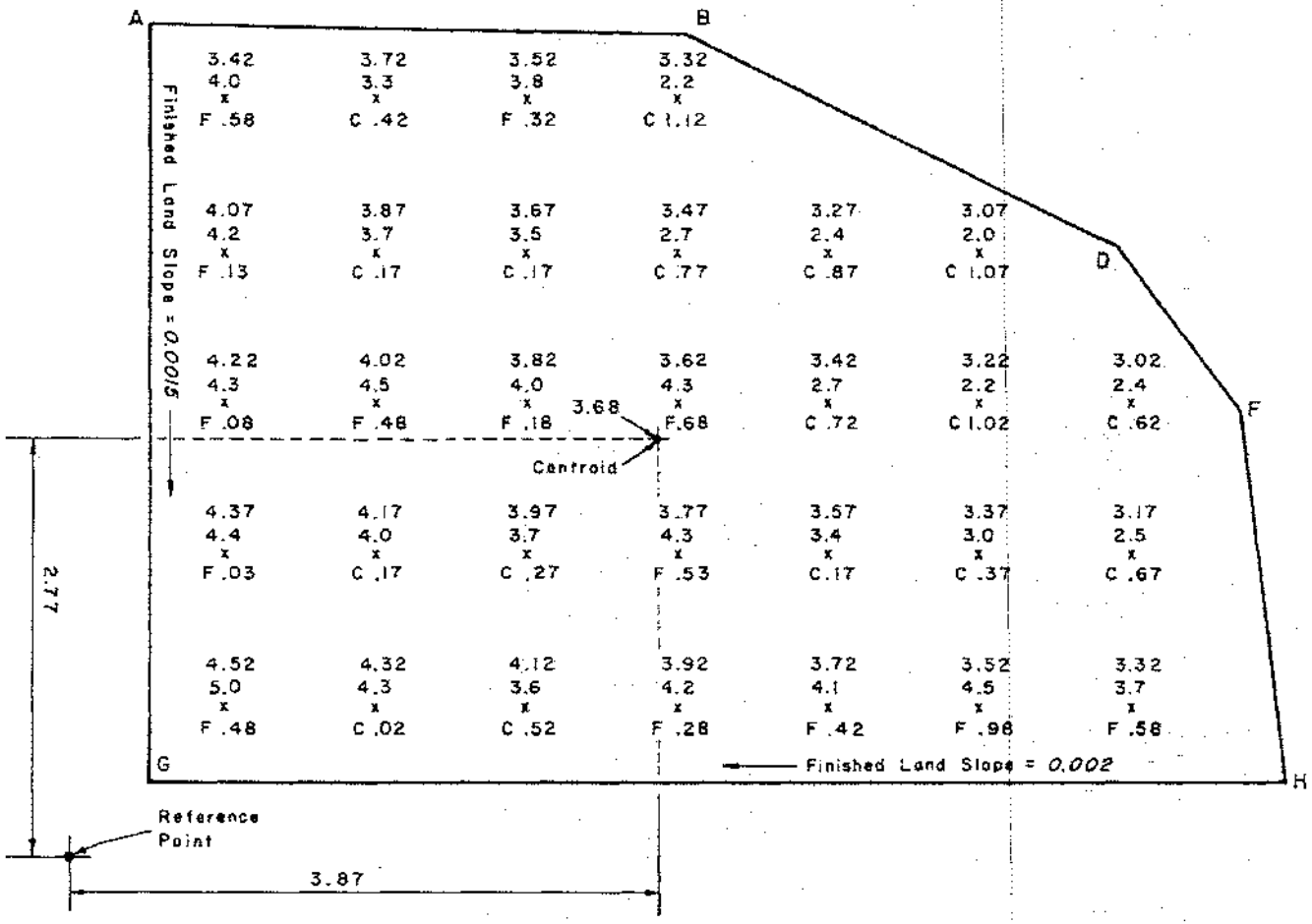
Sum of Ground Rod Readings 110.9
Number of Rod Readings ... 31
Average of Ground Rod Reading 3.58
Adjustment for Shrinkage 0.05
Adjusted Grade at Centroid 3.63



FIRST TRIAL SINGLE PLANE OF BEST FIT

Figure 14-22.3 Plane method for land grading and smoothing

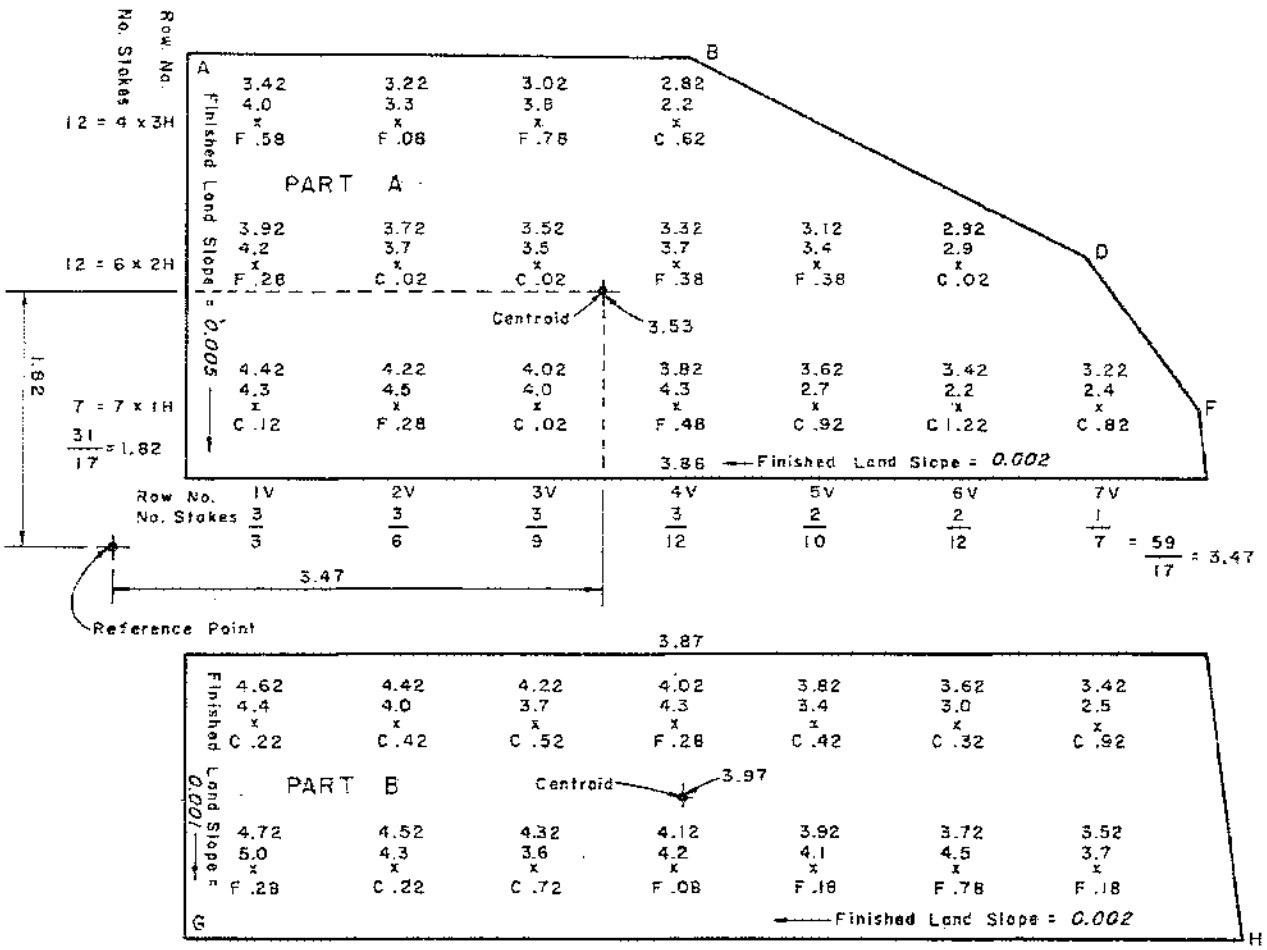
Total Fill 5.75
Shrinkage Adjustment 1.55
7.30
Total Cut 9.14
Variation per Stake ..... $\frac{1.84}{31.0}$ = 0.06
Cubic Yards Cut ..... $\frac{100 \times 100 \times 9.14}{27.0}$
= 3385.0 Cu. Yds.



SECOND TRIAL SINGLE PLANE OF BEST FIT

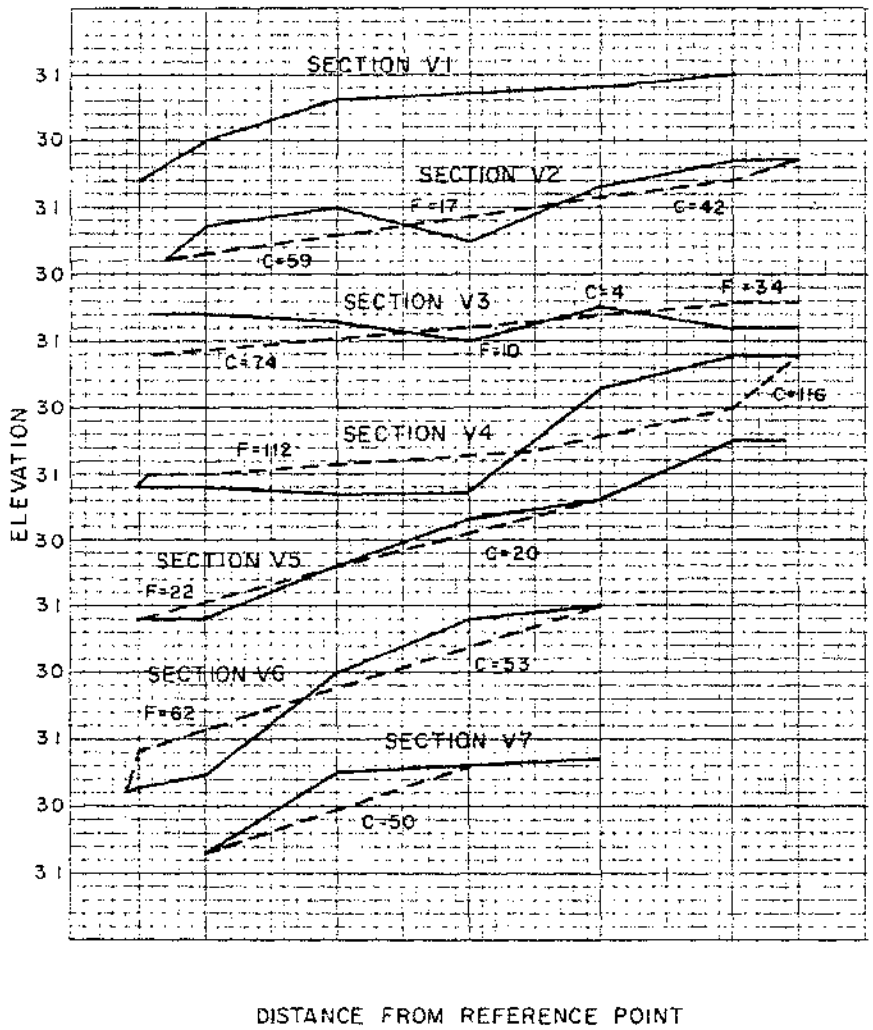
Figure 14-22.4 Plane method for land grading and smoothing

	PART A	PART B
Total Fill	5.02	
Shrinkage Adjustment	1.55	
	6.57	
Total Cut	7.54	
Variation per Stake	$\frac{0.97}{31.0}$ = 0.03	
Cubic Yards Cut	$\frac{100 \times 100 \times 7.54}{27.0}$ = 2792.0 Cu. Yds.	
Sum of Ground Rod Readings	59.1	54.7
Number of Rod Readings	17	14
Average of Ground Rod Reading	3.48	3.91
Adjustment for Shrinkage	0.05	0.05
Adjusted Grade of Centroid	3.53	3.96



MULTIPLE PLANES & ADJUSTED GRADE

Figure 14-22.5 Plane method for land grading and smoothing



SECTION	LENGTH	CUTS			FILLS		
		SUM END AREAS	AVE. END AREA	CUBIC FEET	SUM END AREAS	AVE. END AREA	CUBIC FEET
V1 - V2	100	101	50.5	5056	17	8.5	850
V2 - V3	100	179	89.5	8950	61	30.5	3050
V3 - V4	100	194	97.0	9700	156	78.0	7800
V4 - V5	100	136	68.0	6800	134	67.0	6700
V5 - V6	100	73	36.5	3650	84	42.0	4200
V6 - V7	100	103	51.5	5150	62	31.0	3100
V7 - V8	100	50	25.0	2500	0	0	—
		TOTAL CU.FT.= 41800 CU.YDS. = 1548			TOTAL CU.FT. = 25700 CU.YDS. = 952 15% SHRINKAGE = 143 .05 CONST. VARIATION 24 STAKES = 444 CU.YDS. = 1539		

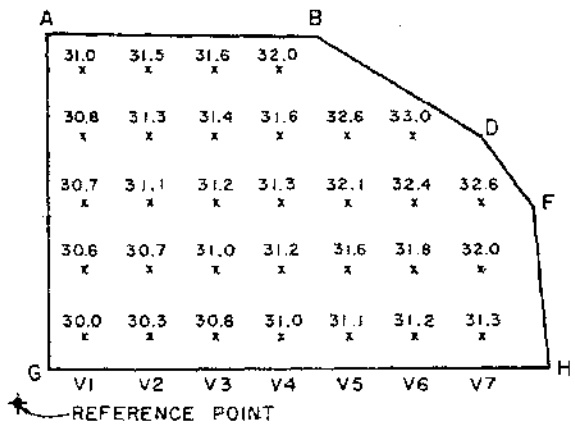


Figure 14-22.6 Profile method for land grading and smoothing

frequently is done immediately prior to construction. Grid stakes set at 100-foot centers in each direction should be the maximum spacing used. Spacings on 50-foot by 50-foot centers may be necessary to pick up intervening surface irregularities, provide for small equipment usage, or provide guidance to inexperienced earth moving operators who have difficulty in carrying grades between stakes set at 100-foot centers. Too narrow a spacing should be avoided as a regular practice since 50-foot spacing, as compared to the 100-foot spacing, requires four times as many stakes to be set, shot, plotted, computed, and checked. Because of irregularities along edges of fields, spoil, and the need for equipment operating room, it is advantageous to set the first line of grid stakes at a half-grid interval from the field edge.

Planning Land Grading

There are four basic methods, and many variations of these methods, that can be employed in planning the grading of field surfaces for drainage. These are the plane, profile, plan inspection, and the contour adjustment methods. The plane and profile methods which are the most likely to be used by the planner are covered herein.

The Plane Method

A true plane surface is established which can provide both a uniform downhill slope and a uniform cross slope. It produces the most desirable field surface for production of crops and systematic removal of surface water from nearly flat land surfaces. It permits a choice of row direction and cross row drainage. However, the moving of a larger amount of earth may be involved than if other methods are used. If the size of field and differences in elevation are too great, the field may be subdivided into several planes to reduce the required amount of grading.

The centroid of the area to be graded to a plane must be found and the plane established through that point to an elevation equal to the average field elevation. When this is done, the volume of excavation equals the volume of fill regardless of the slope of the plane. The plane must be lowered sufficiently to provide extra cut since more excavation than fill is necessary to account for shrinkage in the fill and the plowed up or disturbed surface soil, as well as to compensate for construction variations from true grade.

The following is a step-by-step procedure for planning area ABDFHG in Figure 14-22.2 by the plane method. Rod readings instead of ground elevations are used in this example.

1. Stake the area in a 100-foot grid pattern, keeping outer stakes about one-half grid spacing from the edge of field, and so each stake will represent an equal portion of the total field area. Set lines of stakes parallel and perpendicular to the principal direction of flow or parallel and perpendicular to AG and GH.

2. Take rod readings on the ground at each stake. Draw a scaled map of the field showing the stake locations and the ground elevation at each stake, as in Figure 14-22.3.

3. Determine whether the field should be graded as a unit or by segments. As a guide, plot a profile in the vertical direction on the plan showing the average ground rod of each horizontal row of stakes, and also in a horizontal direction for each vertical row of stakes. The profile of the horizontal rows is shown on the left-hand edge of Figure 14-22.3 and the vertical rows at the bottom of this figure. These profiles indicate no distinct breaks in grade to warrant using more than one plane for the whole area.

4. Establish the approximate downhill and cross slope grades for the plane of best fit from the profiles established in the previous step. The selected plane of best fit has a grade of .002 foot per foot parallel to field side ~~GH and .0015 to field~~ side AG. This should approximate the most economical slope and is in the slope range of 0.001 to 0.005 found to provide good drainage for graded surfaces. In some cases, development of an arbitrary slope may be necessary. Slopes less than .001 do not drain adequately and should not be used, and slopes above .005 may be erosive in some continuously cultivated soils.

5. Determine the centroid of the field. For a rectangular field, it is at the intersection of its diagonals, and for a triangular field, at the intersection of lines drawn from the angles to the midpoints of the opposite sides. Irregular fields, such as in the example, may be divided into triangular and rectangular parts. The distance to the centroid from any line of reference is then equal to the sum of the products obtained by multiplying the area of each part times the distance from the line of reference to its centroid, divided by the area of the entire field. By computing the distance from two lines of reference at right angles to each other, the exact point of the centroid is determined.

   Usually, by assuming each stake on the grid as representing an equal area, a sufficiently accurate determination of the centroid location is obtained by the method shown in Figure 14-22.3 and recorded on the figure along field sides AG and GH. Number the stake rows horizontally and vertically from a common zero reference point. In the example, the reference point has been established outside the field boundary at the intersection of the lines of reference, which are parallel to and one stake interval away from stake lines 1H and 1V. Next, count stakes per row and record this number adjacent to the row number. Multiply stakes per row by the row number and total the horizontal and vertical products separately. Next, divide these totals by the total number of stakes and plot

the centroid location at the intersection of the horizontal and vertical distances from the common reference point.

6. Determine the average ground elevations of the field. This is obtained by adding ground rods at all the grid stakes and dividing this sum by the number of stakes. See top of Figure 14-22.3.

7. Apply an adjustment for shrinkage. When a cubic yard of earth, as measured in its original condition, is loosened by excavation, its volume increases. When replaced in a fill and compacted, its volume decreases below the original volume. This decrease is the shrinkage. Shrinkage varies with different soil materials, but it will generally range from a fraction of 1 percent for well graded sands to 15 percent for clays. For many soils, 10 percent is adequate. Since nearly all soils in the 6- to 8-inch surface depth have been disturbed by plowing and disking, some shrinkage adjustment should be made at the centroid and at each stake at which grading occurs. Assuming 1/2 foot average depth of disturbance over the entire graded area, this allowance would be 0.5 x 10% = 0.05 per stake as shown at the top of Figure 14-22.3.

8. With the location and ground rod of the centroid and the stakes established, determine the grade rod at the stake nearest to the centroid, and thence, the grade rod at all stakes. The grade rod reading at the nearest stake will be the grade rod at the centroid, plus or minus the horizontal distance to the stake row times the horizontal row grade, plus or minus the vertical distance up or down the stake row times the vertical row grade ((3.63 - (13 x .002) - (23 x .0015) = 3.57)).

9. Calculate cuts or fills for each stake. If the calculated grade rod exceeds the ground rod, a cut is indicated; if the calculated grade rod is less than the ground rod, a fill is indicated.

10. Add total fills. Total fills should include the total shrinkage adjustment at each stake. Additional shrinkage should be allowed for the full depth of fill for each stake whose fill depth exceeds one-half foot. All fills should be placed in not more than one-half foot lifts.

11. Add the total cuts. The total cuts should exceed total fills by an amount equal to the shrinkage and a stake variation of about 0.05. This is to allow for construction inaccuracies which occur in grading to within the usual tenth of a foot tolerance above or below the marked grade on the stake. The variation per stake is equal to total cuts minus total fills divided by the number of stakes.

12. If the total cuts are insufficient, a readjustment of the centroid elevation should be made and steps 7 through 11 repeated, as shown in Figure 14-22.4.

13. Mark stakes with appropriate cut or fill.

14. Compute quantity of earth moved as equal to the grid stake area in square feet times the total cut in feet divided by 27, as shown on Figure 14-22.3 or 14-22.4.

To illustrate the procedure whereby several planes and different grades can be established in field ABHG, refer to Figure 14-22.5. Topography of the example does not lend itself to a ready solution. However, arbitrarily assume field ABHG as divided into parts A and B with the break line midway between horizontal stake lines 2 and 3. Use an uphill grade of .005 and downhill grade of .001 with the grade in the direction of the division line remaining at .002.

1. Establish the locations and ground rod of the centroids of each part.

2. Determine separately for each centroid the grade rod of a common point at the dividing line, such as midway between stakes 2 and 3 in vertical stake row 4. If the separately determined grade rods do not agree, an adjustment should be made to establish a match line between the two planes. This may be done by increasing the centroid ground rod for the largest match point reading and decreasing the opposite centroid ground rod reading by one-half the difference in the match point rod reading. It can be done, also, by some adjustment of the plane grade in one or both parts of the field.

3. Establish grade rod, cuts, and fills, separately, for each part.

4. Determine total cuts, fills, shrinkage adjustments and stake variations of parts A and B combined. Since the resulting stake variation is smaller than would be anticipated in the first trial shown in Figure 14-22.5, a further adjustment of the centroid will be necessary before the final construction cuts and fills are established.

The Profile Method

Under this method the designer works primarily with profiles of the grid lines rather than with ground rods or elevations on the plotted map. It is well adapted to grading surfaces with an undulating topography, and permits independent variation of grade along and between profiles. Thus, substantially less earth moving may be required as compared with the plane method. Grades are easily selected on the profile to balance cuts and fills within relatively short haul

distances and at the same time permit development of both downhill and cross slope grades.

1. Plot the profiles in one direction of the grid lines beginning at the top or one side of the field and so locate the profiles on the paper that the profiles are positioned vertically in accordance with a common datum line at an equidistant spacing down the sheet, as shown in Figure 14-22.6.

2. Establish trial grade lines either by inspection alone or with the aid of plotted cross slope profiles. Plots of adjusted grade stakes, as shown on the plat in Figure 14-22.6 are helpful in making adjustments between profiles.

3. From inspection of the original and proposed grade lines, determine cuts and fills.

4. Compute cuts and fills, including an allowance in the fill quantities for shrinkage and construction tolerance. If a satisfactory balance of cuts and fills is not obtained, further adjustments in grade must be made until a balance is obtained.

Construction

Cut and fill stakes for construction purposes must be established to guide the equipment operator. Key grid lines should be permanently referenced so that the grid can be relaid if stakes are destroyed or long delays occur between staking and construction.

Land to be graded should be cleared of trash and vegetative material by mowing, raking, and burning. Grass and other crop material should not be plowed under prior to rough grading, since scrapers operate more efficiently on firm ground. Crop ridges should be removed by disking. Soil should be relatively dry for good grading operation. Excessive soil compaction may be a problem if soil is worked at a high moisture content.

Grid stakes should not be disturbed in grading operations. It is good practice to open lanes adjacent to stake lines and bring these to grade, after which intermediate areas can be worked out until small islands are left around each grid stake. These are left until the field is checked. Fills over 0.5 foot in depth should be built in 6-inch layers or less to avoid excessive settlement. For fills in excess of 1/2 foot, extra fill height of at least 10 percent should be allowed for settlement or a settlement period allowed before final checking and grading takes place. When topsoil must be stockpiled for topping, it should be placed on an area which requires little or no cut or fill and from which it can be removed before final grading of the area.

The finished earth work should check within a permissible tolerance of plus or minus 0.1 foot, with settlement taken into account. However, a reversal of grade in the direction of drainage should not be permitted. Grade checks should be made with an engineer's level.

After removal of grade stakes, highs, depressions and other minor irregularities should be removed by means of a land plane, with at least two passes in opposite directions at 45 degrees to the grid lines and a final pass in the direction of major drainage. This process should be continued until the grading tolerances have been met.