NATIONAL ENGINEERING HANDBOOK

SECTION 16

DRAINAGE OF AGRICULTURAL LAND

CHAPTER 3. SURFACE DRAINAGE

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CHAPTER 3. SURFACE DRAINAGE

General

Surface drainage is the orderly removal of excess water from the surface of land through improved natural channels or constructed ditches and through shaping of the land surface.

Surface drainage applies primarily on flat land where slow infiltration, low permeability, or restricting layers in the soil profile, or shallowness of soil over rock or deep clays, prevent ready percolation of rainfall, runoff, seepage from uplands, or overflow from streams through the soil to deep stratum. The land surface to be drained should have a continuous fall to the field ditch and the field ditch should have a continuous grade to the field lateral. The water surface in the field lateral at design depth should be low enough to drain the field.

Surface drainage systems, when properly planned, eliminate ponding, prevent prolonged saturation, and accelerate flow to an outlet without siltation or erosion of soil (1). In some cases, orientation of crop rows with the land slope may accomplish this purpose. In other cases, use of a diversion or a complete system of ditches and crop row drains is necessary as shown in figure 3-1. Combinations of both surface and subsurface drainage, such as land grading and smoothing over subsurface drains, often provide better and more economical results.

Surface drainage systems include both collection and disposal ditches. Where the system, or parts of the system, primarily collect and remove surface water from a field or small land area, the cross section, slope, pattern and spacing of ditches are essential factors of design as covered herein. Ditches for surface drainage are usually designed to remove the runoff produced by an ordinary rain in time to prevent damage to the crops grown in the drainage area.

The rate of removal is called the drainage coefficient which is the rate of water removal per unit area used in drainage design. For surface drainage the coefficient is usually expressed in terms of flow rate per unit of area, which varies with the size of the area. Where the drainage system or parts of the system primarily convey discharge from one or more fields, farms or large land areas to an outlet, the depth, capacity and hydraulic gradeline are added factors of consideration. Drainage coefficients for surface drainage and design of the ditches of the disposal system are covered in chapter 5, "Open Ditches - Design, Construction, and Maintenance."

Wide variations in climate, topography, soils, crops and farming practices between regions of the United States alter surface-drainage requirements. Therefore, when planning and designing surface-drainage systems, reference should be made to state handbooks and local drainage guides.

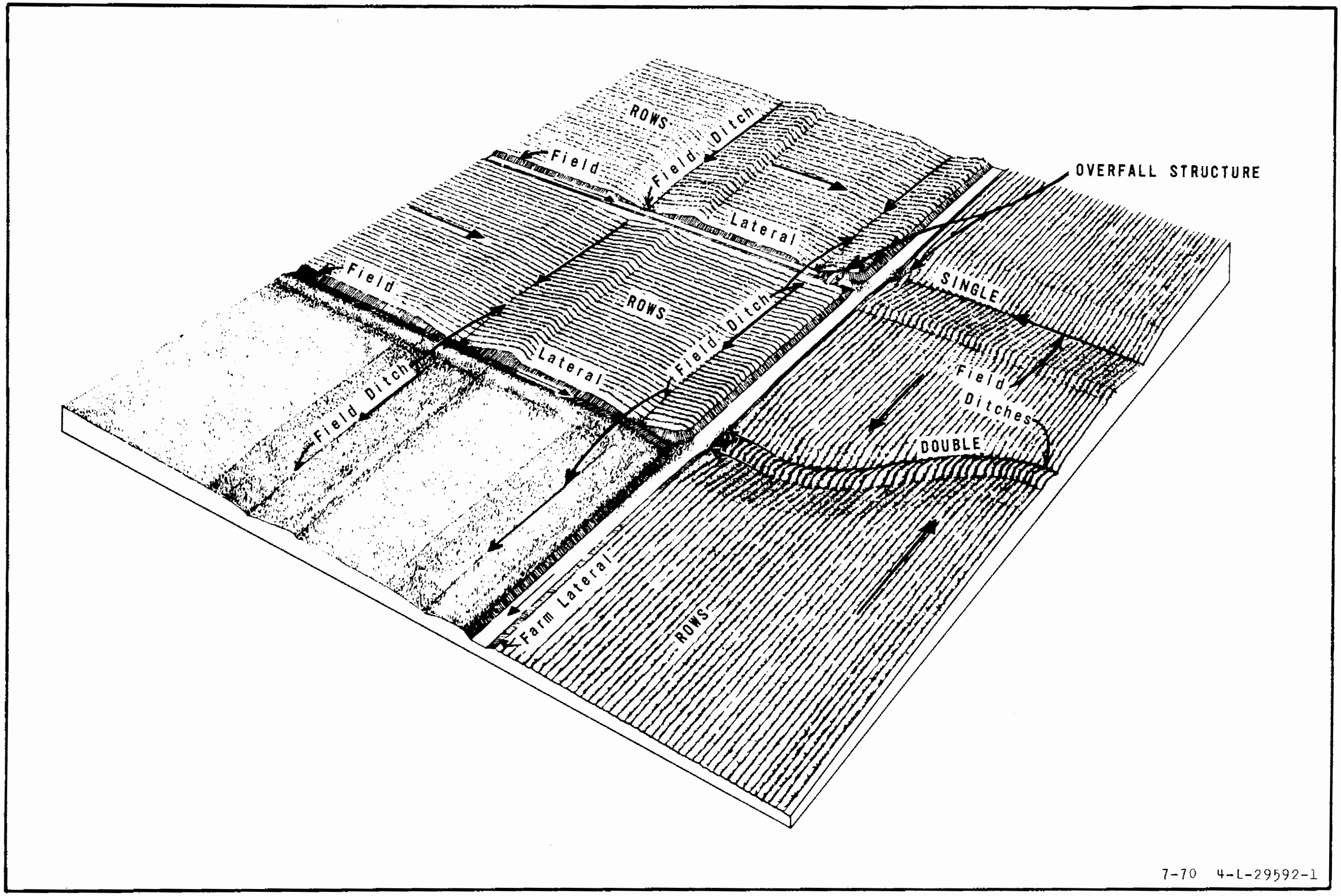

Figure 3-1, Typical layout - individual farm drainage system
(Where the ground surface is undulating, ditches and drains will meander)

Surface-Drainage Systems

The basic surface-drainage systems are the parallel, the random, and the cross-slope or diversion system. The system to be used will depend upon the requirements of the site. The system used should --

1. Fit the farming system.

2. Cause water to flow readily from land to ditch without harmful erosion or deposition of silt.

3. Have adequate capacity to carry the flow.

4. Be designed for construction and maintenance with appropriate equipment locally available.

The random system

Where the topography is irregular, but so flat or gently sloping as to have wet depressions scattered over the area as shown in figure 3-2, a random system is used. The field ditches should be so located that they will transect as many depressions as feasible along a course through the lowest part of the field toward an available outlet. The course should be selected so as to provide the least interference with farming operations and a minimum of deep earth cuts. Cuts over three feet should be avoided although these sometimes are necessary to reach an outlet and leave a farmable field. Field ditches should ordinarily not be shallower than one-half foot deep or deeper than one foot where they are to be crossed frequently by farming equipment. Side slopes for handling farm equipment should be determined from local guides. Ditches should extend completely through depressions, as shown in figure 3-2, to assure complete drainage. Land grading, smoothing or bedding will usually be necessary on the less permeable soils to assure complete surface water removal.

The parallel system

Where topography is flat and regular, and a random system is impractical or inadequate, field ditches should be established in a parallel but not necessarily equidistant pattern as shown in figures 3-1, 3-3, and 3-4. Orientation of field ditches will depend upon direction of land slope; location of diversions, cross-slope ditches and mains and laterals of the disposal system; and access of the established lands to farming equipment. Usually, field ditches should run parallel to each other across a field to discharge into field laterals bordering the field. Laterals and mains should be deeper than the field ditches to provide free outfall. Surfaces of lands should be graded and smoothed for uninterrupted flow along crop rows or over the land surfaces, when rows are not maintained.

When soils are permeable and the field ditches will dry out in about the same time as the adjoining land surface, crop rows may be run across the field ditches so that they can collect and carry the row water directly to field laterals.

When crop rows are established parallel to field ditches, row ditches must be planned to drain rows through depressions and to reduce row lengths. Such ditches are temporary installations and are cut by hand shovel or plow during the course of farming operations.

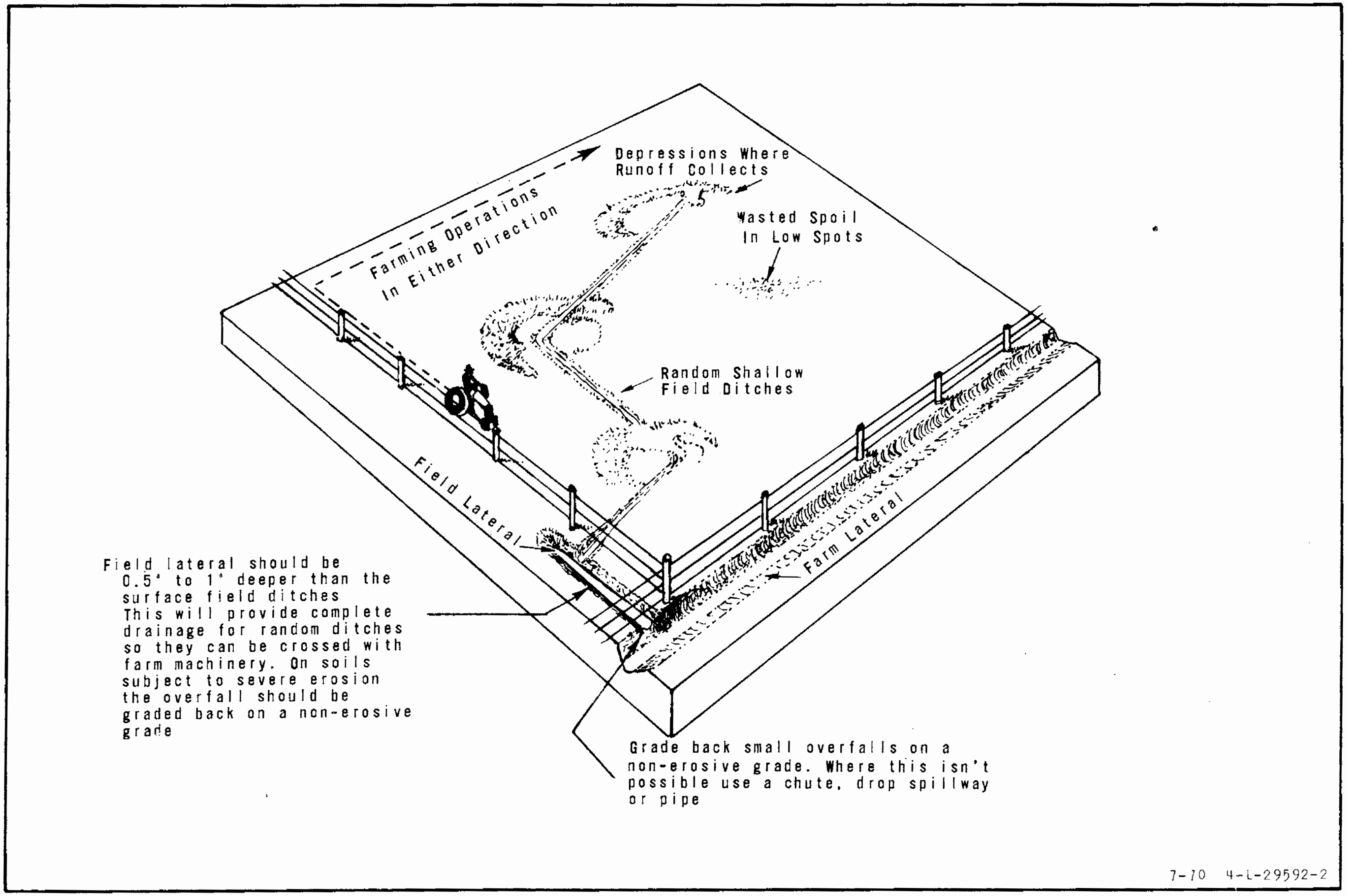

Figure 3-2, Random system

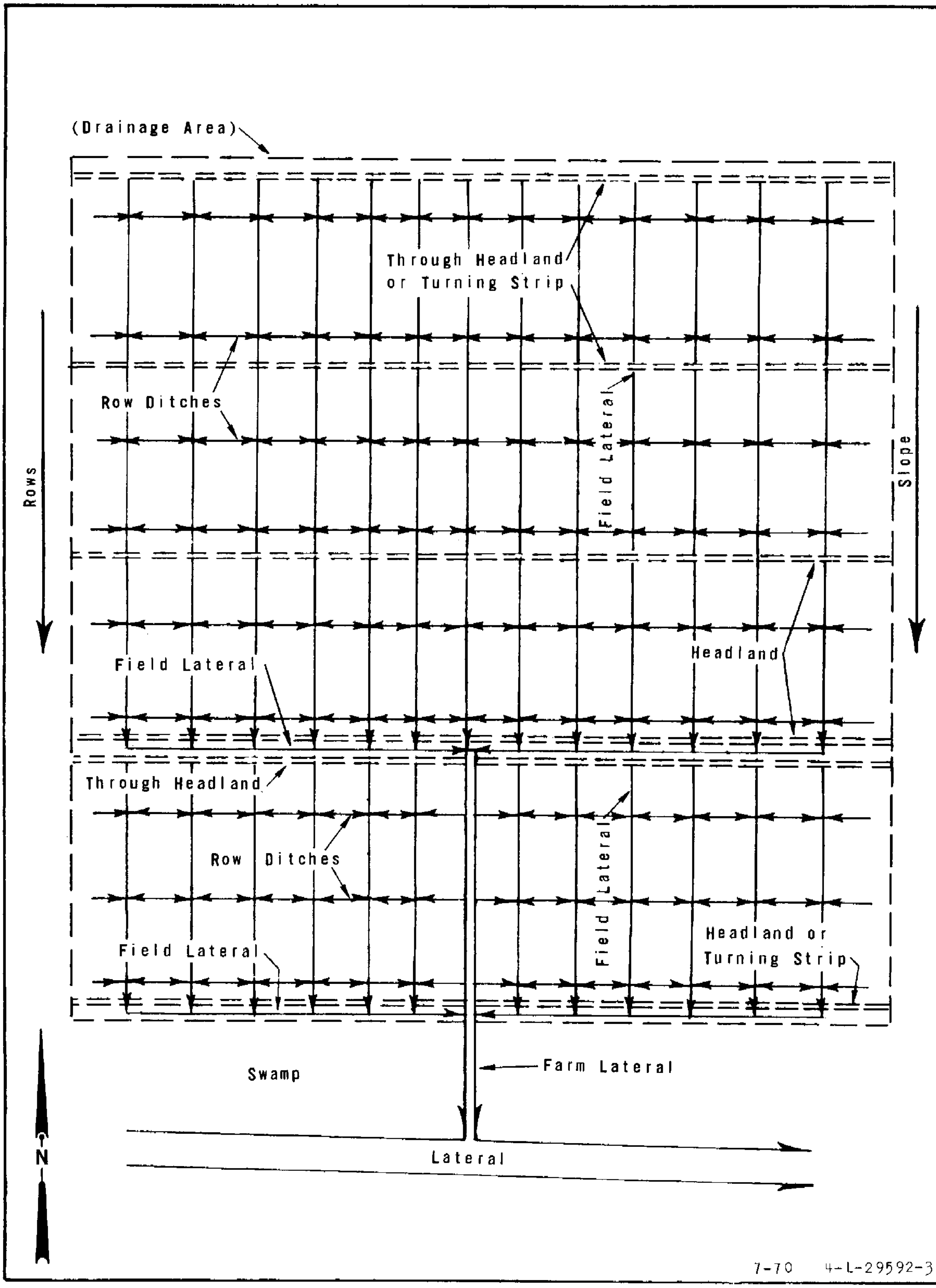

Figure 3-3, Parallel system

(Illustrates field layout well suited to sugarcane)

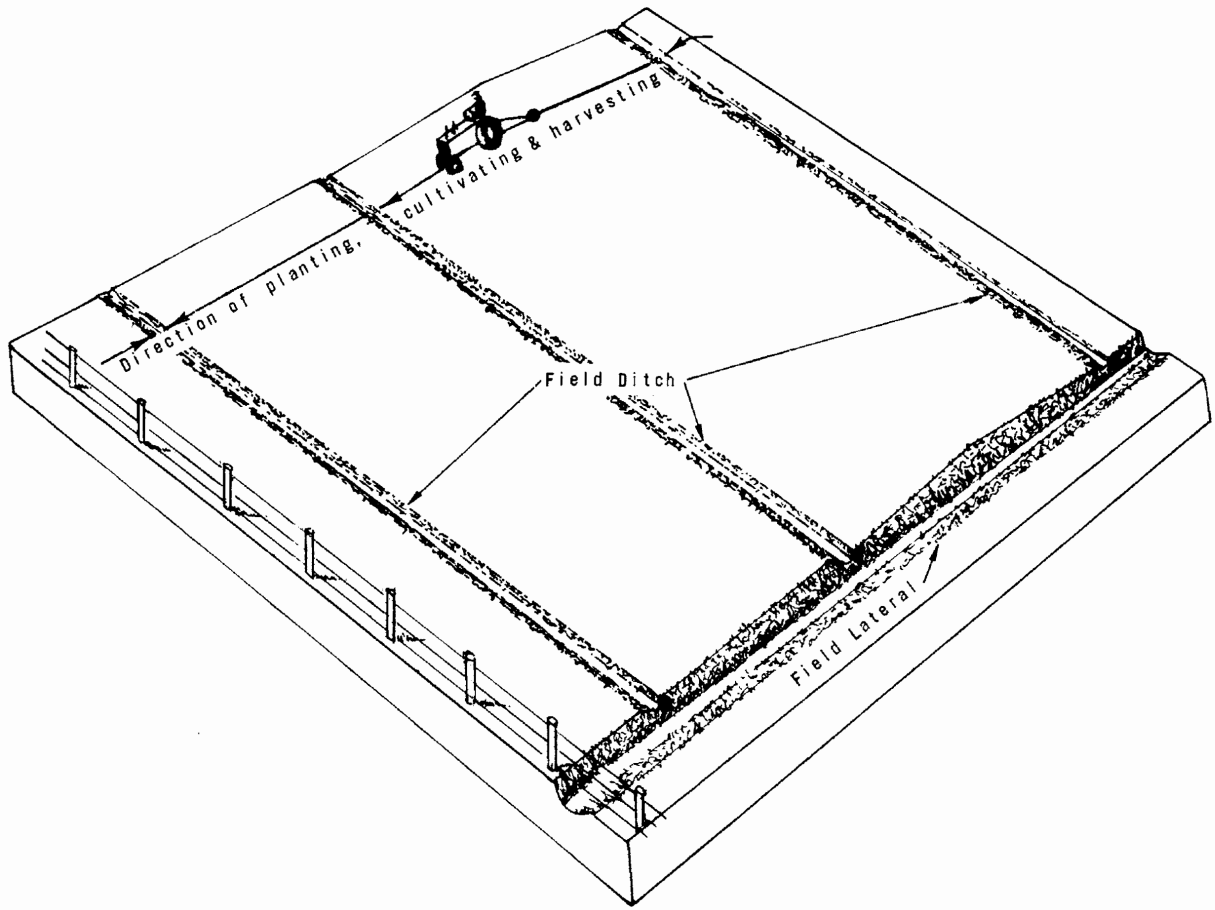

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Figure 3-4, Parallel system
(Illustrates field layout suited to growing a variety of row crops, including cotton, corn, soybeans, sugarcane, grain sorghum, etc.)

Spacing of parallel field ditches depends upon size of lands that can be tilled and harvested economically, on water tolerance of crops, and on the amount and cost of the necessary land forming. These factors must be determined locally. Where subsurface drainage may be used in conjunction with field ditches for protection of crops highly sensitive to water, such as tobacco, field-ditch spacing may need to be adjusted to be compatible with spacing requirements of the subsurface drains. Field-ditch spacing also should be adjusted to accommodate tillage and harvesting equipment to be used in the field.

The cross-slope system (diversion system)

Use the cross-slope system (a) to drain sloping land that may be wet because of slowly permeable soil, (b) to prevent the accumulation of water from higher land, and (c) to prevent the concentration of water in shallow pockets within the field. This system consists of one or more diversions, terraces, or field ditches built across the slope. As water flows downhill--either in the furrows between rows on cultivated land, or as sheet flow on hay land and permanent grassland--it is intercepted and carried off (figure 3-5).

Whether to use diversions or field ditches depends on the steepness of the slope, the permeability of the soil, and the possibility of water flowing from higher land onto the field being drained. Field ditches are best on slopes under two percent. Diversions apply to steeper land. Diversions also shorten long slopes where overtopping of field ditches would create an erosion hazard (figure 3-6).

The cross-slope system also prevents accumulation of water at the ends of long rows or at the lower edges of a field. It may be necessary to build field ditches to collect water from the furrows between the rows along the edge of spoil paralleling large mains and laterals. See figure 3-8.

Use local drainage guides to determine spacing and slope. Normally, erosion-control requirements determine spacing and design of terraces and diversions. Space the channels to control erosion. Design diversions to carry runoff from a 10-year frequency storm, plus freeboard. Where subsurface seepage is a problem, try to locate the channel so as to provide continuous interception of the seep line.

Where the field joins bottom land, use a field ditch (or lateral where several farms or large areas are involved) on the bottom land at the toe of slope. Where occasional overflow of bottom land is permissive, design the ditch capacity for the applicable drainage coefficient. Prevent unnecessary overflow by embankment of the spoil upon the bottom land side of the ditch (figure 3-7). Where shallow surface soils are underlain by slowly permeable soil, make the channels deep enough to intercept any subsurface flow that moves downhill above the tight layer. Spoil should be placed so that the ditch will hold as much water as possible in order to prevent unnecessary overflow.

Build the channels so that they have side slopes of 6 to 1 or flatter or as recommended in local guides if they are to be crossed regularly in farming operations. Blade the spoil to the lower side of the channel to form a low, wide ridge. On land to be kept in permanent vegetation, shape the channels and ridges so that vegetation can be established and mowed conveniently.

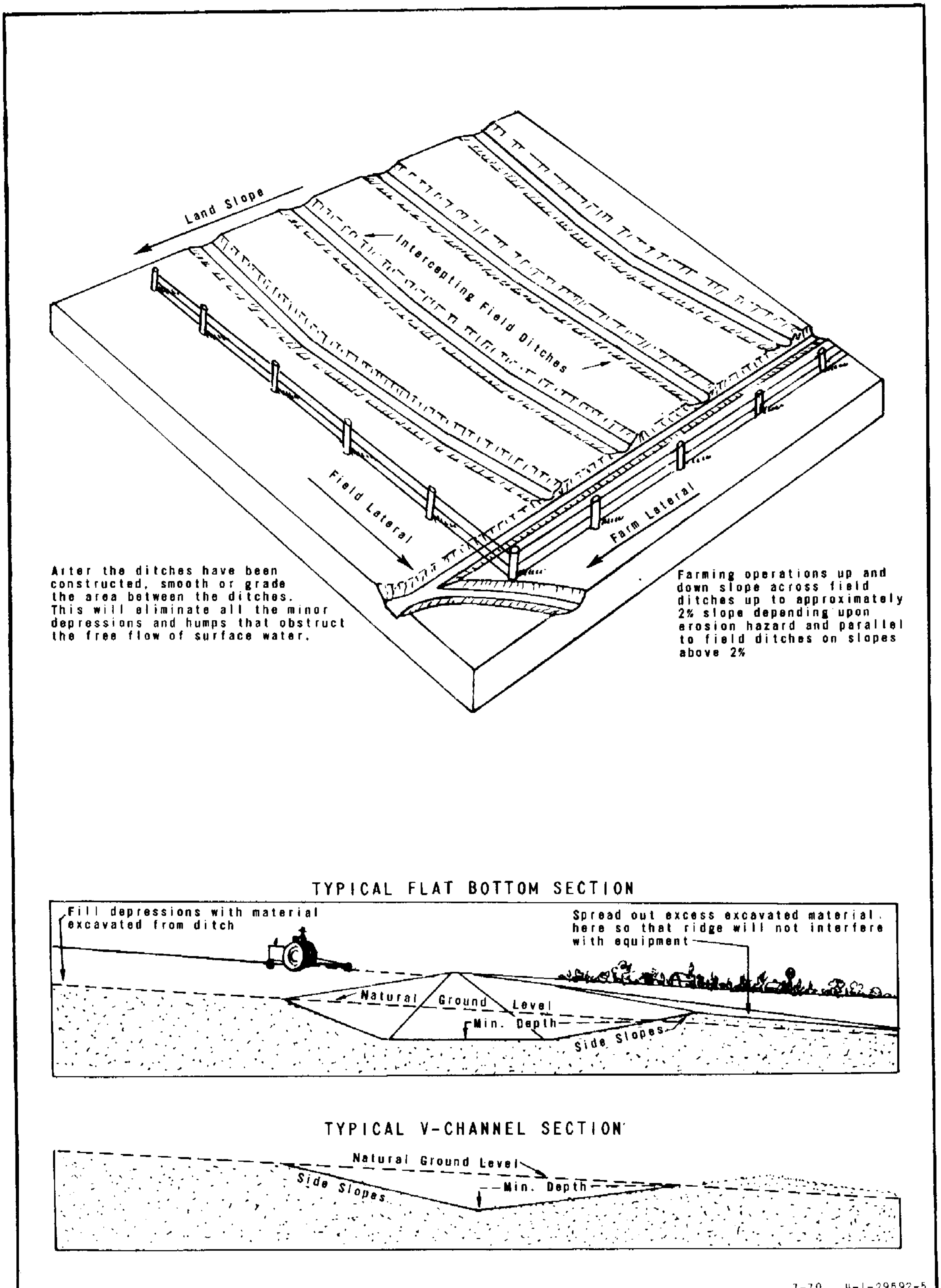

Figure 3-5, Cross slope system on slight to moderate slopes

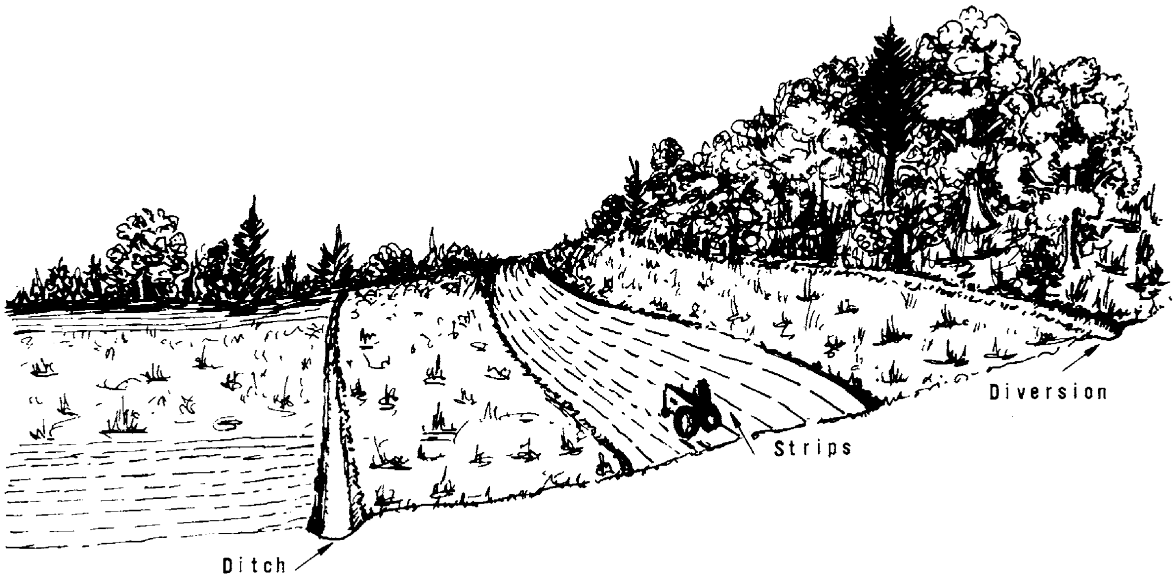

Figure 3-6, Cross slope system on moderate to steep slopes

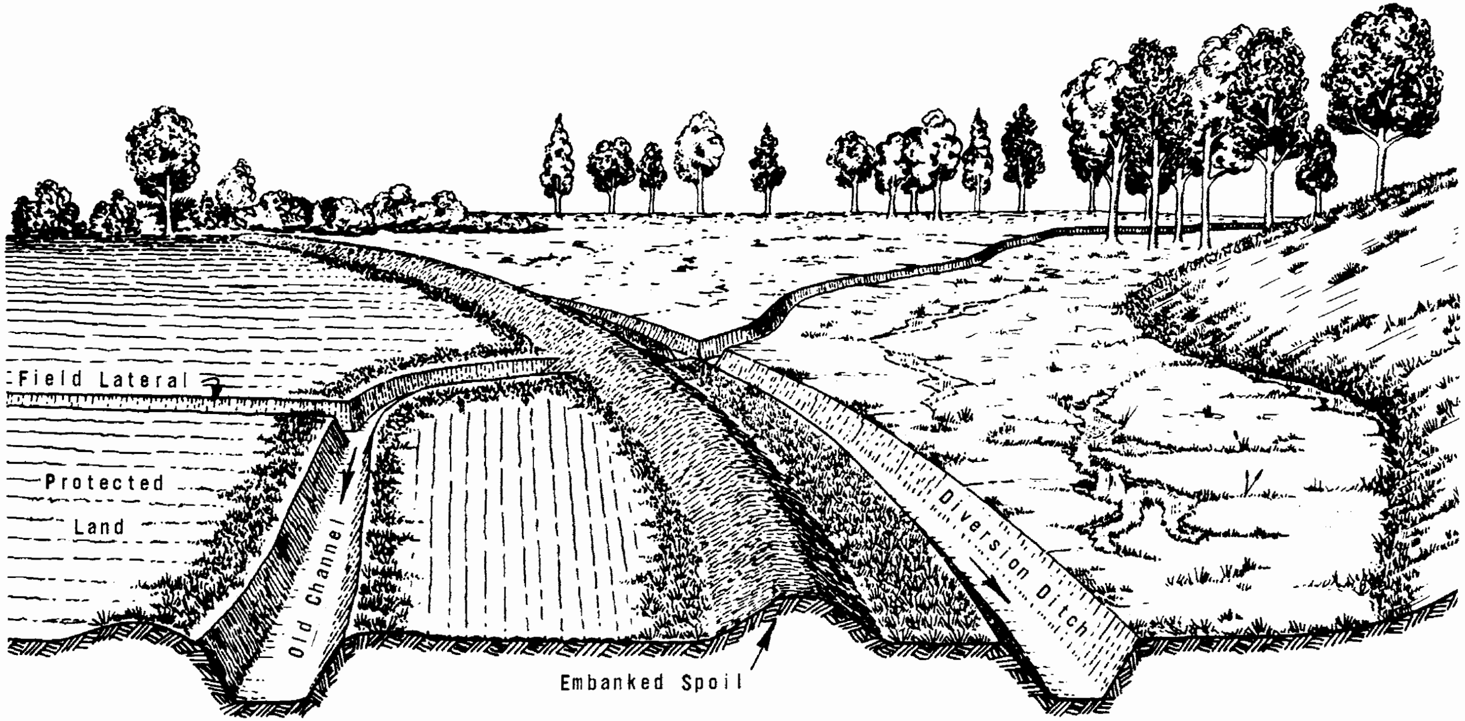

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Figure 3-7, Cross slope system on bottomland

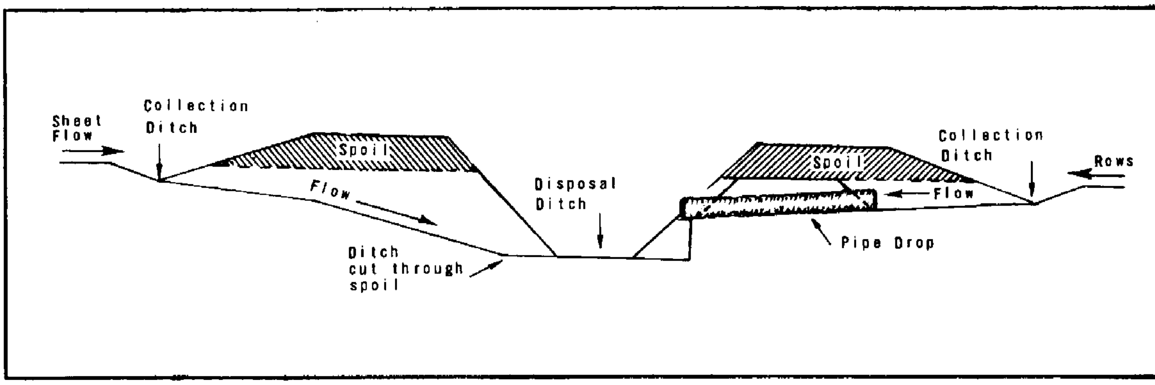


Figure 3-8, Controlled surface water discharge into deep disposal ditch

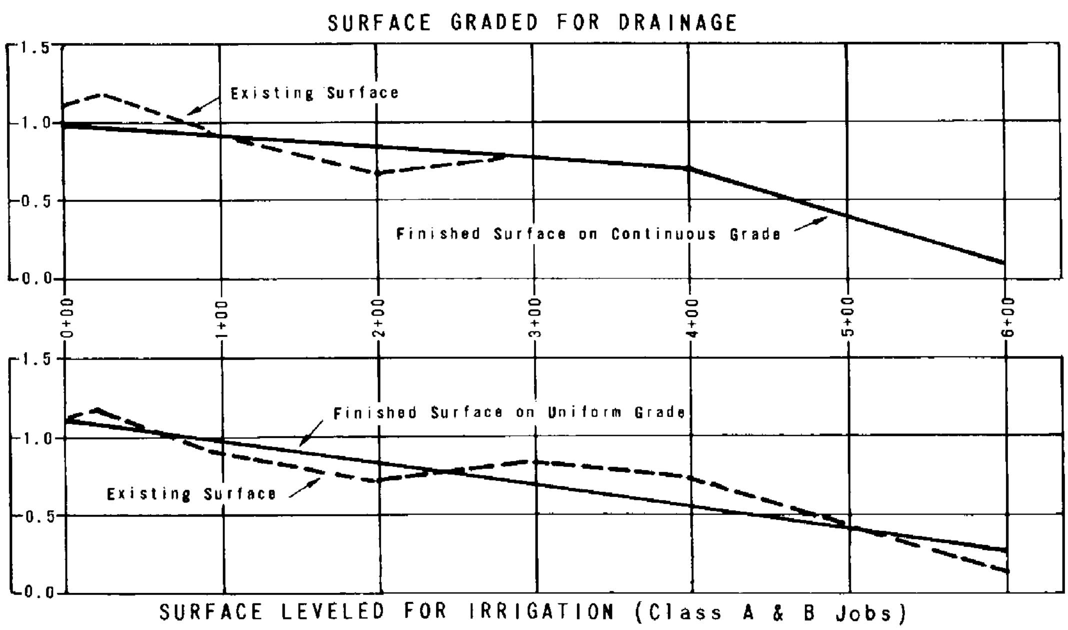


Figure 3-9, Comparative profiles of a land surface graded for drainage and one leveled for irrigation

For small drainage areas, especially those subject to sheet flow, the parabolic or V-type channel is adequate. On larger drainage areas, use the flat-bottom channel.

Channels must be designed to meet requirements of the job without causing significant aggradation or degradation of the channel bed or erosion of the channel banks. Refer to Chapter 5, Open Ditches, for design criteria.

To assure good drainage on slowly permeable soils, run rows up and down the slope and across the ditch on land slopes up to about two percent or to such nonerosive slope limit as determined from local guides. Above such slope limits run rows parallel to cross-slope ditches or diversions.

Types and Functions of Surface-Drainage Ditches

Surface-drainage ditches function either as collection ditches and/or disposal ditches. Each ditch, whether individually or as a part of a system, must be located and shaped so as to accomplish its particular function.

Collection ditches should be located so water will flow naturally into them. To prevent erosion of the ditches by water entering over their sides, make them shallow, with flat side slopes, and protect them by vegetation or mechanical means, particularly when excavated in erodible soils.

Ordinarily, the location of disposal ditches--such as mains and laterals--has fewer restrictions than that of collection ditches. If there are only a few possible outlets, the chosen one will influence the location of disposal ditches. These ditches usually are deeper than collection ditches. Shaping or spreading spoil adjacent to disposal ditches does not seriously affect drainage, but for best land utilization and maintenance, spoil should be shaped, except in wooded areas or where the shaping of sterile subsoils would damage good land. Spoil should be spread in a manner that will allow efficient farming and maintenance operations.

Collection ditches

Field ditches collect water within a field. Their alignment, shapes, and capacities must fit the topography, drainage area, and principal land use of the field. See figures 3-1 and 3-2. Collection ditches should be installed with sufficient depth, width, and flatness of side slopes to allow tillage equipment to open furrows which will drain freely into the ditch.

Furrows

The furrow between the rows is the first collector of water in the drainage system of a row-cropped field. Rows should be so directed that water can move along them without ponding or scouring. Surface-field ditches must be arranged to provide drainage of row furrows. If the row system is a part of a furrow irrigation system, the location of surface field ditches may be determined by the requirements for irrigation.

Row gradient must vary according to topography, soils, and location, but rows should be continuous and should not be on erosive grades.

Row ditch

This is a temporary ditch for collecting water from the furrows between the rows. It is used primarily in parallel and bedding systems for crops having low water tolerances. It may be know locally as a "cross," "quarter," annual ditch or "header ditch." Row ditches are cut directly across the row system to prevent ponding in slight depressions. See figure 3-3. Row ditches can be made by small plows, since they are no deeper than the crop rows. They are short, usually not more than 300 feet, and they can be open at both ends to discharge into field ditches.

Field ditch

This is a shallow, graded ditch for collecting water within a field, usually constructed with flat side slopes for ease of crossing. It may drain basins or depressional areas, collect or intercept flow from land surface or channeled flow from natural depressions, plow furrows, crop-row furrows, and bedding systems. State Drainage Guides and Standards and Specifications contain criteria regarding side slopes, grades, spacing and depth of drainage field ditches.

Disposal ditches

Disposal ditches are laterals and mains which transport the collected water to an outlet. Design should be according to principles set forth in chapter 5, "Open Ditches." Except for the field lateral, which is frequently a V-type channel, laterals and mains are usually trapezoidal. A lateral or main must be deep enough to handle the water from all the collection ditches that enter it.

Excavated material from disposal ditches should be used as fill for low areas, used for grading or leveling field surfaces, spread to permit unrestricted drainage, or placed in shaped spoil banks parallel to the ditch. Disposal ditches should have a flat berm along the bank edge. Its dimensions should be in accordance with recommendations of local drainage guides. See figures 3-2, 3-4, 3-5, 3-8, and 3-10.

Field lateral

Lateral ditches may have relatively steep side slopes since there is no need to allow for water coming over the sides. Shaped spoil along each bank of the ditch protects the ditch sides against damage by surface water. If the ditches are to be maintained by mowing, side slopes should not be steeper than 3 to 1. Usually, a grader is used in the construction of V-type laterals and backhoes or draglines for trapezoidal laterals.

Farm laterals and mains

A trapezoidal ditch should be used where the flow of water will be large. Since this type of ditch usually is at least three feet deep, provisions must be made for the entry of water from shallow field ditches and field laterals. As illustrated in figure 3-8, nonerosive discharge from collection ditches is obtained by means of (a) a nonerosive grade from the outlet of the collection ditch to the bottom of the lateral or ditch; (b) a length of pipe through which the water may be dropped safely to the lower elevation in the lateral or main; or (c) a standard drop structure.

Land Forming

Mechanically changing the land surface in order to drain surface water is known as land forming. It may be done by smoothing, grading, bedding, or leveling. Any of these methods, properly used, will result in better surface drainage.

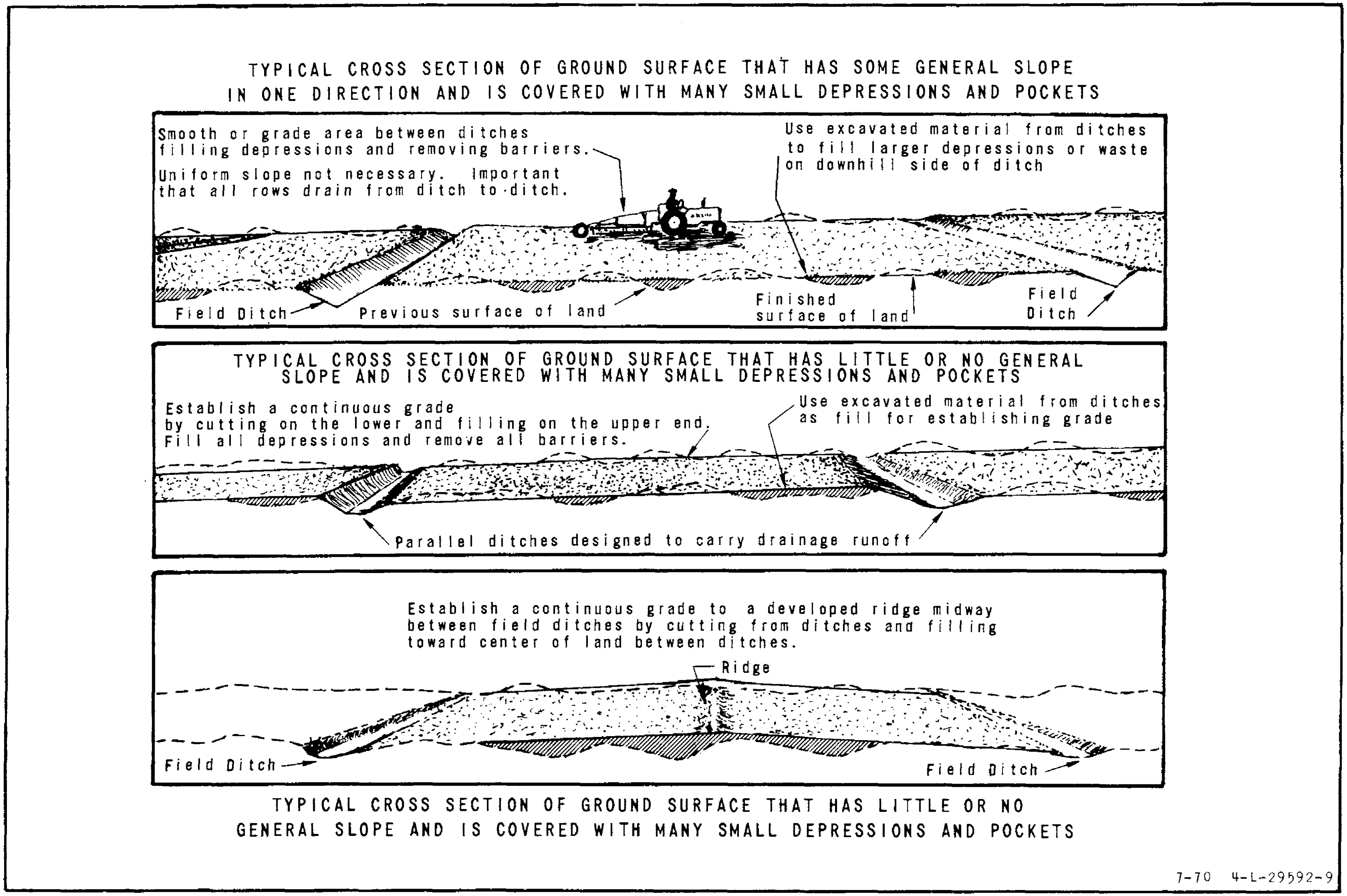


Figure 3-10, Methods of grading land surfaces for drainage

Land smoothing

Shaping land to a smooth surface is important to good surface drainage. Land smoothing does not change the general contour of the land but it eliminates minor differences in field elevation including shallow depressions. Thus, better drainage can be obtained with fewer ditches. This in turn permits more efficient operation of farm equipment, reduces the cost of ditch maintenance, and reduces ice crusting.

Soils to be smoothed must have a profile which will allow small cuts without exposing layers that will hinder equipment operation or plant growth. Usually, land with slowly permeable surface soils and slopes less than about one-half of one percent should be graded prior to smoothing.

High spots and low spots are usually visible without the aid of an engineer's level. Only minor surveys and planning are necessary. Land planes used in land leveling and grading also are used for land smoothing.

Land grading

Land grading for drainage consists of shaping the land surface by cutting, filling and smoothing to planned continuous surface grades as shown in figure 3-9. The purpose of establishing continuous surface grades is to make sure that runoff water does not pond. Land grading for drainage does not require shaping of the land into plane surfaces with uniform slopes.

Emphasis in planning is given in filling depressions with soil from adjoining ridges and mounds. If an excessive amount of filling is required for low places, or if sufficient soil is not readily available, field ditches can be installed and the surfaces warped toward them. By establishing grade in the direction of row development or tillage, and developing cross-slope drainage only when advantageous, required cuts and fills can be held to a minimum. Methods of design and layout as given in Chapter 12, Section 15, Irrigation, SCS National Engineering Handbook, can be used for land grading. State standards for land grading will specify grades allowed.

In areas with little or no slope, grades can be established or increased by grading between parallel ditches with cuts from the edge of one ditch and fills toward the next. See figure 3-10. Surface ridging similar to bedding can be established by shaping and smoothing land surfaces and ditch spoil between closely spaced and graded field ditches, as shown in figure 3-10. The artificial ridge is created midway between the ditches. Approximately parabolic convex surfaces are developed by shaping from the ditch shoulders toward the ridge. Necessary crown height and fill are obtained by adjustment in spacing between ditches, flattening of ditch side slopes, and use of ditch spoil. Ditch spacing and crown heights are established in state handbooks and local guides.

Row length

Maximum permissible row lengths on graded land will vary according to soil permeability and grade and should be specified in local drainage or technical guides.

Row gradient

Row grades on nonplastic, permeable, but easily erodible soils should not exceed 0.5 percent. On plastic and slowly permeable soils with limited row lengths, grades may reach a maximum of 2.0 percent. Limits should be specified in local drainage or technical guides.

Bedding

Bedding resembles a system of parallel field ditches with intervening lands shaped to a convex surface.

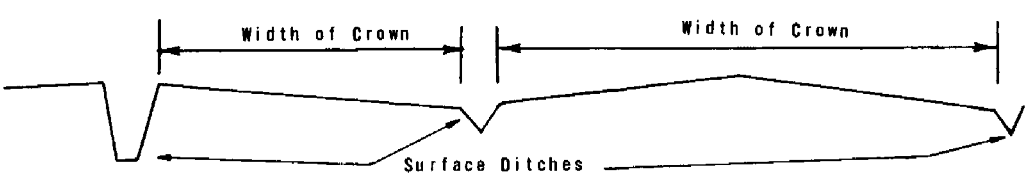
The beds are made by plowing, blading, or otherwise elevating the surface of flat land into a series of broad, low ridges separated by shallow, parallel dead furrows or ditches.

Bedding provides improved surface drainage by establishing adjoining parallel beds of lands running in the direction of the available natural slope, or if there is no slope, in the direction of the nearest outlet. This accomplishes one or more of the following: minimizes water pondage, provides gradients for removing runoff and permits efficient operation of tillage and harvest equipment.

The bedding practice has two distinct forms:

1. Lands or corrugations. In this type of bedding the convex area which is formed by plowing or blading lies between two dead furrows which are usually spaced from 30 to a maximum of 80 feet apart. These lands or corrugations require establishment of field ditches and laterals for collection and removal of runoff from dead furrows. See figure 3-11.

2. Crowning.--In this type of bedding operation the convex area is usually greater than 60 feet in width. Surface slopes are provided across each crown. The side boundaries of each crown are formed by some type of surface ditch. The crown is constructed with blade equipment. In figure 3-3, the area between the field laterals that run north and south would be the crowned area.



TYPICAL SURFACE PROFILE AFTER CROWNING

Lands and corrugations do not lend themselves to the most efficient operation of large, modern farming equipment and generally are used on poorly drained flat lands devoted to grass.

Crowning is usually used on land devoted to sugarcane, or sugarcane in rotation with other crops or grassland. In some areas this system is used for truck crops and other row crops. The crop rows are parallel with the crown length. The use of this system--figure 3-3--is declining in favor of land grading and use of a drainage system requiring fewer ditches--figure 3-4 (2).

The surface runoff from crop rows on all types of bedding is drained to the dead furrows or ditches by shallow row ditches cut across low places in the beds or at regular intervals. The dead furrows or ditches between beds are

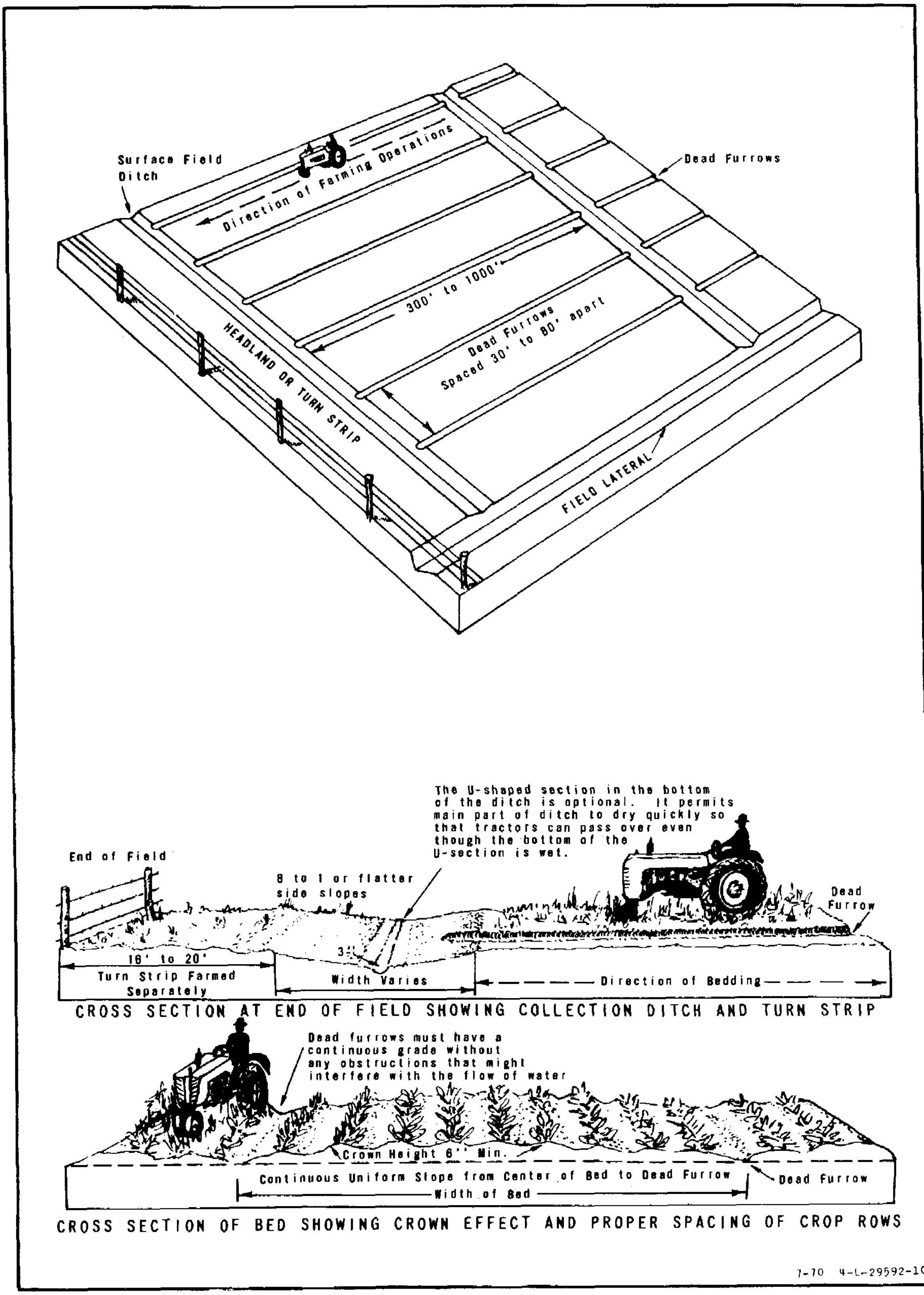


Figure 3-11, Bedding (lands or corrugations) graded to an outlet. Where row water discharges into deeper ditches overfall protection may be required to prevent erosion.

Land leveling

Land leveling is a precise operation of modifying the land surface to planned grades to provide more efficient irrigation. See Chapter 12, Section 15, Irrigation, SCS National Engineering Handbook.

Irrigated land also is leveled frequently to obtain drainage (3). See figures 3-12, 3-13, and 3-14 for typical irrigation drainage system layouts. In humid areas the collection ditches, or irrigation "tail water ditches," at the ends of furrows and along the borders of leveled land, must be able to receive and conduct storm runoff. This capacity must be greater than that required for handling only tail water from irrigation applications.

Classes A and B irrigation jobs, as defined in table 12-1, Chapter 12, Section 15, Irrigation, are established with uniform surface grades. In lighter soils, the length of run is governed by irrigation requirements, but in heavy soils of humid areas it is governed by drainage requirements. Land which has been leveled to irrigation specifications will meet the requirements of land grading for drainage.

For details of surveys and staking requirements for land leveling, refer to Chapter 12, Section 15, Irrigation, SCS National Engineering Handbook.

Joint Surface and Subsurface Drainage Systems

Subsurface drainage systems usually remove some surface water also. However, a joint system of surface ditches and subsurface drains will benefit crops where tolerance to standing water is low and where water may be trapped above a less permeable layer in which subsurface drains are placed. In a joint system, surface ditches are installed as prescribed in this chapter. Subsurface drains are installed as prescribed in chapter 4.

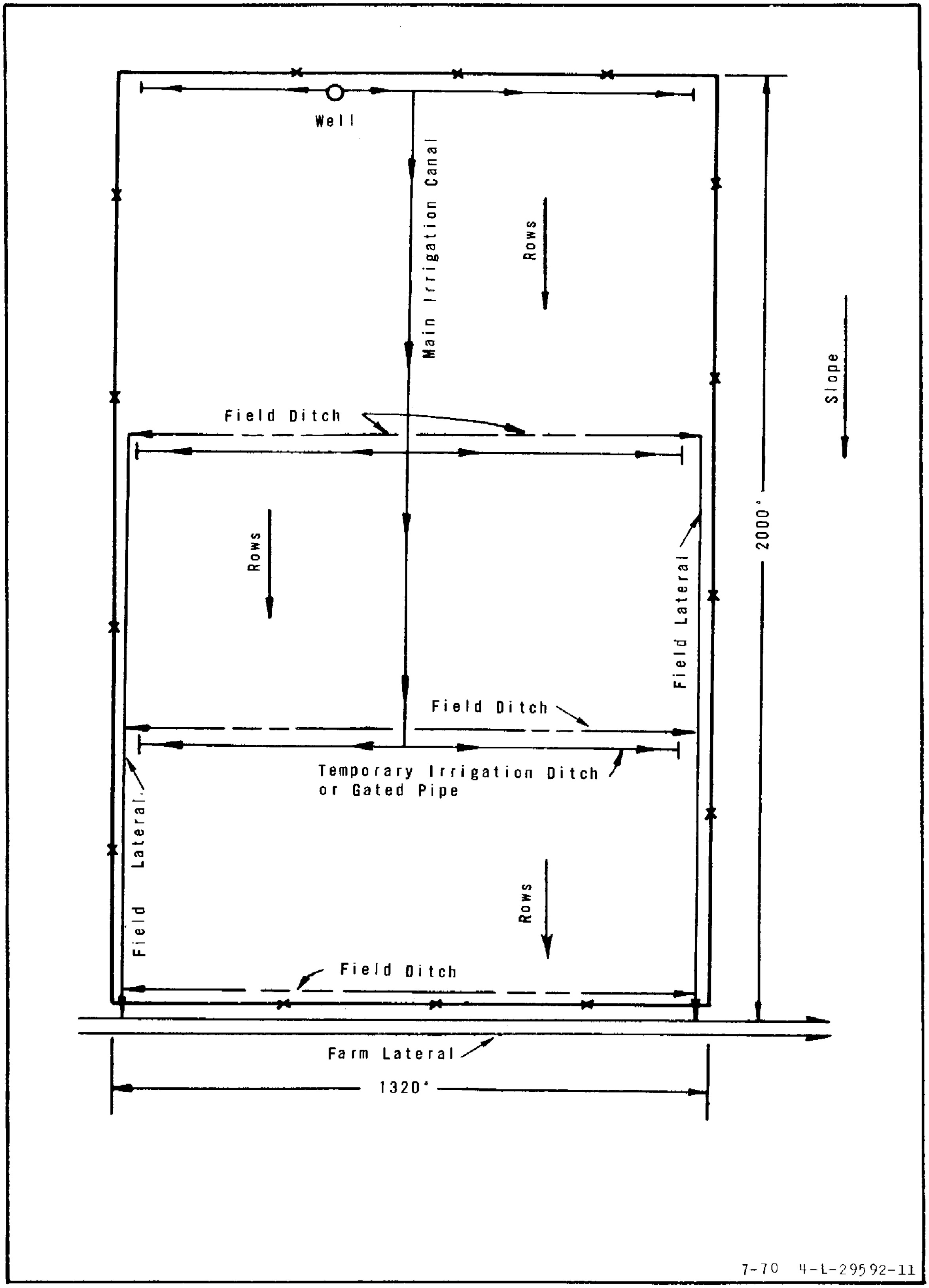


Figure 3-12, Typical drainage system for irrigated land

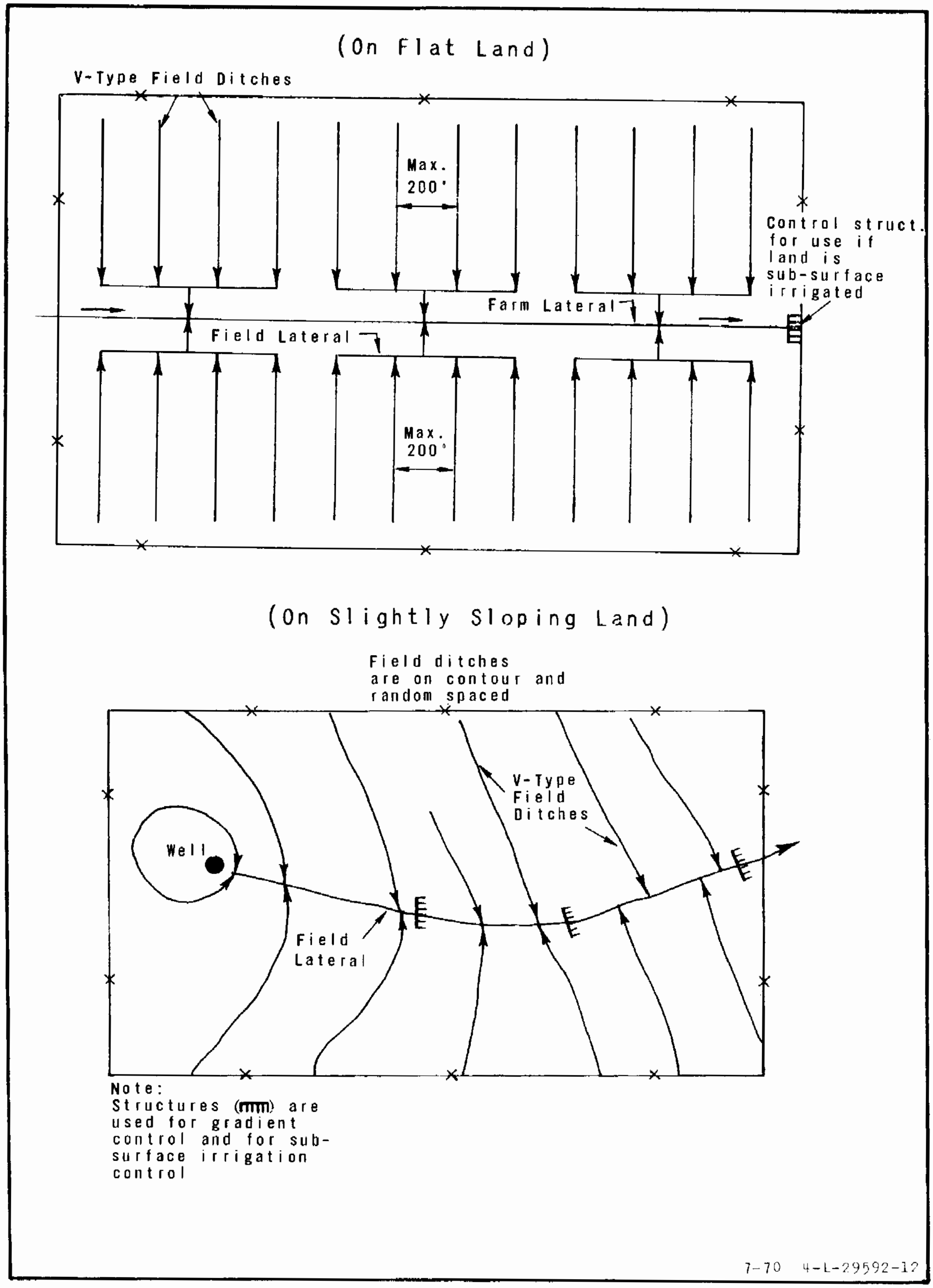


Figure 3-13, Drainage and subsurface irrigation for improved pasture

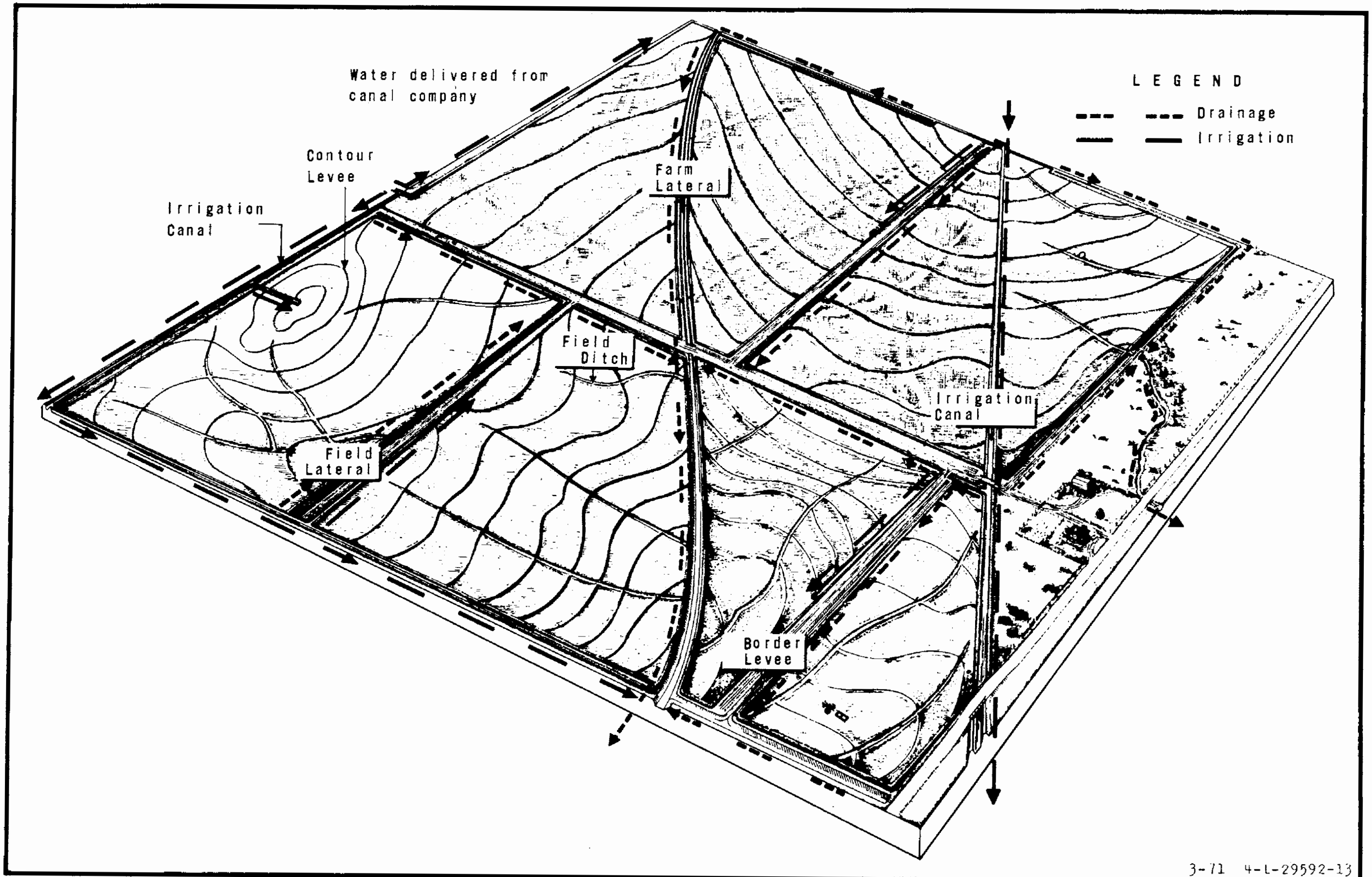


Figure 3-14, Typical layout - individual rice farm irrigation and drainage system

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